**All names have been replaced with pseudonyms to protect the identities of the participants in this study.**

**ETHAN INTERVIEW TRANSCRIPT**

I: Okay so if you could please state your name for the recording?

E: Uhh, it’s [REDACTED]

I: And can I confirm that you have signed the consent form and that you fully consent to this interview being recorded and used for our research project?

E: That is correct

I: Okay excellent, so this first set of questions are going to primarily focus on your teacher training and it’s influence on your own subject knowledge. So which aspects of your undergraduate degree if any helped you to develop your subject matter knowledge for teaching?

E: Certainly when I was, or going even before that when I was doing, I did IB instead of A levels so going back that far, I really did not properly understand things like moles and mole calculations, really didn’t get that until certainly during the undergrad, and it was kind of assumed after the 6th month mark, certainly after the first term it was assumed that you got that It was readdressed but again it didn’t really stick until actually using it in the labs and actually fully understanding that during the undergrad, certainly by second year I actually got that concept, where up until then it was just a bit of I don’t know why I’m doing this, I don’t really know what’s going on here, and then it just suddenly clicked, and now I’ve actually taught it as part of my training, and I was like now I actually understand this, the way that actually helped me understand it, sort of thinking it as like an amount, as a number instead of it just being arbitrary moles, it became [ ] particles moles or whatever you’re thinking about and certainly that has helped me to teach it in a way that I think about it and hopefully the students who I taught that to also start to understand it but going and doing my first placement where I was teaching that as part of my training, coming back and just treating it as seen because I taught them in their later part of the course, and they still got it, hopefully they get it, so certainly that very specific part of the undergrad where it’s real application based labs.

I: That’s really great, and to what extent has your teacher training addressed subject matter knowledge development specifically? If it at all?

E: It has, we had time to do subject knowledge enhancement a lot of it was done here teaching, because a lot of people who has their teacher training in science specialism, we were given different groups we were given groups based on your subject specialism, and then we would have to teach each other where our weaknesses were. So as part of training we would do our own subject knowledge audits and update as we went through the course, and we went back up periodically, like three main blocks throughout the course and we would identify our own weaknesses, for example I’ve done a chemistry degree, I was strong at chemistry, I’ve done applied laser physics, so some of the physics topics certainly the waves topics really not an issue for me, but I haven’t done any biology in any appreciable way, of course I’ve done the biochem at university but that is biology for biology sake, so I was very weak at the biology side of the curriculum, certainly for GCSEs in particular. But with the way the A levels are taught with the crossover, it’s quite strong certainly in DNA side of things, base pairing and hydrogen bonding and all those ideas, but how is that framed in a biologists mind, and how do they think about that, whereas I understand from a chemists mind, so that kind of difference of approach was really useful in saying “I don’t get how a biologist does this, please teach me” so there's a lot of peer teaching.

I: That’s great, yeah

E: A lot of various bits, like the organic side of it, even though that is not my strongest suit, but I knew it better than non-chemists certainly, certainly for functional groups and functionalisation, basic naming conventions and all that learning really properly and detailed at university where it had been mentioned [ ]

I: Okay, great. And did you personally engage in any self-directed activities to develop your subject matter knowledge while you were training? That weren’t formerly part of your training?

E: No [laughs] I didn’t have time

I: No? That’s understandable

E: Because I signed on as well quite late, I applied and was accepted beginning of August for September start

I: Oh wow, okay.

E: So typically they would have recommended doing a subject enhancement course over the summer that quite a few of my cohort had not finished by the time the course started, so they were doing all this subject enhancement during, but a month is not enough time to do it, so they just said don’t bother with that, and it’s PGCE, there’s no free time. So I didn’t do any that wasn’t preparing for my lessons, where preparing for lessons is a lot of re-teaching, especially for A level stuff it’s difficult content

I: It is, yeah

E: [laughs] GCSE’s you can kind of blag to an extent, until you get to the jargon, but A level you have to fully understand in order to teach like gas equations and that kind of thing, it’s very mathsy and there’s a few ways you could approach it, there are many wrong ways to approach it, you just get muddled up so a lot of it is re-teaching for my lessons, but it was specific content that I would be teaching within the next week.

I: Okay, right, that’s really interesting. And what do you remember about, so it's only last year, regarding the impact of any subject matter knowledge activities you engaged with during your training, what about the impact of them on your confidence in your own knowledge of chemistry? How did you find they impacted your confidence?

E: So once I’ve taught something, I’m much happier to teach it again because I know what I did and didn’t do correct [laughs] Certainly for GCSE stuff because I taught at different schools I had the luxury of teaching the same topic again, and I kind of would look back and “Uhh I didn’t like how I did that” or when I did it before it seems I got muddled up on this or on this aspect so I need to do that differently, so certainly when I’ve taught something I’m much more confident. Even teaching our other cohort within those things, one aspect we did in our very first lesson was to the cohort, it was videotaped, and it was a horrible experience [Laughs]

I: I can imagine

E: It was not pleasant, I did fractional distillation, something like that. But after having taught it, when coming back into other aspects of teaching and teaching related not that topic, I could fall back and I do really understand this well and could easily teach you about it, the main thing is if I’ve taught it before I’m much more confident. If i’ve read it the night before….Ish? But if I’ve just come in fresh from it, if you asked me to teach this topic and it’s not something I’ve not taught before, I’d be a bit apprehensive.

I: Okay, no that’s great, that’s really good. So these next set of questions, these are going to mainly focus on what you think makes a good teacher and the role of knowledge and how that can influence that, okay? So we’ll start off very broad, in your own eyes what do you believe makes an effective teacher of any subject? So this is very broad.

E: Yeah, super broad. An effective teacher...A teacher who knows what they want the class to learn and teaches in the most appropriate way to the students in front of them. And makes sure that they learn it, and that they have learned what is intended, so super broad that.

I: No that’s fair, and that’s exactly it, that’s why we’re asking, we’re just interested. And what about an effective teacher of chemistry specifically, what is it, is there something particular about that subject?

E: Specifically chemistry, someone who knows the chemistry, who knows the science behind what is going on, but preferably in more detail than their teaching, so that they can push higher achieving students further. Is not afraid of using the practicals to effectively demonstrate something, or to use practicals for a student to learn themselves. Certainly not afraid of using chemicals, not afraid of leading practicals. Because I’ve seen some teachers who don’t like it.

I: Are they chemistry specialists?

E: No, and it tells you a lot [laughs] but all chemistry specialists should not be afraid of getting dirty, putting the lab coat on, “let's do the demo” whereas others will preferentially show videos, for example group 1 metals being the classic one, because it can go wrong, but the schools I’ve worked at here in [REDACTED] I’ve heard stories of various teachers for whom it has gone wrong, chemists and non-chemists alike because if you don’t do it exactly the right way because you’re demonstrating, you don’t measure out the mass you’re using, the shape of it, there’s a lot of variables we can’t control, it can very easily go wrong, a lot of time with teachers who aren’t very confident in doing that and if it goes wrong knowing what to do, will just show a video.

I: Yeah, that’s good. So you touched on knowledge briefly there, so just how important do you believe a chemistry teachers level of subject matter knowledge is in there teaching? So would you say a teacher should be an expert in their field?

E: I would say if a teacher is an expert in their field, it definitely is a benefit, but I don’t think it’s a necessity. I think certainly any teacher broadly needs to know what they’re teaching, needs to know where it’s going so that they can prepare the class for the next lesson and they’re not just learning for the next lesson but they’re actually thinking ahead and doing the proper mid and long-term planning that any teacher should be doing, so it has a broad picture of the subject knowledge that they’re intending to teach, certainly for chemistry and physics in particular, there’s a lot of equation work. It’s not just teaching an equation and having the numbers, it's actually how do we use these equations to effectively do stuff, whatever it is. Yeah I think it’s not just knowing exactly what they’re teaching, but having context around the area certainly helps. A lot of personal anecdotes I’ve found to be very effective, when I can say “actually I used this when I was” whatever my anecdote is, I’ve had the luxury of working for a pharmaceutical company when I start a story with “when I was working for one of the world’s biggest pharmaceutical companies” the students are interested. Having well-livened personal science anecdotes really gets the engagement up, especially for science which at GCSE is mandatory but you don’t have to pass it, which is a weird place.

I: Yeah I was going to say, so do you think that helps having those other experiences of you know work in the different fields of chemistry or physics or whatever? Do you think those who haven’t, those who are teaching who say have just gone through their undergraduate degree, no placement and then just gone into teaching, do you think it’s going to be more difficult for them to relate the chemistry to the outside world essentially?

E: I wouldn't necessarily say so because I know quite a few excellent chemistry and other science teachers who had the experience you’ve just described of going straight from university into teacher training, off they go. One of my cohort when I did my PGCE did exactly that, and it wasn’t so much that they can’t be as good, but I think it’s harder to find the anecdote, because that’s one big issue I’ve found that a lot of students have, in science because the new GCSE is so content heavy is why do I care? And a question of why is this relevant to me, students often struggle, and so for me having personal anecdotes helps me make the point, I don’t have to think about it as much as someone who might not have the personal experience, but could instead say “but if you were to go to this career or this profession this might be a way that you could use this piece of science” or just relating it to the world around us, and I think you’d have to work harder at that. But again that’s an experience thing, and if you’ve been teaching for 10 years you probably would have an anecdote related to most areas that you can pull out from those lessons to make it relevant again. So I think it makes it harder if you don’t have that, but I don’t think that would exclude you from being an excellent teacher.

I: Okay, that’s great. So do you feel, I mean obviously you’ve only just done your first year, but do you feel that your teaching of chemistry is limited by an external factors, so things that are outside of your control. So that could be anything from the schools that you work in, resources or the time you have to do things?

E: I mean certainly I would like to spend more time on certain topics than on other topics, and If I had the freedom to say, to throwaway the textbook, to throw away the scheme of work, to throw away the curriculum, I would do things differently. Of course I would. There certainly are a lot of constraints.

I: I was going to say, so what would you…?

E: So we’ve got our schemes of work, so ideally..

I: Yeah, we’re talking ideally

E: Ideal world I would love to spend more time on the practicalities of using the science, using chemistry because I mean I was talking about this to someone last week and they said “actually, what specific in your chemistry degree…..” or even before that in my case IB, a level equivalent, “what have you actually used?” And the answer unfortunately is very little, in terms of chemistry specifically. When you talk about biology you use it most days if you take medications, and you just don't think about it, but you do easily see the links. Physics, if I pick up my coffee cup and I drop it I can tell you what’s going to happen because of the physics associated with it, whereas chemistry isn’t, if you don’t know all the chemistry, you can’t think specifically about what’s going on, it’s a lot harder to think of the day to day applications even though it is still happening everyday all around us, all the biochemistry in the body, it is still that extra layer of scale down from the biology that you think of. I would focus so much more on the applications side of it rather than the reactivity series for example, while it teaches very useful skills, problem solving and you can frame it in a really interesting way, the actual reactivity series for 99.9% population I would imagine is completely irrelevant information, so I would focus much more on that angle of doing it.

I: Yeah, and what’s your opinion on exams, terminal exams, that kind of thing? So do you think that’s a good/bad way of assessing those skills?

E: Sure, I think the new GCSE exams, in that they are a lot less recall and more application, more skills based, I think is a better exam than the previous GCSE, which was more recall based. The lack of coursework in final grades, I’m really torn, because it’s too easy to doctor the grades especially if my performance management is affected by it, and there's a real conflict of interest position there, because of course my students are all going to pass it, they are all going to get great marks but then it’s not really a representative test. But I also fully appreciate some of my brighter students really don’t test well, and I can talk to them in this kind of environment, and I ask them questions and they can fully understand explain all the science in great detail, really get it, when it’s written down on paper they’re lost, they answer the wrong question, they just don’t answer right bits of information that they need and they really struggle in that environment. So I don’t think written examination is the best method for it, but it certainly is what we’ve got, but I think it can be quite effective.

I: Yeah, okay that’s great. So the next section of questions, so this is section 3 of 4, these will primarily focus on your own opinions curriculum and how you’ve gone about teaching bits and pieces so far. Before we get on to that though, just a quick question about do you personally engage in any activities outside of schools, such as watching TV or wider reading to expand your knowledge of chemistry or things to do with chemistry that you’re interested in? Listening to the radio or anything like that? And it’s okay if the answer is no.

E: Specifically looking at chemistry? Not so much.

I: Generally for sciences then?

E: General science, I read all the news, I’m very up to date in the tech world, that’s more engineering but I’d still say science, I’m very up to date on the latest developments there. I’m very interested in cryptocurrencies and that kind of thing, which is certainly technology but not straight science as a physical science at least. I keep up to date on what’s going on in the world, certainly global politics especially being international myself, I’m very interested in what’s going on around the world. But specifically for science, not so much, no.

I: No? That’s fine. So if a student asks you a question that relates to content outside the specification you’re teaching, how do you approach that situation? And if that has happened in the past please provide an example.

E: Alright, it certainly has, kids are notoriously inquisitive [Laughs]

I: That they are, yes [laughs]

E: And I love it. Often times what I do is, again it depends so much on the situation but what I’ve found myself doing more often than not is saying “I’m going to come back to that question” finish whatever I was doing and then come back to it and say “do you still want to know about this?” and if it’s yes I address it, if they say no we move on from it, because if they’re not interested anymore we’ll move on. If they say yes, I’ll be clear this is not something you need to know for your GCSEs, your A level, this is not on your curriculum, but actually I think it’s very interesting. So one thing we were doing with my A level class, we were talking about the shapes of molecules and they were asking why things adopt either tetrahedral shape or square planar shape. The reason why something does that is university level material, and I said “you don’t need to know for your exam, you will be told which shape it’ll adopt and you will go from there but the way it's actually done is, again you don’t need to this” and mentioned dn configurations and a few other bits and the relevant jargon, and said if you want to know more about this talk to me after the lesson. But I certainly didn’t shut down the interest, because they’re asking great questions, and I say that as well, I say “brilliant question, you’re asking all the right things, you don’t need to know the why, but I will tell you the why” or if it's something I don’t know, or not my field, I’ll say “actually I don’t know why, but also interested” so we’ll google on the board and go through how to find out what we don’t know, and go through a whole exercise of don’t go through wikipedia, even though that’s what I do, it's not what you’re meant to do, so you go through this is a good source for the structure of the heart then you go to the British Heart Foundation, they seem like a good source for this, brilliant so let's see what they have to say about this, and that kind of idea. So I teach a whole different skill that they didn’t think they were learning by just asking a harmless question, but then you can extract loads of other teaching moments.

I: Yeah, that’s great. And how often do you find yourself teaching content that lies beyond the specification, if at all?

E: Certainly most lessons I’d say, it depends. If it’s a lesson that’s going well, yes. If it’s a lesson that’s not going well, and it’s a real struggle probably not. Because if a lesson is not going well and it’s a battle, the students are not engaged I probably won’t even get to that point [laughs]. If the students are just fully not bothered by anything to do with what I'm trying to do, it’s not going to work, they’re not going to be asking questions, they’re not engaged.

I: Of course

E: But if it’s a group who are engaged in what I am doing on that day, probably we’ll get there, there’s hands going up left and right, there’s engagement, questioning from me and them, it's an effect of that. But it depends a lot on whether the lesson is going well or not, its not to do with ability, it really isn't, I’ve had some of the best questions from my lower groups, like “Why does that happen?” “Thumbs up, love that question! I’m going to come back to that, but keep that, don’t lose that question we will come back to that if we’ve got time” that kind of thing, it’s certainly not ability. It’s none of those things, it really is whether they’re engaged or not, because they’re thinking, they are saying “Why is that?” that’s what I want [Laughs]

I: Yeah, that’s great. So we touched on this earlier, so what the scope of the chemistry teachers subject matter knowledge should be. Do you believe it to be an issue if a teacher’s matter knowledge of chemistry is limited purely to the A level specification?

E: Good question…

I: That’s why we’re asking!

E: I mean they’re all good questions but [laughs]. I think when you’re talking about A level these are typically wider students who are very engaged with the science and interested in learning about what’s going on. And because of that, you probably have really smart kids who are inquisitive and asking the right questions, and even in that example from a moment ago about why we’ve got tetrahedral or square planar, if you just know only the specification, you can’t answer that question, and it’s not an issue of looking silly in front of a class, because it isn’t that. But it’s, for the students who want to find out, you can’t help them, and I think that’s where the struggle would be. I don’t think you’re a bad teacher if you know only what you need to know, at this point I only know the biology I need to know, so far for GCSE stuff I’ve taught. That doesn’t mean I’m a terrible biology teacher but it certainly it means I’m not as effective a biology teacher as a trained biologist, I would say. And so I don’t think it makes you not good, but I think it makes you less effective, because with that example I was very easily able to just I can just tell you the answer and we’re going to move straight on, everyone’s happy at that point, the inquisitive students want to know more, now they know that little tiny piece more they’re happy their question got answered and not slummed off as “don’t worry about it.” Because if that student’s going to go on to A level, if they’ve heard the right terminology before, when it comes up again “Oh I know where that fits in!” and that’s just better [laughs]

I: Yeah, exactly [laughs] that’s great. Okay, so the next set of questions, these are going to primarily focus on specific topics within the A level, and potential issues involved in both teaching and understanding them, so regards to the content, I’m not going to testing your knowledge and trying to tell you you don’t know anything, just so you’re aware of that. So in the pre-interview survey that you did online I asked you about which topics you felt most confident and least confident with, so I’ve got all of that here.

E: Okay [laughs]

I: We’ll start talking about the topics you felt most confident in your subject matter knowledge of, so you stated that atomic structure and molar calculations and analytical techniques were your topics that you’re most confident with?

E: Yes

I: So what is it in particular about those topics that you feel more confident in your knowledge of them, so we’ll start with atomic structure and molar calculations first?

E: First thing, I’ve taught it, that helps a lot, I mean we talked about that a little bit, I’ve taught it before it helps so much because that particular topic is very equation heavy, it’s very linear, you learn the method, you apply the method, you learn different ways of applying the method and then it’s just application at that point. It's kind of once you’ve cracked it you’re good [laughs] Because again it’s more skill rather than content, because the amount of actual content to learn for recall type stuff is very limited in that topic, and so I kind of refreshed on the skill and we’re good to go, so I’m much happier on that particular topic because I’ve taught it.

I: Okay, that's great. And what about analytical techniques?

E: Analytical techniques...That’s more because I’ve used most of the ones myself during my time at university and so it’s not just a textbook understanding of how these things work, it’s I've actually done it, and I’ve had to get the results myself and go “Oh, what does that mean?”. I’ve had all the head scratching moments with all the different techniques you learn, NMR, IR, Mass spec all the head scratching, “why does this do this? I don’t know” “Oh it’s because of this” so I’ve had to do it myself, I’ve had to analyse it in all the various techniques. I think once you’ve done something it’s a lot easier to explain how it works, if you actually understand what’s going on admittedly, but it’s much easier, especially to teach it and say “all you actually have to do to do this is, for IR, it sounds like a very complicated technique but the practicalities of it are actually really straight forward” as you’re running an IR spectrum, 5 minutes and you’re done. It really isn’t a big process whereas something like NMR takes time, and being able to explain that and saying, “all you’re doing is one thing to it, you’re shining a beam of light, if it interacts you see the interaction, you analyse it, you’re done” and explaining it in very frank terms, I’ve found certainly for techniques “all you’re doing is this, these 4 steps and you’re done”. I find students actually realise that it isn’t complicated, the science is but actually it’s not a difficult process. So mostly because I’ve done it.

I: Yeah, that’s great, and how do you approach teaching those topics? So when you know you’ve got that coming up, how do you go about planning those lessons and delivering those lessons? When you feel more confident in your knowledge.

E: I found the topics I’m more confident in I rely, I’m a lot less resource reliant. So when I’m teaching a topic like atomic structure and I’m doing all the molar calculations I’ll put one up on the board and I’ll use a PowerPoint slide and I’ll show with every click the next step of the calculation one after the other, so all the students can follow what's going on, I’m doing it on the board, but then the next one is just the question is on the board I know how it works, I don’t bother with the animations and showing the calculations, I just have the answers written in the comments on the slide, I’ve scribbled down the answers myself and like “yeah that seems reasonable, okay?” We’re good. It’s because I’m confident with it, I know that I would be able to instead of relying on the animations and PowerPoint, just be able to do it on the board. It saves me planning time, saves me a lot of time preparing things which is crucial [laughs] and instead then if I’m working on producing a homework or worksheet to go with that, which is the way i typically teach, I just write a long list of questions out and that’s it. I give that to the students and while they’re doing it, and I’m going around answering questions, In a free moment I’m also kind of working on the answers myself so that when we come through and peer mark it, whenever or even when I collect the homeworks in, I’ve got the answers right there. But i’m not doing it all whilst I’m preparing the worksheet because that’s time [ ] [Laughs]

I: Yeah, exactly. So now we’ll move on to those topics that you felt less confident in.

E: Sure

I: So you said here that it was electrochemistry and kinetics that were your least confident in, so we’ll start with electrochemistry, what is it about electrochemistry that makes you feel less confident in your knowledge of it?

E: Mainly because I never fully got it [laughs]. I was taught it, obviously I passed my university degree, I understood it to a point, but it never fully clicked in my head, like the whole topic. It just never, it wasn’t my thing, so I didn’t ever fully get it. And so now looking back at teaching it at A level, I also because, for a lot of these topics because I’ve done university, I don’t actually remember how far you get at A level equivalent, I know the specification of the curriculums change, A level is something I didn’t do myself, so I don’t know exactly what used to be there, what’s there now. Some of these are areas on the specification that I’ve not taught yet and haven’t looked into at great depth because I haven’t had to, I’ve just not got there. But the main thing is it’s stuff that I never fully got and I don't know exactly what I have to teach for, so if you said “first topic you have to teach in 2 weeks starting with your new class is electrochemistry” I’d go “Oooh boy, okay then” we’re going to spend some time at it, we’re fresh at what I need to teach, because that comes with the confidence, and I know actually how far I need to push is because I know it all to the next level at university, even if I didn't fully understand it I’ll know bits and pieces, and it’s actually don’t use those terms, they’re correct but not helpful for what they need to learn because it overcomplicates it if you use too much jargon. Simplify it to the point of their understanding, but don’t dumb it down, it’s that fine balance.

I: Yeah, okay. And what about kinetics?

E: Least favourite topic [laughs] Really don’t like kinetics.

I: Yeah? What is it?

E: It’s all the equations associated with it, I always got them messed up myself, got all the first order, second order, zero order all of them muddled up and all the associated graphs, even though you can work it all out, it’s just I never got my head around it fully, and so that’s I’m least looking forward to teaching, and will be the most re-teaching for myself to get my head round it.

I: Okay, and so how will you approach teaching those topics, or have you if you have taught them already?

E: So neither of those I’ve taught yet, but the way I would approach that, and will in the coming year when I am teaching that, it will be first off a case of read our textbook and find out actually how far we go in it, to what depth we’re going to, and how many lessons we’re doing? Okay, how does it break up into that number? Have I got nice chunks to put it into? Very practical planning type stuff, but more about do I get how to actually do this because with both certainly kinetics is very equation heavy, so I will go and probably watch a few YouTube videos myself on tutorials of how to actually do this, this way I’ve found a few good chemistry teachers who are putting up their own videos for A level with the new specification. Because it’s all new there’s loads of people putting out videos for it, which is nice because it’s up to date, so it’ll mostly be re-teaching myself, finding what I need to teach and then breaking it up trying to find my own examples so that I know. For these that are very skills/application based, these aren't the content heavy topics per se, there’s relevant jargon and recall but not much actually, for kinetics certainly. You can memorise the answers, but why would you? [Laughs]

I: Exactly [laughs]

E: I mean that is what I used to do for it because I just didn’t get it, but because it’s skill based it’s re-learn the skill, master the skill and make sure I fully understand it before I go in. Because I had loads of students correcting me on my PV= nRT and the has equation and all these different calculations, I went in and the first thing I said was “to be clear, everyone is going to make mistakes with their unit conversions” because it’s so easy to get it wrong, to be off by a factor of 10, 1000, 1,000,000 even without even thinking, so easily done, and here I am on the board doing exactly this, mistakes, students are correcting me and I’m like “Okay, what have we learned guys? First off, I’m not perfect, but also that this is difficult and very easy to mess it up.” “There’s a reason I’ve laid it out the way I’ve tried to, I’ve not got it right but I’ve done this in this way so that I will give you a good a chance you can possibly have to keep it all in order and not make these silly mistakes, but here I am doing exactly that.”

I: Great, no, that's great. I guess, my next question is asking about reflecting on the approaches you take between teaching the concepts you feel less confident with and those you feel more but I guess you’ve already summarised that in you’re more resource reliant for those topics that you’re less confident with.

E: Definitely, for a topic that I’ve not taught before, first thing I would do, this is chemistry or GCSE, all of these, is see what resources there are in terms of PowerPoints, worksheets etc just on the sort of school server, whatever there is from people who have taught it before. See if there is anything useful there, and then I’ll go throughout and go “Mm, I do or I don’t like these bits of it” maybe I’ll end up reteaching it myself, I might see how this person has taught this recently and then I might tweak it and take it, and then I’ll probably go onto TES and download most likely 4 or 5 different PowerPoints and flick through them pull in different slides that I do like, tweak it all and just kind of amalgamate loads of different resources into one that I’m more happy with, and go from there.

I: Yeah, that’s great, no.

E: One of the key things they said at the beginning of teacher training is never ever make a PowerPoint from scratch because someone’s done it before, exactly the way you want to do it. If you spend 5 minutes finding it or 10 minutes making it, it’s a no brainer. [Laughs]

I: Exactly that. And I guess because you’ve only been teaching for a year, do you get any support for subject specific CPD or have you not really had the chance to engage with…

E: Definitely!

I: Yeah?

E: A lot, because we’ve got all these GCSE required practicals and all that, we’ve had a lot specifically of physics, [ ]

I: Oh right, okay

E: Because the, I forget but one of the various teaching physics groups come down, all the schools [REDACTED] go to one school and do a CPD session, obviously I met [REDACTED] at one of the sessions from the RSC at one of the schools here, so there’s an awful lot of subject specific CPD. At the school I’m teaching at next year, one of the things we did is, we used to have school-wide CPD triads where we’d go and talk to other teachers outside your subject area and do all these different things, but we actually said because of the nature of science being so content heavy, and we’ve got specialism that no other subject really has in the same way, what we said next year is we’re just going to do our own departmental CPD and there might be me or one of the other chemistry teachers goes up and says this is how you do this required practical, vary practical very hands on skill based stuff, this is one way of teaching it, this is the actual science going on here, because with a lot of the practicals there are multiple ways of doing it, like the rates of reactions required practical you can do either as the disappearing cross, you can do it as making hydrogen gas, there’s 2 different ways of doing the exact same experiment to get the exact same results to analyse in the same way, but they’re completely different procedures. If you’ve only ever done one, why would you bother learning the other one? And I get that, teachers are too busy to actually go sit down with the technicians and say “can you talk me through this?” with physics you’ve got waves and different experiments so you’ve got the wave generator, you’ve got the ripple tank, there’s two completely different ways of doing the exact same thing both with orange pieces of kit that you’ve got to figure out how to use. If you’ve done it once you’re good, we just don’t have the time to spend a lot of CPD time ourselves unless it’s organised in, so I’ve done quite a lot of that yeah.

I: Great, that’s really good. That's really good that you get the opportunity to do that. So the next few questions are going to centre on kinetics, so sorry to bring you back to that [laughs]

E: No, no that's cool

I: Umm, but as part of the A level reforms of 2015, the Arrhenius equation was reintroduced to all of the A level specifications, so you say you haven't taught this yet…

E: That’s correct

I: The question is how have you adapted that, how will you adapt to the reintroduction of the Arrhenius equation, I guess you’ve already answered that in your discussion of

E: Yeah, I mean fortunately I have not taught that yet

I: [Laughs]

E: Which means that I don’t have a whole pool of resources to shoehorn that into, which I know is an issue which a lot of teachers are having with all of the restructure and everything is “well I’ve already got this nice set of resources for this many lessons on this topic, how do I then shoehorn that in?” Because nothing has been removed from any, it’s always just adding more in, so it’s how do I shoehorn in that new chunk of topic in, or what is effectively going to be a lesson for the Arrhenius equation, how do I do that, so I don’t have that which is nice. But yeah It’ll kind of be what I’ve said about relearning it myself, going through it and put some stuff together and figure out a way, I mean for that it will be lots of worksheets.

I: Sure, yeah

E: Yeah, because it’s equation based.

I: Sure, so considering the fact you haven’t taught that yet, there’s not much point in me asking the next few questions. So we’ll move on to structure and bonding, so what I’m going to show you now, this is a question we asked a bunch of students and a bunch of teachers, so I’ll give you a bit of time to browse over that, so the question is, it’s a true or false question, a sodium ion in the gaseous form is more stable than a sodium atom. We asked people whether that’s true or false, you’ll see on that side, 70% of year 10 to year 13 students said it was true, 30% said it was false. If you flip over that piece of paper, you’ll see how teachers responded to it, you’ll see that 53% have said it’s false and 47% it’s true. So I don’t want the correct answer from you, what I want you to do is, I just want you to say why you think student’s typically responded the way they did, and why teachers have responded slightly differently. So why do you think that might be the case?

E: I think because student’s probably think of sodium as a solid, the only time they will have seen sodium is most likely as a solid, probably in sodium chloride, and know that’s a solid because you put it in and it’s an aqueous solution and those kind of things but not have seen, certainly won’t have experienced sodium as a gas, and so they’ll think, and student’s particularly at this range will know that to make something go from a solid to a gas will require a lot of energy to get all the way through the liquid phase. So it’s a lot of energy it’s going to be quite energy, A level students should know that that’s less favourable than the solid. Sodium+ student’s know, sodium chloride is stable, it’s, well not here but it’s on most tables and they know that that’s a very stable compound and so sodium on its own they probably won’t think that that’s stable.

I: Right

E: Because they think that it’s going to be sodium chloride.

I: Okay

E: That’s what I would assume

I: Okay, then what about the teachers, more of them have said false? I mean it’s not much in it it's only 47% 53%, but more of have said false.

E: I mean deceptive graph there [laughs]

I: Yeah it is, yeah I know [laughs]

E: That’s alright. Well, to ionise something takes a lot of energy to do. For sodium+ it’s not as much as certain other ionic species, but to pull that electron off takes an energy to do, an unionised species is going to be more energetically favourable than ionised species, so that’s what I would go for.

I: Excellent, that’s great because, that’s pretty much you’ve hit the nail on the head there of why we think it is, but we’re just interested to see what teachers think. So we’ll move on to a question regarding equilibrium and Le Chatelier’s principle, this one’s a bit more complicated, so this one’s actually more of an undergraduate level question than A level question, and it was designed to tease out misconceptions. So, don’t worry if you don’t know the answer because most of the people I’ve spoken to don’t know the answer, it’s a tough problem. So what we’ve got, we’ve got an equilibrium system here of PCl5 in equilibrium with PCl3 and Cl2 and we’ve asked what the effect would be of adding neon at constant temperature and pressure, so even after the neon’s added that system will have the same pressure, what effect that will have on the equilibrium position. So we got a bunch of teachers to answer this question and there initial responses in blue, so the majority thought there would be no shift in the equilibrium. We then got the teachers to talk to each other and then after they spoke to each other we asked them to answer the question again, and more people after they spoke to each other thought there would be a right shift, so the equilibrium shifts to the right. So again, I’m not going to ask you what the correct answer is, I just want you to say why you think those were the typical responses. So what do you think caused the teachers to say those two things?

E: Well, so constant temperature and pressure, okay so that rules out all that stuff. So it’ll be to do with the number of molecules of gas and on which side you’re talking about, and so obviously on the right hand side as it stands right now you’ve got 2 different molecules of gas as opposed to the one on the left hand side. So adding in extra gas would mean that you’ve got more on the right hand side, in the case here I’d assume it would be written as 3 molecules of gas and 2 on the other side. Then because of that you’ve got more molecules of gas on the one side than the other, which would make it shift, that’s how I would approach it.

I: So why do you think a lot of people have said there would be no shift in the equilibrium?

E: Umm, people I would assume would say no shift because you’re adding the same number of molecules of gas to both sides. I mean in the case of neon it’s completely inert, it’s not actually going to be doing any interaction, the chemistry on here won’t change, you’ve got no shift, no change in temperature or pressure, so those effects are all gone away. And in the case here it won’t actually do anything, and so the equilibrium here will still exist. Which is why people said no change because there’s no, the chemistry happening will not be affected.

I: Yeah, so this is a really tough question, and the actual way of going about answering it is by considering the fact that everything is at constant pressure when you add neon, although the pressure remains the same, the volume is going to increase because you’ve got more gas there, so the partial pressures of all of the constituents are going to decrease so the concentrations of all these species decreases and so because there’s 2 moles on that side it’s going to shift that way, that’s how it works. So it’s one that is very difficult to figure out using just Le Chatelier’s principle alone, if you have the Kc and Kp and all of those numbers it’s very easy to tell what way it shifted, but without that it’s not. So my final question then is regarding those two problems. So considering those problems I’ve just presented to you, what are your opinions on teaching the limitations of chemical models and analogies, and do you think they should be taught at A level, at GCSE, at all? And to please explain your response, so the limitation of models that is.

E: Well because you do teach Le Chatelier's principle at GCSE now and it is brutally difficult for them, especially when you talk about applying it to something like the Haber process and why you still do it at a higher temperature because that’s just because it goes against everything Le Chatelier’s principle would say, where it says cool it down, cool it down, cool it down and then actually you’ve got other effects coming in to play, and so I do use that exact example to highlight the limitations and say “even though you want it to be at 0K ideally, you actually don’t because at that point it’s impossible but actually at a point because of what’s actually happening in terms representing a molecules movement and all that, actually your model stops work properly” and so it’s at what point the models come into different plays, and what point kinetics start going in and matter more than Le Chatelier’s principle in that specific example is really difficult for 16 year olds to get their head round. Like really hard to be able to say “oh yes, of course this model actually is kind of more important at this point!” because it all is such a fine balance of when to apply the models so...Whether it’s appropriate to teach it or not I think the skill is important to teach, that you don't just have one size fits all for all models because that’s not how the universe works, that’s not how science works, it’s we use a model until it stops working and then we go “well we might need a different model” [laughs]. It’s finding the limitations when you talk about big or small scale, you talk about Newton’s laws or you talk about quantum models, but actually quantum’s stop working as well on a massive scale and also we can’t do it, but on a tiny scale the Newton’s models just don’t work. And so it’s finding that interplay about when to apply them is I think a useful thing to at least address.

I: Yes

E: Not necessarily to get students to do, because 16 year olds from my experience can’t do it, it’s too difficult because it’s so hard to say “actually this model, one thing we knew from one another lesson a year and a half ago is actually the reason we’re doing this” and student’s don’t do that, so introducing the concept that no scientific model is infallible is crucial, but actually getting them to use that and apply it, I think is almost cruel [laughs]

I: Yeah [laughs] that’s fair

E: And testing and expecting them to have that skill which is something still university student’s struggle with, I struggled with it a lot, all my peers were just like “Ahhh, of course” when you talk about organics and organic retrosynthesis, and you’re like “Oh because of the Pk of this hydrogen, it’s actually something completely different” you’re like “oh, right.” I just didn’t think about that, but that is the correct thing that does happen, but I didn’t think about that one thing going on, and uni students struggle with it, 16 year olds can’t do it effectively unless they’re absolute geniuses, but that’s rare. [Laughs]

I: Yeah, excellent, well that’s really great, thank you ever so much.

**DANIEL INTERVIEW TRANSCRIPT**

I: Okay, so if you could please state your name for the recording.

D: Sure, my name’s [REDACTED]

I: And can i confirm that you’ve signed the consent form and that you fully consent to this interview being recorded and being used for our research project?

D: I have, yes.

I: Okay, excellent. So these first few questions are going to focus mainly on your teacher training and your undergraduate degree and the influence it’s had on your subject knowledge, so which aspects of your undergraduate degree, if any, helped to develop your subject matter knowledge for teaching?

D: So my undergraduate degree was in chemistry and I think it’s been incredibly useful, I think that since I did my degree an awful lot of the degree level curriculum has now trickled down into A level for instance VSEPR for instance were very strictly a degree only thing when I did my A levels and my degree, and now very much is a solid A level curriculum thing. I think a lack of a degree in that would leave me in a very very poor standing having to do A level teaching now, yeah.

I: Okay, and to what extent did your teacher training address subject matter knowledge development, during your training period, if at all?

D: Pretty greatly actually, the person who ran our subject sessions in my PGCE was very hot on subject knowledge and that sort of thing, made sure we very meticulously went through and document how we went through our subject knowledge and got us to reflect on what it might be.

I: Oh really? Wow

D:Particularly pedagogically about, it’s okay to know it, can you teach it?

I: Great, and did you engage in any self-directed activities to develop your subject matter knowledge while you were training?

D: Absolutely, I’d say most of my subject knowledge matter was done individually, so looking at areas of the curriculum that I thought I was lacking in, particularly because I trained in science, physics because I was teaching physics to GCSE and I only hold a physics GCSE, so going back and re-remembering everything I did 15-16 years ago for that, making sure I still understood it, making sure I could explain it and teach it to a level that potentially you know students could be achieving a grade higher than I actually got qualified myself.

I: Cool, that's great. And what do you remember about the impact of the subject matter knowledge activities you engaged in during your training on your confidence in your knowledge of chemistry?

D: Umm so initially, I would have said to you “Oh I have a fantastic knowledge in science and particularly in chemistry because of the fact it’s kind of my bread and butter and had been whilst I was working in industry” I very quickly realised that, looking back at it, it was quite patchy when I actually dug into it and saw what was to do. But none of it was quite actually I’ve forgotten this is completely, it was more like I’m a little bit rusty on this and if I'm going to teach it I would need to brush up on my subject knowledge a little bit to get to a level where I can teach it well.

I: Yeah, okay. And you mentioned you did a bit of work in industry? So you were in industry for a few years…

D: Yeah

I: Do you find your experiences in industry have influenced your teaching at all?

D: Massively, yeah in various ways. I could talk to students about how the techniques they are doing are directly applicable to industry, things like titrations that chemistry students do at A level and sometimes even at GCSE now are still done in industry as a standard procedure to work out various things, so they are absolutely one of the most important things they do, and getting them to understand that is really important. Being able to give them anecdotal evidence for when particular techniques, particularly I used a lot of chromatography during my time doing analytical chemistry work and so I can talk to them about that. Talking to them about how different wet chemistry techniques and sort of safety in the lab is directly applicable to industry. I also find that you get a certain level of, sort of almost respect from students on times if you can say to them that you’ve actually worked in those areas. And lastly you can give them careers advice because some of them are actually maybe thinking about those kinds of areas that I’ve worked in industry, and being able to tell them honestly what it’s like, it’s quite nice.

I: Yeah, and do you think having those experiences puts you at an advantage over a teacher who say, has just come from university and straight into teaching?

D: Yes, I would say so. I think that it definitely gave me a lot of real-world experience, it made me appreciate the kind of things that those students might need or want if they’re ever going to go work in a lab or do that kind of work. Admittedly being a few years out of my degree probably meant I was a tiny bit rustier on subject knowledge I would have otherwise been but it also meant I gained masses of additional subject knowledge in a few very specialised areas that I could then talk to the students about more, and tie in kind of industrial things a lot better than your average teacher might be able to, into what actually happens in industry.

I: Yeah, that’s great. So these next few questions are going to focus specifically on the role of subject matter knowledge and teaching, and what you think makes a good teacher. So that’s where we’re going to start, this is a very broadly speaking question now, what do you believe makes an effective teacher of any subject?

D: [Laughs] wow.

I: So this can be...You know you don’t just have to give me one answer, you can give multiple.

D: So I suppose the most important thing is for them to be able to convey information appropriately to students and that will involve having a versatile varied approach that needs to be differentiated to learners needs to know what level to pitch different language and that kind of thing. It will involve having a suitable level of subject knowledge to be able to teach at that level. It would involve having sufficient behaviour management techniques in order to keep a classroom in order and that's especially more important probably in the younger years than we teach here at the sixth form college, but it is still important here. The ability to keep a safe working environment so kids when they come into the classroom don’t feel like for whatever reason that is an unsafe place to learn, that they want to be able to kind of relax and kind of absorb knowledge and learn things. Very important one is effective use of questioning and feedback, they are both shown to be incredibly important ways that show students how they’re doing. Yeah, I think those combination probably cover most things [laughs]

I: Yeah [laughs] that’s great, and in addition to everything you’ve just said, do you think there’s anything else that makes an effective of chemistry specifically?

D: Umm, so a lot of teachers particularly if you go into a secondary school end up for instance being biologists having to teach chemistry to triple chemistry classes, if they’ve not got the kind of right distribution of classes or staff or whatever, and they can often find that very very difficult, that they can find themselves quite lacking, and I’ve often seen that being a dedicated chemist when I was working in a secondary school people would often come to me and ask me questions about some of the more difficult parts of the chemistry curriculum, particularly things like mole calculations, electrochemistry that kind of thing, equilibria, bits that were quite theoretical and quite...But physicists didn’t normally struggle quite as much on those bits.

I: Yeah, to be fair it tends to be more physical chemistry concepts

D: Yes, absolutely. So those physical chemistry concepts, the biologists really really struggled with that, so...I’ve lost my tangent now, I can’t remember what your question was.

I: It was about what makes an effective teacher of chemistry specifically.

D: Oh yes, so I think that it is possible to teach chemistry as a kind of rounded individual, but a degree in chemistry does massively benefit you when you’re trying to teach it. Having a dedicated chemist teaching chemistry, particularly...I mean it doesn’t really happen at A level because I think that would be almost impossible to do, but GCSE level I think it is really important if sort of schools who are trying to teach all three subjects and had just biology teachers, they would very much struggle, particularly, probably on physics but also on the chemistry to do that. I think that’s really important yeah.

I: Okay, so yeah so this was, well that leads into my next question, so how important do you believe a chemistry teachers level of subject matter knowledge is on their teaching? So do you think a teacher should be an expert in their field is basically what I’m trying to say I guess.

D: Umm, it depends to what level they’re teaching. I mean that would be almost impossible at primary level, so at secondary level sort of KS3 and 4 I would say that’s a certainly desirable at KS4 and probably highly desirable at KS4 and at KS5 I would say it’s essential, absolutely essential, there’s no way that I would be able to teach A level physics, and there’s no way I would expect a Biologist to teach A level chemistry either, it just wouldn’t be fair on the teacher to expect them to hugely expand the level of subject content knowledge, and also the pedagogical knowledge to encompass that.

I: Yeah? Okay. Do you feel that your teaching of chemistry is limited by any external factors? So things that you personally don’t have any control over.

D: Umm, so it depends how deep we want to go really. There are certain aspects of both the GCSE and A level curriculum that I think are in some ways lacking and in some ways slightly unnecessary and I think that that time could be better spent teaching other areas that have maybe become more important in more recent years.

I: Can you expand on what areas those are?

D: I think certainly at GCSE I think students learning what the history of the periodic table was and how that got developed is a nice, slightly academic exercise for maybe the cleverest students, but bearing in mind its compulsory for all students to do, even the most weakest ability students, that time could be far better spent brushing those kids knowledge up of other areas because that's essentially a blind learning thing, and doesn’t actually gain them much at that level. For the highest students they might be able to appreciate the like kind of scientific rigour, but I think if you were trying to get students to understand the like scientific discovery and scientific rigour the development of the periodic table is not where I would start with that, there’s far more interesting less dry topics to do than that. Things like for instance learning what the different fractions are in a fractional distillation column that’s fractionating out alkanes, I mean if I worked in petrochemistry that would be vaguely applicable for me to know but really for a bog-standard student who may be wanting to go on and take a hairdressing course after they finished their GCSEs that's a pretty pointless piece of information for them to have to uphold. That’s not really helping them to appreciate the world around them in any sort of reasonable way, so I think that’s a sort of pretty pointless bit of the curriculum. And then other things therefore have to fall by the wayside and get taught in a bit of rush, when actually those things would be really useful, I mean thinking about most students and what would benefit them in real life, I mean how many people out there in the real life know why cement sets? That’s something we could easily teach in science very very quickly and easily, pretty much anybody who does DIY or works in the building trade would find that a fascinating subject to teach, and that would really help level of engagement but people aren’t taught that sort of thing. Learning for instance the basics of how the wiring in a house works or how a houses plumbing works that sort of thing, sort of falls vaguely somewhere between, somewhere within the STEM subject, somewhere between kind of probably technology and science somewhere, but would be a pretty useful thing for kids to know when they’re actually in their own houses and want to know what the hell is going on when there’s a leak, or the taps don’t turn on and that sort of thing. I know it's not kind of maybe the most useful thing in terms of pursuing a career in chemistry, but those science subjects are incredibly important for 95% of the students coming through at GCSE. But A level, I think it’s an awful lot better. I think the course at A level is a lot more carefully thought out and really sets students up for doing some sort of a STEM degree, it ties in really beautifully with maths biology and physics, students who do those other STEM subjects find there is so much mutual coverage of different areas, areas like forming esters and amides beautifully ties in to so much of biology and you find that students learn those things really nicely and easily, things like if you have students doing geology or physics, things like Gibbs free energy makes beautiful sense to them because they tie into both of those subjects really well, you find that the geological chemistry side of thing uses Gibbs free energy, sometimes even before the chemists learn it and so they actually, that ties in quite nicely as well. So I have far less misgivings with the A level curriculum than I do with the GCSE to be honest but yeah, I’ve probably waffled on far too long.

I: No no it’s fine, it’s good no. It’s really important to get those things across. So in an ideal world how would you personally like to teach chemistry? Is there anything you would change about the way things are at the moment?

D: Wow, what a question. First of all what I would do is I would almost be tempted to say I would scrap doing triple chemistry and I would probably setup a GCSE of applied science. So I’d an applied science GCSE that is what, it would be even applied and basic than what was originally core science, and that’s what the default would be for most students to do. Most students don’t need to be doing the high level of science that is, I mean we can talk about having a scientifically literate populous, but actually probably the key bits they actually need is the applied science bits of that, knowing why global warming is happening, why evolution works and why cement sets is far more important to them than learning about the structure of the atom, which is probably never going to come up in their lives again. So it’s important for them to learn the more applied stuff and for those who maybe want to pursue it at A level, you could have a sort of a single or a double course available that would then probably encompass enough. I think that bearing in mind what students have to do for other subjects, the fact that we do so much science at GCSE is quite astonishing really, it is amazing the amount of content, you know there is no other subject where you expect students to sit 6 exams at the end of the year to get 2 GCSEs for them, and that’s regardless if they want to do it or not, they have to do that, and I just find that level, and maybe we don’t need to scrap doing triple sciences but I think the fact that at the moment lots of students are having to do double award science, those students either can’t access the curriculum or frankly don’t want to, they don’t understand how it fits into their lives and frankly neither do I. There’s bits of it that I think are vital and they should be learning but that could probably take a half short course GCSE of Applied science. So that’s my personal feeling on it, I think we could still uphold our feeling of having a nice scientifically literate populous but just really streamline it.

I: No, that’s great, no that’s really good. So these next few questions will focus on your opinions on the A level chemistry curriculums specifically. But before we get to that though, do you personally engage in any activities outside of schools, so that could be wider reading, watching TV, listening to the radio to expand your knowledge of chemistry? Would you say?

D: Hmm, well I’m a member of the Royal Society of Chemistry and so I regularly use their website to read up on their new science news. I’m a regular reader of New Scientist. I sort of, I don’t do this as much, I have less time now than when before I was a teacher but I do tend to try and read some of the scientific journals, particularly science and nature because you get more of the kind of big things, big discoveries in those, although that’s not all encompassing of course, it does give me at least a brief overview of them, and I do really enjoy that. I also, just because I generally enjoy it, I really try to keep up with the recent technological innovations, analytical techniques because it’s what my bread and butter was for 5 or 6 years of my life and so I want to make sure I don’t kind of lose my eye-in with that, because it’s something I found really interesting and I never want to really kind of lose that level of innovation that I did know about. Yeah, that probably covers most of it really.

I: Yeah, I was going to say, do you find that ever creeps into your teaching? That stuff you’re reading?

D: Definitely, I mean being able to give students a periodic table and saying to them of course as of yesterday we’ve got 3 new elements to put on the end of this, so we’ve got, or 4, it was 4 the last time wasn’t it?

I: Yeah it was 4.

D: So Nihonium, Moscovium, Tennessine and Oganesson and then being able to talk about why those have been discovered and that sort of thing, students quite like that sort of thing if they’re particularly into their chemistry, they like to see the brand-new stuff that’s coming out right now because unless they’re really lucky they very rarely come up against stuff that is brand new. They really don’t see the big innovations ever really. I quite like talking about the innovations that are going on with things like nanotubes and graphene and that kind of stuff, because one day hopefully those sorts of things are basically going to solve an awful lot of our problems with very expensive semiconductor, superconductors, screens for mobile phones and that sort of thing made out of graphene would be marvellous, lightweight, would never break its those sorts of things students like hearing about, so it’s nice being able to relate to those.

I: That’s good, that’s really good. So if a, a scenario now, so if a student asks you a question relating to content that lies outside the A level specification in class, how do you approach this situation?

D: I’m pretty enthusiastic, so if I know about it I will probably talk to them at great length if I have the time to do so, or at short length if I don’t. I will usually find the time to do that because I think if students are asking those questions we should indulge them because you’d never want to quash that enthusiasm if they’ve got it really, because sometimes it's hard enough to keep it. I think if I don't know the answer, I will usually try to point them in the direction of how to find it out, whether that might be, I mean I had a student come to me in student surgery earlier and ask me about blackbody radiation and I haven't got a clue about that other than vague stuff I know from being vaguely interested in astrochemistry and so I told him what I know about basically curves of energy versus kind of number of particles and this sort of thing, and the different wavelengths of light therefore might come out different temperatures and that sort of thing, and so he was happy with that because basically what had happened was he was reading a book to do with astrochemistry in fact and he’d come across this name, this word and he didn’t know what it was, so he’s clearly reading around his subject and is really enthused in it, and just needed that little thing sorted for him because he didn’t really understand it and he said wikipedia was useless because on wikipedia it literally just went straight as if you were already an astrophysicist and knew all the terms and everything like that, and so he didn't really, he didn't have the kind of layman's explanation given to him in what he’d done his research in so it’s quite nice to be able to do that.

I: That’s great and how often do you find yourself teaching content that lies outside the A level spec? Just regardless of whether students ask you about it?

D: I like to tie it in to as many lessons as I can possibly can, even if it’s a little snippet of a piece of information because it might not be in the curriculum but if it ties into the real world for them a bit more, that’s what I want to do. So, the good example might be, giving an anecdote in the lab, for instance teaching flame tests. Flame tests are still used in analytical labs determine what metal is in something but it’s done in a much more carefully controlled way, which is atomic absorbance spectrometry but they, so essentially you bung your sample into the thing, it burns and then you have a lamp that detects whether or not a certain frequency of lights being given out by that flame and if it is it’s a particular metal, and if it’s not it must be a different metal. So to say to them “Basically what you’re doing looking at the colour of the flame, this thing here does the exact same thing but just really controlled. We can tell the difference between these three red colours that you’re seeing, because they’re slightly different frequencies of light.” And certainly the kind of more able students love that sort of thing because they're often thinking this is nice as a kind of academic exercise but how does this fit into the real world? And to be able to say to them “well this is the real world, if I had an unknown sample of stuff, I don’t know, this sea waters got too much zinc in it, and is therefore going to be dangerous to pump through this plant, then I can take a bit of the seawater, put it in this machine and it tells me”. So, it’s that kind of thing where they actually can, therefore can grasp a bit of the reasons why it’s such an important thing.

I: And, so in your opinion what should the, I guess we’ve touched on this already, but what should the scope of a chemistry teachers subject matter knowledge be? So basically, do you personally believe it to be an issue if a teacher’s subject matter knowledge is limited to the A level specification?

D: Not at all, I think that if they are limited to just the A level specification that would be good enough to get a student to pass the A level, whether or not that student then will continue to it further is another matter. So if the question is will that prevent that student getting a good grade? Probably not, it would probably be absolutely fine. If you're trying to spark a bit of enthusiasm in students and maybe get them to pursue chemistry further, which is a little bit of our job to be honest, it’s what we should be, you know if somebody is going to entice them in it’s probably going to be us, we’ve probably got to give them a little bit more than the curriculum, the curriculum in places is pretty dry. And being able to give those real-world examples is a really good way to kind of entice people in that there might be a little bit more. I like enticing students in a little bit more with doing things like, saying to them “Oh okay, we’ve learnt about all these different subshells and what their shapes are and stuff, and we’ve learnt all these bond angles, and you’ve learnt that the bond angles in something are 109.5 degrees, but all these p orbitals are at 90 degrees to one another, so how are we going to get something to bond to another thing at 109.5 relative to each other?” And they sit there, and they haven’t got a clue, because they can’t make those two pieces of information that they’ve rote learned at A level fit with one another, because they haven’t at that point done any hybridisation of orbitals. It’s only at degree level normally hybridisation comes up, it sometimes comes up in some A level curricula but I like to give them little snippets and I say “look, if you do a degree, I’m not going to tell you why that is, but if you do a degree you’ll find out why that is” Those little snippets for the most high ability students are sometimes enough to make them maybe think about doing it more. Talking about the kind of cool instruments and that kind of thing you get to play with at degree level sometimes entices them a little bit more. So I think it does help to talk to them a little bit more than just the syllabus yeah.

I: Yeah, that’s great. Okay, so this final section is regarding specific in the A level and the potential issues in both teaching them and understanding them. So you may remember in the pre-interview survey I asked you what topics you’re most confident in and which you’re least confident in.

D: Yeah. I was probably a little bit cautious doing this because I was thinking the whole time about pedagogically whether or not you wanted me to purely capture subject knowledge and what I felt I was good at, or if you were actually saying okay would you comfortable then talking about how you would pedagogically sort of have that subject matter nailed. So I was maybe a little cautious here. Just a little bit of a caveat.

I: Okay, that’s fine, yeah thank you for saying. We’ll talk about those topics now, so the ones that you put at the top, the ones that you said you were most confident were analytical techniques and organic chemistry.

D: Yep

I: So what is it in particular about these topics that make you feel more confident? So we’ll start with analytical techniques, I guess a lot of that comes from your…

D: Uhh I did a PhD in it and then I worked for four and a half/5 years in analytical labs up to the point of being a lab manager.

I: That’s a good chunk of time.

D: So yeah, I pretty much feel like if there’s anything to know about analytical chemistry I probably know it, particularly organic analytical chemistry there’s lots of stuff to do with kind of various instruments to do with the inorganic side of things that I know about but I’ve never used as much, but certainly in terms of the analytical techniques I’m really really hot on that. My PhD was in organic geochemistry so I’m very happy with organic chemistry, I really really know it very very well, nothing really phases me there. I think I would probably have to get up to pretty high-level synthesis reactions and that sort of thing to start unpicking myself. So yeah, those would be my two that I really am strong on yeah.

I: Yeah, and how do you approach teaching those topics?

D: It’s weird actually because sometimes it can almost make it slightly harder because I know so much about it, because you forget just how little other people know. It’s not so much of a problem at A level, it’s way more of a problem at the lower levels, if you were talking about trying to teach year 9s chromatography then in my head chromatography just makes sense, it makes perfect sense and to me actually picturing it not making sense is a really hard thing to envisage. At A level, by that point they’ve got a level where I can access their kind of zonal property development, I can certainly teach for more within their ZPD than I can a student of year 9, and I find I’m far better therefore teaching the A level curriculum for it. Basically by that point they’ve learnt the skills for me to kind of drop my level of knowledge and occasionally throw in the odd kind of keyword and explain that keyword, and they can follow it really really fine. I actually think in some ways it’s a little bit of a downside knowing so much about a particular subject, it can end up being worse, but then on the flipside of that it can end up being massively better because you can then, if a student asks a question slightly more advanced than the curriculum, you can really really go to town and really get them enthused and excited about it because you know exactly what they’re kind of talking about, because frankly that’s probably what got you involved in it in the first place anyway. So, I also think maybe I’m more overly critical about how I teach those particular areas, and I probably do teach them absolutely perfectly beautifully fine but because I’m very very aware I should be teaching those best sorry that was best in inverted commas there [laughs], that's kind of like I should be kind of teaching that to the best of my ability, but actually sometimes it might be I have to think about it a little bit more to dumb it down to the level that is required to teach it.

I: Great. So let's move on now to the topics where you felt the least confident in your subject matter knowledge. So what is it in particular about, we’ll start with kinetics, so what is it about kinetics where you feel less confident?

D: So, because I’m an organic chemist, it’s always been the physical side of things that I personally have found I’m weakest on. Things like kinetics often contain an awful lot of physics in them and frankly because I only took GCSE physics they’ve always been the bits of chemistry that I have always found the most difficult to grasp myself. So although I teach it perfectly acceptably at A level if people start asking really advanced questions about it I then come unstuck because I can’t teach, like if they start bringing in stuff they’ve learnt from A level physics, I don’t know that stuff, or If I do know it it's only because I’ve learnt it off my own back. So it’s sometimes, I can get unstuck with that. I wouldn’t say like kind of any of those subjects I mentioned I’m actually weak at, if that makes sense, but they would be the weakest. With kinetics it’s probably more of a case of because I understand, I’m one of those teachers where I understand the curriculum and pretty much the curriculum only for A level doing kinetics, anything outside of that is a few little snippets. Kinetics is also an area massively where, huge amounts, I learnt Arrhenius in second year of my degree, and now that stuff is in A level curriculum. That’s amazing that it's dropped from being kind of quite advanced degree stuff all the way down into being taught at that level, so, not only has it been something I haven’t really touched in a while, but also all the stuff I learnt at degree is now being taught at A level, so it’s as advanced almost as I ever learnt anyway and so that's why I think it’s quite difficult if you’re out of the loop for a while that can happen.

I: Yeah, and so what about electrochemistry?

D: Umm, electrochemistry is a funny one because I struggled with electrochemistry at degree level, and that’s what made me think about the fact that I’m absolutely fine with it before that, electrochemistry though once it starts going in to kind of using the Nernst equation and that sort of thing and when you’re talking about kind of how it ties into like fermi levels and things like that, it’s stuff I can kind of do, but if I’m being really intellectually honest if you gave me degree level questions on it now, I probably wouldn’t do very well on them, I think that would be somewhere I struggle on yeah.

I: Because electrochemistry has been one of the topics that most teachers have said that they feel less confident in. What is it about that, that the subject causes quite a lot of universal concern?

D: Umm, probably the fact that it’s quite physics heavy and the fact that it’s got electro in the name and people all of a sudden think about physics when they hear that. And probably in people’s minds they’re expecting electrochemistry to be as advanced as you know electrochemistry at degree level was, which really goes to town proper heavy level physics, and probably that’s what’s invoking in their heads when they think of it. I mean it got to the point where I worked my butt off and I was actually quite good at doing electrochemistry at degree level, but if you gave me questions now I’d really struggle, so yeah it’s a really difficult area. And certainly if you were to talk to me about teaching it, again I mean yeah I can teach the A level curriculum all that fine, but if you were to give me a bunch of second year degree chemists right now and told me to teach dynamic equilibrium and electrochemistry to them, I’d struggle, I’d really have to brush up my subject knowledge to do that.

I: And how do you approach those topics that you’re less confident with? Is there a difference in approach to how…?

D: Massively yeah, If I’m doing a section of the curriculum that I’m very very confident on I can pretty much just teach it, even if I didn’t have a PowerPoint in front of me, if you told me what these kids need to know I’ll probably just do it. The areas where I’m weaker I make sure that I’m really meticulous, I read up on everything, I try and pre-empt the questions may ask and make sure that I know the answers to them, pre-empt what sort of questions around the subject they might want to know and actually try and research those myself, make sure that I’ve got really good PowerPoints nailed, worked examples that work really really well so I haven’t got to think of examples off the cuff, you know things for instance like organic nomenclature of naming compounds, I could draw you the most complicated compound and still name it and I’d be absolutely fine, I couldn’t do that for just trying to work for an off the cuff electrochemistry experiment or something like that, I’d have to really carefully think it out beforehand.

I: Yeah, okay that’s great. So the next couple of questions are going to focus on the A level topic of kinetics, so as part of the A level reforms in 2015 the Arrhenius equation was reintroduced to all of the A level specifications. How have you adapted to the reintroduction of the Arrhenius equation?

D: So I wasn’t teaching A level before 2015 so it’s kind of irrelevant to me.

I: Ahh okay.

D: But, having to re go back over degree level stuff for me essentially, and then tie it in to the other A level stuff it ties into like the equilibrium that they're already learning. I actually think it’s something that does work really well being taught at that time, I think it ties in really nicely and it shows kids how things like activation energy and temperature relate to rate, and I think that’s really important to do with an equation.

I: Okay, and do you feel that your students understand the mathematical processes involved in the Arrhenius calculations?

D: I think those that are good at maths do, those that are bad at maths probably struggle with it, yeah.

I: Okay [Laughs] that’s that. Okay, so the next question is regarding atomic structure and bonding, so I’ve got a question here that a few, we got a few students and a few teachers to answer, so we gave them that question. A sodium ion in the gaseous state is more stable than the sodium atom in the gaseous state, and 70% of the students who took part said that’s true, 30% said false, now if you flip that over you’ve got the same question again and that’s the split with teachers, the bars aren't really representative of the minimal difference between them, but this time 53% of teachers said it was false, 47% said it was true. So I’m not asking you what the correct answer is, we just want you to say why you think these are the typical responses?

D: So this example here from students year 10-13 is because they’ve had it absolutely drummed in to them that things like having a full outer shell, or an empty outer shell of electrons and that is stable and happy and wonderful, and therefore to them a sodium ion being more stable than a sodium atom makes sense because that sodium atom seems really unstable and is wanting to lose that electron and therefore do that. This side is probably, that’s probably the teacher side is probably more like likely to think you’re trying to catch them out. I think actually most of them wouldn’t think about the fact losing that electron is going to require energy and is therefore actually the ground state of the sodium atom is going to be lower than the sodium ion, and the reason why ionisation is okay there, kind of the reason we talk about it being energetically favourable is actually because of the flipped side, it's therefore the think that's gained the electron has become much much much lower in energy, and we’re talking about almost like yes “okay yes we’ve lost a little bit of energy making sodium ion, but actually we’ve gained a massive load by making a fluoride ion, therefore overall the energy change is negative” and that’s why it’s energetically favourable. It’s a strange one really because what we probably teach students is, it’s too much of an oversimplification at GCSE level, that’s probably why this has come about and I think probably the teachers either know that and that’s why they’ve given that, or I reckon they’ve probably, if it’s a post-16 teachers conference and you’re giving that as an answer they’re probably like “Oh well if they’re asking me, then it can’t be obvious right?” So that's probably why you've almost got a 50-50 split of some people thinking they know the answer, and some people just guessing because they’re thinking it might be a trick question.

I: Yeah, okay that’s great. And so I’ve got another one of these questions a bit similar to that, this is on equilibrium, chemical equilibrium.

D: Okay.

I: This one’s a bit more complicated because it’s aimed at first and second year undergraduates because it’s part of a paper regarding, it’s taken from a research paper. So we gave a few teachers this equilibrium problem, so what would be the effect when you add neon at constant temperature and pressure, so that’s keeping the system at constant temperature and pressure before and after the addition of neon. We asked the teachers who were in attendance to suggest what would happen to the position of equilibrium, that’s given in blue, then we asked them to discuss their ideas with the teachers around them, and then once they finished discussing it with their peers we asked them to answer the question again, and that's what the red shows. So to begin with there was the majority thought there was no shift and the majority thought there was a shift to the right after discussing it.

D: Interesting

I: So, why do you think this might be the case?

D: Why did more people end up being wrong do you mean or?

I: Well, why did people put no shift and then why did people put right shift?

D: The way that equilibria is often taught, is essentially what you’re talking about is there being a number of particles and the pressure of those. So on the right hand side what you’d have more particles than on the left hand side so the fact that you’re adding a bunch of neon to that you might argue you’re adding more particles and increasing the pressure and therefore…

I: Ahh, but we’re keeping it at constant pressure.

D: Oh okay, in which case you’d have loads more particles but less of them would be actually what you’re interested in, I can’t understand why more people have thought about it being a right shift. I can’t work that out.

I: So what we’re looking at here is when you keep the system at constant pressure with neon there, the partial pressures of the species are decreasing of the PCl5, the PCl3 and the CL2 because those partial pressures are decreasing, what that’s going to do is shift the equilibrium position to the right, if you think of the Kp equation.

D: Oh I see, right.

I: This wasn’t to try and catch you out, it’s designed to be a tricky question.

D: So ahh, yeah I’m with you, it’s because of the constant pressure thing I was trying to think at in my head. So actually it’s not going to really affect the number of collisions that are occurring because the same number of overall collisons should be occurring, should be the same if the temperature and pressure are the same, right I’m with you now.

I: Yeah, that’s alright no problem. Yeah so, when you just used Le Chatelier’s principle looking at this question, you know you need to look at Kc, Kp whatever to be able to be able to actually really get deep into this question which is why it’s so difficult. So having considered this problem and the one previously given to you, both of them involve the use of models or principles so Le Chatelier’s principle, the octet rule, do you believe that the limitations of chemical models and analogies should be taught at GCSE? At A level? At both or at neither?

D: I’m incredibly intellectually honest when I’m giving kids models that I know are an oversimplification and I will tell them that they’re an oversimplification but just roll with it for now, and one day it will get explained if they want to do chemistry further. I think otherwise you end up with people probably in retrospect are rueing the day you ever taught them something that they think is wrong, and actually it’s just because it’s necessity, sometimes you have to teach an oversimplified model in order to get your message across at a certain age. We can’t teach primary school children about wave-particle duality because they wouldn’t be able to access that and so therefore we have to make big assumptions to them. We have to tell them that radio waves are a wave, but they’re not they’re both a wave and a particle and so we can’t tell them that at the time because that wave makes sense to them. So I mean you always have to kind of make a model that is it a level that the students can access it, and sometimes that means you have to oversimplify and I think that’s okay, I’m just normally honest and I tell them this is an oversimplification but don’t worry about it.

I: Yeah. Do you find yourself using analogies when you teach?

D: Yes, all the time. Even as so much as talking about a chlorine radical wanting to react for instance. It doesn’t want to react it’s not got a consciousness or any sorts of wants or desires at all, but what I mean by that is it would be an energetically favourable thing for it to take part in this reaction we’re considering or whatever. Sometimes using analogies makes very theoretical far more accessible.

I: Yeah, and do you find yourself using analogies more or less with the topics that you’re more familiar with in terms of your subject matter knowledge? Or do you think there’s not really a distinguishable difference.

D: I don’t think there’s much correlation there really, it depends, I think for me I use more analogies with more theoretical things, so with things we have to grasp concepts far more, and you haven’t got the kind of intuitiveness to maybe kind of get that across then maybe you have to use an analogy more yeah.

I: Okay, excellent that’s all the questions I have.

D: Great.

I: So thank you ever so much.

D: No worries at all.

**HANNAH INTERVIEW TRANSCRIPT**

I: Okay so if you could please state your name for this recording

H: Uhh my name is [REDACTED]

I: And can I confirm that you’ve signed the consent form and that you fully consent to this interview being recorded and used for our research project?

H: I have consented, yeah.

I: Okay excellent, so this first section of the interview is going to be about teacher training, and they are going to primarily focus on that and it’s influence on your own subject knowledge.

H: Okay

I: Ok, within chemistry, so...We’ll start off with your chemistry degree, so which aspects of your degree, if any, helped you to develop your subject matter knowledge for teaching would you say?

H: Uhh, I suppose definitely my first-year training, as its all quite relevant to the A level syllabus. Some of the thermodynamic stuff has been quite useful because obviously it gives me a little bit more in depth knowledge about things that I’m teaching now, but I suppose everything that I did at uni kind of gives me a bit more information about what I need to tell the kids, and if they ask any extra questions, that I can say “well, actually this leads on to this, and this leads on to this” But in particular, I don’t think on a daily basis I would delve into the things like that we did in 3rd year, for example, yeah it’s just overly complicated.

I: Of course.

H: But yeah, definitely first year content was good.

I: Okay, that's excellent.

H: It’s a long time ago though [laughs]

I: Yeah [Laughs] and to what extent then did your teacher training address subject matter knowledge development specifically, during your training period?

H: Well we had, I did the school’s direct route so we were at university once every 2 weeks, and then we would have lectures on teacher training and just general paperwork filling out, and then we would have some specific areas, but it wasn’t always chemistry because obviously I trained in a state school, and the majority of people did was PGCE in Biology, Chemistry and Physics, so quite often they would give us physics training because people were weakest on that…

I: Right

H: But they did give us some practical techniques and things that we could take, particularly in chemistry, take back to the classroom. But there wasn’t necessarily that much on content, there was a moles clinic I think they did with us, but yeah it was only once every 2 weeks and that might have been for an hour for that day, the subject knowledge.

I: Right, I see, okay… And while you were undertaking your teacher training, did you engage in any self-directed activities?

H: Yeah, I had to [Laughs]

I: So what did you, what kind of things did you do?

H: So, obviously I was teaching syllabuses I didn't follow as a student, so I had to quickly just check what things they needed to know, what was actually GCSE, what was A level, and what was KS3 because i was teaching all of them. And then just referring...Sometimes actually just looking back, because some of the stuff we did, I taught A level that I hadn’t done since I was A level myself, because I didn't choose those options at uni because I didn’t like them, or I wasn't very good at them. So i had to really re-learn the A level course in particular, definitely in my NQT year, everything I had to look over again in my PGCE.

I: Right, okay. And you said that you, so in the pre-interview survey you did online a few weeks ago now, you said that you didn’t feel as confident in the beginning, and then you felt your confidence increasing. So would you say that the impact of those activities that you engaged in helped your confidence in your knowledge?

H: Yeah, I think...I took a gap between university and teaching so I think that gap kind of misted over some of my subject knowledge, just because, yeah. I needed, I had maybe 3 years I didn’t do any chemistry so I needed to refresh everything.

I: Okay, so what were you doing in that time?

H: Umm, I was building and landscaping.

I: Oh right, okay.

H: And also, I worked in [REDACTED] as a fundraising manager for a major charity.

I: Right, and just out of interest, do you find that those experiences that you’ve gained from those areas have helped you in teaching? And if so how?

H: Oh yeah, definitely! So working in the construction company I was dealing with people that would quite often know more about certain areas that I did, and I would really have to assert my authority and put my foot down and sometimes argue to get the best price or deals, or not get overlooked, as a woman as well. And then in my fundraising job, I was head of generating income for [REDACTED], so that was my, so I had to come up with ideas to bring in money basically, and make sure we hit targets. So now I’ve taken that on to my current role of teaching, and I'm head of house for [REDACTED] which is one of our, so that’s all the charity and sports for that.

I: Excellent, that’s really good

H: So I have used them [Laughs] Later down the line.

I: Yeah, exactly, okay so this next section of the interview is going to focus on what you think makes a good teacher, and how subject matter knowledge can come into that. So broadly speaking now, this is a really open question, so say whatever you want, what do you personally believe makes an effective teacher of any subject?

H: Okay, I think that a good teacher is somebody that can be quite patient and get the student to understand something that they didn’t know before the lesson. Not telling them a fact but getting them to realise it for themself. So, you might hint at it, or give them some guidelines, but I think the best way that students learn is to actually discover it themselves, and just guide them slowly along that line so that they think they’ve done it themselves.

I: Yeah, of course, that’s great. And so, what about an effective teacher of chemistry specifically?

H: Specifically chemistry, I think you have to have quite a few different skills obviously, because we do have mathsy areas, we do have areas where you just have to remember something, or link back to something else. I think building up a picture and just developing that idea, yeah but similar to any other teacher really but just I think kids come in and think “Oh Chemistry’s really hard” you’ve got to definitely break down that barrier first before you can do anything else, and make them enjoy it, and make it fun. Definitely have a responsibility to make it their favourite lesson first, and then you can hit them with the harder stuff once they gain their confidence.

I: Yeah, okay. And how do you important do you believe that a Chemistry teacher’s level of subject matter knowledge is in their teaching?

H: I think it’s really important, I think obviously when you’re starting out, and I wouldn't say that mine was 100% what I would want it to be, but I work as hard as I can to make sure that before I go into a lesson I’m as prepared as I can physically be. But sometimes they do throw curveballs at you and you just have to put your hands up and say “right let's have a look at that” or “I’ll get back to you”. But I think if you aren’t confident in your subject knowledge, the kids are just like “I don’t really want to listen to anything you’ve got to say, because I don’t really trust you, and I don’t want to learn that” and then it’s quite a bit of effort to then understand something. Especially at A level when they don’t feel confident in your ability. So you’ve got to be really spot on so then they think “Right, if I do exactly what they say, I’ll get there.”

I: Yeah, that’s great. So do you think a teacher should be an expert in their field then? Or do you think there comes a level?

H: Umm, they don’t have to be an expert in their field, but I think they need to know the course and the content of that course really well. It helps because sometimes, the kids are much more confident with a few of my colleagues because for example have got PhDs in their subjects so they’re like “wow they must know what they’re talking about” whereas I, a young female coming in, they’re like “have you even done your A levels yet” [laughs]. But yeah, I think it does give that layer of something, but I think that if you’re on it and you know exactly what is going on with, oh you know that will come up in question 4, or like the next semester then they gain confidence quickly.

I: Yeah, okay. So moving on from there, do you feel that your own teaching of chemistry is limited by any external factors? So that’s things that you don’t have any control over, so that could be the school, the syllabus, anything like that?

H: I think...The limiting factor that I have is not having taught the children up until that point. So we get quite a lot of kids who might come to our junior school and they’ve got a really good science knowledge and good confidence, or we might have children from other state primary schools and they come through and they haven't done any science, they’ve literally just focused on English and maths for their SATs tests, and they are like “Oh I’m bottom set, I’m rubbish at science, I can’t do it.” And then they sort of carry that sort of negativity with them throughout GCSE, and then they might get to A level and think “Oh, I’m just not very good at this”. And some of them as well, in particular this year, I’ve got a girl in my lower sixth class and she’d done double award science rather than triple, and I feel that her confidence was just really low and that’s something that’s completely out of my control. So i think that the preparation that they have compared to their peers is massive, because it doesn’t matter if you say to them “If you work hard, you know…” They really compare themselves to their peers, and if they are already on it because they’ve done a more intensive course, then it does make them feel a bit insecure at the beginning. So I’d say that definitely.

I: Yeah, and in an ideal world, is there anything you would change about how you would teach chemistry? So under what circumstances would you like to teach it?

H: Umm, I would say no afternoon lessons [laughs] I think, to be honest where I’m in an independent school because there is no limit on the facilities that we can have, and if I want to do an experiment, our technicians like “Yeah, we’ll just buy in the chemicals” we can pretty much do whatever we want. And If I want to run a trip, the head is really good, as long as you can make sure there’s no sports fixtures on that day we can do it.

I: Wow okay.

H: So they are pretty good in that aspect.

I: Yeah, that’s great, so have you had experience working at others schools?

H: Yes, so I trained in a state school.

I: Okay, so how does that compare, so the difference between a state school and….

H: [Laughs] So we actually had one term where they said to us we’re not allowed to do any practicals because we’ve ran out of money.

I: So no practicals whatsoever in any Biology, Chemistry, Physics….?

H: Yeah, exactly…

I: Including for A level?

H: Including that, I think the required practicals we had to do, obviously, but they said we’ve run out of money, and the technicians have gone down from 3 to 1, so they just can’t do it.

I: Wow.

H: Yeah, and they were class sizes of 35 children, a lot of them were... A lot of them had special educational needs and needed extra support in a lesson like 1 to 1 with a TA, and we might...There was one class I think where I had 12 children with special educational needs and just me.

I: That’s really interesting how different it is between…

H: Yeah, massive difference, massive.

I: Wow that’s crazy. Okay, so this next section, third section of four, these are going to primarily focus on your opinions of the A level Chemistry curriculum

H: Okay

I: So...Before we get on to that, I’m going to ask you briefly, do you personally engage in any activities outside of schools, so that could be wider reading, watching tv, listening to the radio, to expand your knowledge of chemistry or science?

H: Yeah!

I: What do you do?

H: Well obviously I listen to some podcasts like Brian Cox and things sometimes, particularly because I’ve started teaching physics this year as well. I will watch documentaries on the telly if there’s anything, generally it’s to up my subject knowledge and make it interesting for the younger kids, but I will read articles on TES and things like that. And we have the general, New Scientist magazine in the staffroom, but generally it is news related. But I have read a book on digestion, but that’s biology based [laughs].

I: I mean, you’re teaching all three subjects at the end of the day, so it can be quite difficult in that respect. Okay, so going back to A level chemistry, so if a student asks you a question relating to content that lies outside of the A level specification, how do you approach that situation? And if it has happened can you give an example.

H: Generally, It happens all the time, but I can’t think of any example right at the moment. I think it’s something to do with “What venom do spiders inject and how does it affect your blood chemistry?”

I: Wow [laughs] that's quite pharmacological.

H: Which obviously isn’t quite in the front of my brain [laughs], so obviously he knew that wasn’t on the course, but generally I will, if the conversation flows I’ll answer the question straight off if I know it, and then I’ll say “that's not on your specification though, so you won’t need to remember that, but it does it because of this, and this is quite interesting”. And then if I know anything else I refer them to..I try and keep it short and sweet, and I try and simplify it as much as possible initially, so that it does not overcomplicate things, especially if it’s in a class situation because some of the other kids are like glazing over at this point thinking “what on earth are we talking about?” and they think this is really difficult, so if that is the case and other people are listening in, I will say “that’s not what we need to know, but if you want to know…” I’m not going to say “No we’re not talking about that, it’s not on the content” because, well we’re trying to teach an interest of science aren’t we? So I like it when they ask other questions, but yeah I think there’s always that one person in the class who’s trying to write down everything you say, and you’re like “hold on, don’t write this”. But yeah, I think that’s my example [laughs]

I: Yeah, and what, and if you don’t know the answers to the questions, how do you approach that?

H: I google it.

I: Yeah? In the lesson or do you wait to…?

H: Sometimes I...No no I do it there and then, especially if it’s something that is not on the syllabus, if it’s something that is on the syllabus, I will do the classic “That’s not what we’re doing today, stop being disruptive, we’ll move on” Because otherwise if they smell that you don’t know something they’re like...I will yeah, if they catch me out I will try and deflect slightly.

I: Of course.

H: Like “we’ll come back to that tomorrow, I don’t want to confuse anyone” but if it’s something that is not on the course but it is quite interesting that links in, I’ll say to them, “why don’t you just use my computer quickly, and we’ll get it up on the screen and we’ll talk about that”. Because generally it’s the kid who has finished the work quickly and then you can go and help someone else. Keeps everyone busy.

I: Yeah, that’s great, and how often do you find yourself teaching content that lies outside the A level specification, would you say that’s a rare thing or quite often?

H: Umm, fairly rare, just because it’s quite fast paced, and trying to get everything covered and where it is quite complicated, you tend to say to them “any other questions?” and they are like “No.” But I think, this will be my first year of teaching the upper sixth.

I: Right.

H: Because I’ve taken them through...Yeah, so I’ve only ever taught the lower sixth.

I: Right okay.

H: So, they might then ask a few more questions I think, and we’ve got a bit more time, but it will be exam prep as well. But, Christmas and Easter sort of time I try and do a practical that is not on their syllabus, like we do silver mirrors, and making snowflakes and sort of stuff, and we learn a bit about that.

I: Yeah, that’s always fun.

H: I try and break it up a little bit.

I: That’s great. So moving on from there, what should the scope of a chemistry, we touched on this earlier but, what should the scope of a chemistry teacher’s subject matter knowledge be? And do you personally believe it to be an issue if a teachers subject matter knowledge in chemistry is limited to just the A level specification?

H: I think you need to have a higher understanding definitely. I think it comes back to that classic, people teaching chemistry when they’re not a subject specialist. It just turns the kids off. I’ve even seen colleagues of mine, and they’re brilliant teachers, but they are biologists and they teach chemistry, and its just so boring because they don’t like it.

I: Yeah, exactly yeah [Laughs]

H: They try and get through it as quickly as they can and simplify it as much as they can, but that just makes it so boring. I think if you enjoy it and you’ve actually gone ahead and studied it at a higher level, you’re always going to make it more interesting. So I think it is important to have a wide breadth because then you can, like, one of my colleagues who’s recently retired he’s obviously been teaching for 40 years, and he’ll just walk into a classroom and be like “what’s that?” “why does that do that?” and the kids are like “ooooh I don’t know”. Where as I haven’t quite got the confidence to do that yet, but I’m working on it, but he can just walk into the prep room, the technicians don’t like him doing this [laughs] but he’ll walk in and just take stuff and throw it together and then say to one of the kids “why does that do that?”, and just build a lesson on that, he’ll cover all all the content and he gets good exam results, but he just knows what he’s doing.

I: Yeah, exactly.

H: And there’s always that element of mystery, and that you’re working out something, yeah he’s very good at that.

I: Yeah, and I guess that’s maybe comes from experience, it's something you need to learn over time.

H: He’ll throw a bit more sodium in the water than I will [laughs], he mushes them together!

I: Blimey.

H: He put sodium and potassium together and threw them in the water basin, and I was like “what are you doing [REDACTED]? “[Laughs]

I: Yeah, you get it why some people become chemists [Laughs].

H: The kids are like “[REDACTED] does this.” and I’m like “I am not doing that” [laughs].

I: Excellent, right so this last section, this is probably the biggest one, this is on common misconceptions then, it specifically focuses on some of the topics of the A level, don’t worry I’m not going to be testing your knowledge or anything like that. And so the potential issues involved in both teaching these concepts and understanding them. So you may remember in the pre-interview survey I asked you what topics you were most confident in and which ones you were least confident in. So we’ll start with the ones that you felt the most confident teaching, and you said atomic structure molar calculations and kinetics were the top two.

H: Yeah

I: So what is it in particular about those two topics that make you feel more confident in your knowledge of them?

H: I suppose because atomic structure, the kids just tend to know what’s going on anyway because they’ve learnt it from year 7 and it's reinforced every year, and then moles we introduce in year 10, so and obviously I’m teaching all through the school so actually I might teach a moles lessons three times in one week, so yeah I think that’s why I’m more confident with it. And obviously children have seen it before, they are just like “Oh yeah we’ve done this”.

I: Yeah, and what about kinetics?

H: Kinetics, It seems to make sense. It’s quite a short topic on the A level syllabus as well, and it’s graphs and visual learning, you can team it up with some experiments, and you know that if you raise the temperature of something it’s going to make the reaction faster. The kids seem to think “yeah, that makes sense what happens in other subjects as well” like if you get hotter you can move faster and you can talk about the particle model and everything they’ve learnt in year 7 and probably in year 5 even, so it links back in. So I think that’s why they are easier to teach because it’s familiar territory.

I: Okay, that’s great, and how do you approach teaching those topics? So when you know those topics are coming up, how do you go about preparing and your teaching, and then teaching and delivering content?

H: I always start my new topic with a bit of a chat about what we know before start. And I will start from the absolute basics and question like “why does that do that” and just get them to work in groups and discuss what they know, what they can remember, and then maybe do an experiment and then actually think about, “right now we know what the basic bit is, we’ve looked at it in terms of a practical, is there anything else we can add from the things that we know because we’re A level students, we’re mature students” and just pick it apart from there and layer it in, that's what I would do.

I: That’s great, okay. So now we’ll turn to the topics that you felt less confident with, so the ones you put at 9th and 10th were acids, bases and buffer solutions and electrochemistry.

H: Yeah.

I: So we’ll start with acids, bases and buffers, so what is it in particular about this topic that makes you feel less confident?

H: I think for me, it’s just because it’s normally on the upper sixth course.

I: Right, okay yeah.

H: So I haven’t actually taught it once since I did it myself, and I found it difficult when I was an A level student myself, I think it’s just the whole mathsy thing. I’m not the strongest with maths, I have to have a strategy and once I’ve done that, you know ask me in a years’ time and it’ll probably be my favourite one once I’ve taught it and done it, but I think that’s why. And I think the students do get confused with the like one going down and one going up, and the crossover graphs, and also just rearranging equations, it is just like a maths-based bit isn’t it? And when they come up in exam questions, they are quite long answers, there’s like 10 marks for 1 question and they are quite intimidating for the kids, and you can just miss out one unit it and it could mess up the whole thing.

I: Of course, yeah, and I guess the similar is true of electrochemistry? Because it’s not really on the lower sixth is it?

H: Yeah, that would be the reason, and I haven’t taught it at GCSE yet either because it’s on the, well no I have, so this year I’ve been teaching year 10 and I’ve been teaching year 11 biology, so I haven’t taught any electrochem in the GCSE one yet, so that’s why that one was on there as well.

I: Okay, okay that’s great. And I guess you as you said, you haven’t really got in to teaching these topics yet, but will you approach teaching those topics the same way do you imagine?

H: Yeah.

I: Yeah? Will you….

H: Yeah, just break it down because I know it’s on GCSE content, and obviously I’ll look it up, and well find the easiest way for myself to really understand it, and then bring that to the classroom as well.

I: Yeah, okay that's great. So we’re going to focus specifically on the topic of kinetics now, very briefly. So as part of the A level reforms that happened in 2015, the Arrhenius equation was reintroduced to the A level specification, so that’s part of the second year I believe, the upper sixth, it may come up in lower sixth I don’t know.

H: Yeah, I think it’s in the second year.

I: So have you had to…?

H: I haven’t had to teach it yet. I did do a revision session with upper sixth last year, so I think I did mention it to them then, but I haven't taught it to them from scratch yet.

I: So do you feel confident in your knowledge of the Arrhenius equation? How it works?

H: Well, I think, yeah so the Arrhenius equation has just got quite a few different components in it, and the main difficulty with that I think for them, is rearranging it, because it's obviously got the superscript.

I: Yeah, that’s it, and it’s got the natural log in there that sort of makes it complicated.

H: Yeah, exactly, and not all of them are doing maths, so they look at logs and think “oh my god!” [laughs] but yeah it’s quite a basic rearrangement really isn’t it, if you break it down into steps.

I: Yeah, it’s not too bad.

H: And you just get them to remember what each of the symbols is relating to and just, I get them to write a revision card for that one straight off.

I: Right, okay.

H: Yeah, “make this massive in your notes, take up like half an A4 page and make it colourful so that you remember it”

I: Yeah okay, great, so I guess, the next couple of questions are about the understanding of the maths, so do you feel that you understand the mathematical process involved in rearranging the Arrhenius equation?

H: Well, I’m not very good with maths at all, so I try and simplify it the best way I can. Obviously if you’re going over the equals sign then you do the exact opposite of what it was doing before, and that’s how I explain it to the kids.

I: I see, okay, and this is something that come up in another interview I did a few weeks ago, do you feel that when you’re teaching topics that you are less confident with before, because you’ve had to look over them before the lesson do you feel, is there any change in the confidence you feel during those lessons compared to ones where you didn’t have to brush up so much? Or do you feel that they are quite comparable?

H: Some things I just know like the back of my hand, so I know that I’m not going to feel nervous about teaching it at all, I think I still feel nervous teaching some that I know I’ve had to look up, even though I know I’m more prepared, but as soon as I’ve done it once it doesn’t bother me at all, and I’m quite good at blocking things out because I’ve got so many things to do [laughs] I’m like “I’ll worry about that 5 minutes before I go in” [laughs]

I: [Laughs] I see, and do you get any support for any subject specific CPD at your school?

H: We did do a CPD day and [REDACTED] was there, but that was for the whole island, no we don’t really do chemistry, but if I’m struggling with anything I’ll always go to my colleagues and say “Oh what have you done for this?” we’re quite a close knit team, there’s only like 4 of us in the chemistry department so we’ll just catch up, or I’ll even just text my boss like “What’s this?” and he’ll go over it with coffee in the morning. We all get on really well so it doesn’t really matter.

I: Yeah? That’s great, that’s really good. So we’re going to move on to atomic structure and bonding now, so I’ve got an actual content question to show you, so don’t worry, this is designed to be tricky. I’ve got this question here, a sodium ion is more stable than a sodium atom, true or false? And this is a single sodium ion or sodium atom. Now this is how a group of year 10 to year 13 students responded, so 70% of them said that was true, 30% said it was false. Now on the other side, this is how a bunch of teacher’s responded at a conference that was run a few years ago, so 53% of them said it was false, and 47% of them said it was true. So why do you think these are the typical responses of students and teachers? What do…

H: So a sodium ion is more stable than a sodium atom. So teachers are saying that it’s not more stable.

I: It’s a fairly even split. It’s just that the graph makes it look less so.

H: Yeah, and then the kids are saying it’s more stable.

I: So why do you think that….

H: I think the kids are saying its more stable because we always tell them “right, it wants to lose that electron and then it’ll become more stable because it’s got a fuller outer shell”. And I think the teachers are saying that it’s less stable because its ion, so as soon as it comes in to contact with something it’s going to want to form an ionic bond.

I: Yeah, you know you’ve pretty much hit the nail on the head there of what we think. Because it’s all about that language that’s sometimes used when describing.

H: Yeah, so we always tell them that….

I: Yeah, and I guess you know it is true, in a way. But at the same time, if you’ve just got a sodium ion existing, I mean it's such a hypothetical situation you could never get a sodium ion on its own, but to form a sodium ion it’s got an ionisation energy that is positive, you have to put energy in.

H: Yeah.

I: So a lot of, as you can see with the teachers, I mean it’s fairly even, a lot of them are saying it’s still true. There are arguments both ways it’s such a hypothetical situation that it’s difficult to judge.

H: Yeah, hmm.

I: It’s just trying to make….

H: That is quite an interesting one as it’s all on what we say to the children as language and...Yeah.

I: Exactly! And now I’ve got a question regarding chemical equilibrium for you as well.

H: Okay.

I: Now this one is quite tricky, so we gave this question to a few teachers at a conference last year, so I’ll give you a bit of time to interpret this graph. So the question is, it gives you this equilibrium system PCl5 going to PCl3 and PCl2, and we’ve asked what the effect will be of adding some Neon into the system at a constant temperature and pressure, so that's adding the Neon but keeping the pressure of everything consistent, okay?

H: So adding Neon…

I: Yep, and the pressure of the system is still staying the same with the Neon in there.

H: With the Neon in there!?

I: Yes, so the pressure from before with just those 3 species.

H: But there’s still going to be more moles, isn’t there?

I: Yes, and what we asked is what effect do you think this will have on the position of the equilibrium, will it shift to the left, will it shift to the right, will there be no shift? And we got them to answer this question, and the blue indicates how they originally answered, and then we got them to discuss them with one another, and you’ll see that there was a change in opinion and more people though there was a shift to the right.

H: Yeah.

I: So can you explain why you think that the teachers changed their mind, or why they answered no shift and right shift more commonly than the others?

H: If you’re adding it in, then that would say you’re adding it to this side, so that wouldn’t make it a left shift, because, well it should be no shift, shouldn't it?

I: Should it? See this is the thing, it is a really tricky question.

H: My reasoning would be, I was going to argue, that if you add, so the pressure is not increasing

I: No.

H: So that would mean that wouldn’t affect the equilibrium, so if you add, oh hang on...So currently the equilibrium position is going this way because it is a gas, so it will move to the side with less moles, but you’re adding some moles here, so actually...It will shift it to the middle which would mean it’s shifted to the right slightly.

I: Right, that's fine, as I said it’s a really tricky question, I’m not trying to catch you out or anything by asking this. What we’re showing here is by using Le Chatelier’s principle it becomes almost impossible to answer this question, because Le Chatelier’s Principle is a guide essentially, its a way of predicting but it doesn't necessarily tell us what happens in all situations, so I’ll tell you what the correct answer is deemed to be. So when you add neon at constant pressure, though the overall pressure is the remaining the same with the neon in there, what you’re effectively doing is increasing the volume, which means the partial pressure of all of those species are decreasing

H: Oh, of course!

I: Obvious when you know, but it's hard to see that from this, this is not an A level question, this is at an undergraduate level and it was designed to catch out undergraduates with their understanding, this was taken from a research study in 1995 I think it was, so it’s designed to catch people out, and that's why there’s a right shift as with everything going down with constant pressure, partial pressures are essentially concentrations decreasing, it will shift to the side with more moles to counteract that change. But, if you’re using Kp and Kc, this would be a lot easier to see.

H: Yeah, if you put the numbers in you could see it.

I: You could see it, but when you’re just using Le Chatelier’s principle it’s much more difficult to see, okay? So that's the last of those questions, so I’m not going to make you feel bad about yourself with anymore, I hope I haven’t done so already [laughs]

H: [laughs]

I: So final comments now, having considered those problems I’ve just presented to you, what's your opinion regarding teaching the limitation of chemical models and analogies, so we teach Le Chatelier’s principle, we teach about full outer shell is more stable etc etc, these are obviously models and analogies, do you believe we should teach the limitations of these models as well as the model?

H: Definitely at A level yeah.

I: Yeah?

H: I think at GCSE and below it would make it complicated, but at A level I think it is important to say that there are things that break the rules, but this is a general idea to help us understand it but there are limitations to this idea, and yeah then maybe show them something like this, but say if you have got more information than you can then use it. But I think quite a lot of our students know that an atom doesn’t look, the way that we’ve told them, and you know we’ve sort of talked about an electron being a particle or a wave and that they can understand that it’s a model that helps us understand this bit and a model that helps us understand this part of it and it's a mixture. So I think they’re starting to get to that point, although they do say to me “Oh it’s one of those, everything we’ve learnt before just forget it” [laughs] but I try and say to them “Look it’s not that, it's just a stepping stone to help us understand”. But yeah definitely, I think its good, and I remember somebody talking to me, it might even have been at degree level, saying models “this isn’t actually what happens” and being like “oh my god, I didn’t realise, I thought it was that” [laughs]

I: Yeah

H: Until somebody says actually this is just an idea that we’ve devised to help us to visualise this idea

I: Yeah, that’s it, the example I always give with that whenever I’m talking to that is organic mechanisms, I mean we throw arrows around the page, and it's all wrong.

H: Yeah! Electrons aren’t moving there.

I: It’s very easy for students to forget that there’s not just one molecule in there, there’s thousands, millions even.

H: And with moles again, I try to do that.

I: Yeah, exactly, the other thing that you find is a lot of GCSE students don’t realise that ionic bonds aren’t just two ions but a huge lattice because you represent them in ionic dot and cross diagrams.

H: Yeah of course.

I: That’s where models are an interesting one, and that’s what we’re looking into at the moment, models and analogies.

H: [REDACTED] did do some stuff I think at our CPD about models.

I: [REDACTED] did yeah. So okay excellent, that’s all of the questions I have for you, so thank you ever so much for taking part.

H: No no, no problem.

**MARTIN INTERVIEW TRANSCRIPT**

I: Okay if you could state your name for the recording.

M: Uh, [REDACTED]

I: And can I confirm that you’ve signed the consent form and that you fully consent to this interview being recorded and used for our project?

M: Yes

I: Okay, so these first few questions are going to primarily focus on your teacher training and the influence it had on your subject matter knowledge. So, before your teacher training though, which aspects of your undergraduate degree, if any, helped you to develop your subject matter knowledge for teaching? Specifically for teaching.

M: Sorry, can you repeat that again?

I: Yes, of course certainly. Which aspects of your undergraduate degree, if any helped to develop your subject knowledge for teaching, that you use in teaching?

M: So I actually had the opportunity, I went to university in [REDACTED] and one of the options you can do in third year, well what should be your final year of your undergraduate, but I was on the four year course at the time because I did an undergraduate masters, I had the opportunity to do an educational research project so that was probably what prepared me most. So admittedly, thinking back now I don’t know why the school let me do it, I came in and I taught an entire topic at the [ ] absolutely nothing, no training…

I: Wow.

M: I remember going and seeing the teacher “okay, if you give me a lesson plan by next week” and me having to go home and google lesson plan because I’d had no training whatsoever, but I got the feeling it was non-chemist specialist, I never asked who didn't feel very confident and just handed me this A level class for my project, which I did on intrinsic connections intrinsic motivation. So that was really interesting and that I learnt a lot about sort of the ins and outs of just being in the classroom, how sort of much more difficult than you first think, you kind of think when you first, “oh you’re just explaining” I think also there is that tendency that you’ve got used to how you’re being taught so it’s pretty much all lecturing, because I spent the last 3 years being lectured at so I didn’t know anything other, so I lectured the students, was kind of what I did.

I: I see [Laughs]

M: So that was the biggest thing I would say that was probably...I gained a lot of knowledge but also I probably developed a bit of an incorrect style which was swiftly corrected when I started doing my PGCE.

I: Okay, yeah so you say you did a PGCE, so during your PGCE to what extent did that teacher training address subject matter knowledge development then? Specifically, if at all?

M: So my PGCE was at [REDACTED], so all of the science subjects you have a subject knowledge audit admittedly it’s not, they don’t test you on it and then give you, it’s done pretty much voluntarily of what you’re good at, what you’re bad at, and then you have a meeting and they go “well, between now and the end of the year you need to adjust, you need to think about and do something about these areas” and then they’ll put things in place or tell you where you should go and maybe do that, they tell the schools that’s an area you need to develop on, so often you end up teaching the thing you’re not very good at, which actually often works better for when you’re planning teaching, because if you don’t understand it, you then have to think really logically about how to explain it, because you’ve only just learnt it, and then the whole often leads into the way into teaching it is better because sometimes the thing I find hardest to teach is something like rearranging equations because I’ve always been good at maths, so when a student’s just fundamentally staring at me going “but that makes no sense” I am staring at them going “but it makes perfect sense”, and there's this disconnect where I can’t explain something that I just so intrinsically get how that works, I think I’m quite good at spatially thinking. So when someone can’t spatially think I’m like “How do you even explain this?” so often I find that quite interesting, it’s often things you’re worse at, sometimes means you’re a better teacher at it.

I: Yeah, okay and while you were undertaking your teacher training did you engage in any self-directed activities to develop your subject matter knowledge, that weren’t formerly part of the training?

M: Well the knowledge audit is a bit self-directed because you just sort of rank what you are, and what your problems are. They do tell you “oh you need to go away and do this” but it’s not, it’s not that structured, they kind of let you decide what you’re going to do and then just make sure that you’ve done it. So my main thing was acid buffers and bases because there’s certain things that you don’t, you become more and more niche as you go through university, and there were some things that I just dropped, electrochemistry and buffers, I was like, I didn’t like them at A level so when I had the option at degree, well I’m not picking those because those aren’t my favourite bits because I found them hard. So it meant that actually when I came round to having to teach it I was like “oh my god I actually still partly have a problem with this” but fortunately because I’d done so much chemistry it was not as hard as I thought, but there was almost a block because I didn’t understand it I then didn’t pursue it and didn’t perfect it on my own.

I: And how did you go about adjusting your knowledge with those areas that you…?

M: So typically I tried to look at online resources, two resources I pinpoint students at too the most because it’s how I learn the most are chemguide and Khan Academy. They are very good, I like chemguide a little bit more because it’s pitched better for A level students, but that is honestly where I go. But there’s also for the maths bits there’s also the book that the guy from chemguide did, I can’t remember what his…

I: Yeah, don’t worry I know the book yeah, that's great. And what do you remember about the impact of those subject matter knowledge activities you engaged in on your confidence in your knowledge? Because you’ve already said in your pre-interview you were quite confident in your knowledge anyway didn’t you?

M: Yeah [laughs]. It was one of those weird things that I think I was a little bit kidding myself in the fact that I’ve got a degree in chemistry so actually it’s almost been the reverse of what I would imagine you’d think that when I first did my PGCE I was like “oh yeah I’ve got this” I thought “Oooh electrochemistry and this I need to review” so I did review, but there were some areas where I was like “I’m really good at this” and then I came round to actually teaching it and planning the lessons and I thought “actually there’s some questions here that I’m not as 100% on this as I thought” but doing those activities, especially with the ones that scared me massively improved my confidence, because I didn’t really touch the others, it was actually a bit of a confidence knock when I first came round to teaching it was like “actually I don’t understand that fully” but through the past few years I’ve actually found it exciting because it means I don’t know everything, I’m not just regurgitating this, I’m improving my teaching, I’m teaching the sort of very little things a little bit better, things like that.

I: That’s great. So this next section of the interview the questions are mainly going to focus on what you think makes a good teacher, and how you think a teachers subject knowledge comes in to that. So we’ll speak very broad to begin with, so what do you personally believe makes an effective teacher of any subject? As I said this is very broad so go as you….

M: Very broad [laughs]. Sorry, I’m trying to not like let my training...Right so I for the past four years, I’ve trained trainee teachers as part of my role.

I: Right, I see.

M: So I’m actually thinking about people. Sort of, it seems...There’s a level of confidence you need in sort of to teach to capture a room, because if they’re not paying you attention fundamentally, it doesn’t matter how good your subject knowledge is, then that’s a problem. I imagine a place like here, you don’t need to capture their attention, but in my old school if you didn’t have the basics of that confidence to make sure the room is quiet and things like that, then that...It doesn’t matter how good your lesson is, if that’s going to be the barrier to you being able to do anything then that’s the first level. But once you’ve actually sort of start planning lessons, I would say probably empathy is really important, not emotional empathy but sort of the idea that you can put yourself into their shoes and go “well how much do I know?” If I was that student, how would I pitch that? And the key thing is what do they already know? How am I going to link this new knowledge to the knowledge they’ve had in the past? And then how do I build on that? If I didn’t understand this what would be another way I could explain this? And that sort of being able to put yourself into their mindset because it’s really easy to, if you get something just to explain the way that you were taught but kind of coming up with new ways of teaching it or sort of a different plan of action is really important.

I: Yeah, and broadly speaking again, what do you believe makes an effective teacher of chemistry specifically?

M: So it was really interesting, when we had this CPD right at the start, and we got given this list of all this different qualities of what makes an effective teacher and their impact size, and there were things like learning styles, which I knew was going to be at the bottom and things like that. The one that I misplaced entirely, I had teacher subject knowledge third, they put on impact factor that it was way down, and I think for chemistry I’m not sure that’s true. Because being able to not get yourself into a muddle, especially because this is more in the context of A level teaching here isn’t it?

I: Yeah this is all, we’re speaking A level.

M: Because with GCSE having taught GCSE physics with only GCSE physics as my biggest qualification, I know you can do that with the same rough knowledge for what they’ve got and work ahead. With A level, if you don’t know how to connect things and can’t sort of explain eloquently and when a question comes up kind of get them right on the correct path, you can easily create a lot of confusion, so I do think subject knowledge is really important. Because I think everything else feeds from that because then you can explain things better if you understand it better and have also read lots of different explanations. I realise that the reason why I read the chemguide and khan academy for subjects that I do understand just to get someone else’s take on how they explain it because there are multiple different ways, especially electrochemistry is the worst one, there is a million different ways and I hate all of the rules people try and overcomplicate it I realised, it took me a while to realise it, but it’s like they talk about the anti-clockwise rule and this, but they’re all just cheats for if you actually don’t fundamentally understand what the numbers are. So, I’ve just got rid of all of that and we just fundamentally focus on what does more negative mean, what does more positive mean, and then if you know that it doesn’t matter if they mess up the electrochemical series. Because I realise when I first started teaching it if the electrochemical series was not in order they couldn’t do it, they got absolutely confused. My student’s had to rewrite out what they were given in the right order in order to then see, because I was using tricks and tips and things like that to get the exam answer rather than fundamentally understanding what was happening, and now students find electrochem relatively straight forward because if they understand what’s happening then it’s quite good. So I feel like I quite veered off the question there [laughs].

I: Yeah, yeah, so yeah that was, I guess you’re saying subject matter knowledge is...You need a good, you need that to be good to teach chemistry. Would you say there any other particular qualities that make an effective teacher of chemistry in particular?

M: I think it’s also you have to be able to motivate students, I think it’s making them realise because it is a subject where everyone's going to get stuck at some stage. If you can’t motivate them and keep them on track and sort of things like that then they are going to struggle, it is a subject that people give up on, and I’ve seen it time and time again and they’re just like “I’m not smart enough for this”, and often they are, it’s just some sort of comparison problem where they’re looking at someone who is cruising even if they are working really hard behind the scenes, and thinking they can’t do it. I think the only other thing is organisation, because you have to be organised in order to put things into the right order to make the connections more obvious and make what's happening more obvious, and also not to let them compartmentalise their, because at GCSE you can “this is unit 1, this is unit 2” and no-one’s going to punish you for not linking those subjects, that knowledge. Whereas at A level if you can’t do a question that contains pretty much lots of little bits, you’re not going to be able to answer.

I: Do you think that the new A level specification has helped with that now that they’ve got rid of the modules and they’ve made it a terminal exam now? In the last 3 years or do you think….

M: So the thing that I find interesting, they always, the A level paper doesn’t lean that heavily on the As stuff, even with the linear because they want to test them on the hardest stuff and because it builds up it kind of all intermingles anyway. The only section from AS that now appears more is I would say is sort of ionisation energies sort of area because that’s kind of separate, but obviously with the energy that gets put onto the lattice enthalpy and like redox gets slotted onto transition metals element. So I have to say the one thing that shocked me most when I looked at the first paper that was released was how normal it looked, how much like the previous papers it had looked. There was a little bit more AS in there, but I didn’t think it was that far removed, I don’t know whether my expectation was it was going to change massively, I do think the fact they have to know all their knowledge is good, does prevent them from biting it up a bit, and I do like the fact they split it up into organic and physical but I don’t know whether I teach, if I’ve adapted my teaching enough to be for the linear, because I’m not sure how well I’ve prepped my students for synoptic, and then they always do worse in synoptic, probably nationally I imagine.

I: Yeah I think that’s true.

M: But yeah, that's the one I need to prep them better for.

I: Okay, cool. So we’ve discussed this already I mean how important do you believe a chemistry teachers level of subject matter knowledge is? You said that you believe that it’s important.

M: Yeah, I still couldn’t believe that when they said it had a low impact, I was like “But surely…” But then I thought that if it’s, if you’re thinking about maybe in an English context, does your absolute knowledge of the ins and outs of this particular book affect your ability to teach that book? Possibly not because it’s going to be more skills based. Maybe in sort of absolutely there is a correct answer subject, like maths or chemistry, I think maybe that impact would be more, maybe it was more generalised. Because I definitely do think it is important. Because I know from having people who don’t have the...In my old department I was actually the only chemist, everyone else was a biochemist, which isn’t that far removed but it meant that the physical stuff they did not like.

I: I was going to say, so to what extent do you believe that a chemistry teacher should be an expert in their field? So to what point do you think they need to have a knowledge? I guess what I’m asking is do you believe it’s an issue if a teacher’s subject matter knowledge is limited just to the specification, or do you think they should have a bit of knowledge?

M: You have to have a bit of knowledge above. I have to say, because when I first started teaching, I did “you just need to know what’s in the spec” but there’s so much in just the way they examine it, even if you are thinking about A level chemistry they always put stuff you know in an unfamiliar context and the more you can push students a little bit beyond the spec, and get them used to applying what they know in a context they’ve never seen before, the more they find those sort of questions fine, and that’s also entirely what any degree will be like. They’re always going to be pushing their knowledge a little bit beyond what they actually know, and have to apply it. I don’t think it is that much of a problem, it depends how seriously the teacher takes the sort of going through the, doing that side of the course. Admittedly me and the other teachers started at the same time, and I just was like “I have a chemistry degree, you pick what you want to do and I’ll do the rest”, so admittedly I never gave that teacher the opportunity to improve on those sides, because I was like we may as well take the path of least resistance, you pick what you want to do. But then admittedly that did mean I get acids, bases and buffers, electrochemistry, kinetics and I was like “No this is not a sensible thing” but it was good for me [laughs]

I: Yeah [laughs]

M: It meant I had to make sure I had everything sorted.

I: Of course, okay. Do you feel that your teaching of chemistry is limited by any external factors? So that’s things you don’t have any control over.

M: There is a little bit that I still, fundamentally you do still teach to the spec it’s something way up off, because you do have time constraints and things like that, it does cause problems. But that’s why I do things like the Olympiad and C3R6 because it goes, it gives you, really good students will come outside of lessons to those things and then you can go nuts and basically go, because that gives you the remit to basically go through anything, because if and what is on those papers they only have to be vaguely connected because often they will just give them a chunk of information teaching them about this new thing and ask questions on it. So that gives you the freedom to do it but obviously you can’t do that with absolutely everyone. There’s also this phenomenon where in year 12 they’re very happy typically to know additional information, in year 13 after year 12 mocks they then go “is this on the spec?” They close themselves down to outside things because the pressure is suddenly on and they realise they have to get that A or that grade or whatever it is in order to succeed, and actually the students will close down some interesting conversations. I don’t know if that will be here but in my old school that's always what happened, the 13’s were not interested, and they could kind of tell when I was going off on a tangent and they would actually go “is this on the spec?”

I: Yeah, so this is a very broad question now, but do you feel that that's damaging to chemistry education as a whole?

M: The fact that they just wanting to get the A?

I: Yeah.

M: I think yes, I do think there is also the fact that, there is always a large portion of the class who quote unquote, “don't want to be there” because they’re medical students, and I’m not 100% sure they’d pick...If it was for medicine you have to pick X Y Z they’d just go for that, it doesn’t really matter what they’re studying, and it’s normally those students who are the ones who will go through, although admittedly I do think it's a little bit damaging, I do wish they did see what the purpose of it’s for. When I tell the medical students why we’re doing this, because I was once told by someone that the university’s prize chemistry more than biology for medicine, and I put that down to the fact that biology realistically from what I’ve been told by students and teachers, seems like a memory exercise, it seems to be an awful lot of content there, but I always describe chemistry as a problem-solving exercise, you’ve got some information you’ve got to apply it to this, and I say to them “Your degree, they don’t really care do you know all this chemistry, they care can you problem solve, because that is going to come up in your day to day job as a medical student” and that’s normally how I try and hook them back in. We need to do this additional stuff because I need to prep you for a scenario where you look at the page and go “what is this? I've never seen this before” and you have to problem solve. So that’s normally how I try and hook them back in, but I do think there is a bit of an issue there if you can’t sort of get them back round, it can be a problem.

I: Yeah, okay. So in an ideal world now, how would you personally like to teach chemistry. So what would you change about the constraints that you have, how would you?

M: What’s weird is here seems to be a very different way of teaching chemistry. It was very interesting when they said they had the departmental analysis and they, their results were down. They said “we all knew this was coming, the paper was too easy” and I was like “why would your results be down if the paper was too easy?” and they said “it’s because they teach the subject really well, they don’t exam prep them very much” which is true, I have to say I’m quite shocked about realistically how few exam papers they are handing out. They’ve got these massive booklets of all these worksheets, all these things that really challenge and there’s been a few things in there that classically I did not realise were a thing, it was something really tiny about a clock and continuance monitoring in how accurate the initial tangent is because it’s an average of that or if you continued monitored it has a subtle change, which I was told at one point at university, but I’d never tell my A level students something so small and so minute, but they focus really in on doing that sort of thing. And they said if the exams rock hard their students do really well because they’re prepped for anything basically and they understand, but if an exam’s too easy, their students make mistakes because they haven’t been absolutely drilled in that. So I think that’s going to be the interesting thing about working here, I think what they’re doing, what they’re trying to make it more interesting because they’re not prepping them purely for the exam, they’re trying to make them good chemists.

I: That’s fascinating, that’s really interesting.

M: That is definitely the impression I’ve got from here, and if you look through the booklets they do have some exam questions but I think every homework I set for the last 4 years pretty much has been here’s some exam questions, and I’d mark them and we’d go through them in minute detail and make sure they didn’t make any silly mistakes because my whole focus for the last four years has been get them their grades, whereas here it’s do they understand chemistry. And it was quite interesting they have sort of, a letter on where they have tea, I can’t remember where it was and it says about an interview candidate that they had for a university, about someone applying for chemistry and talking about how amazingly and eloquently they could talk about chemistry and how they’re offering them a place because of this, they’ve probably got the grades to back it up as well, but I thought that was interesting that probably universities can tell when someone has had an education which is more well-rounded and do you understand chemistry rather than exam focused, and also it probably preps them better as, I’ve told my students through years you wouldn’t believe what a university exam looks like, it’s like 5 lines and 3 pages, “off you go” and that’s terrifying, “this is a 30 mark you’ve got to figure out this thing, here’s your data sheets or whatever, off you go” It’s very different.

I: It is, yeah.

M: So [REDACTED], who’s the principal here, talks about this being cushioned adulthood and they do see themselves as a halfway house between GCSEs and university, and they seem to take that quite seriously. So I found that really interesting, and I think that's something that realistically I’m going to enjoy, just teaching purely do they understand and worrying less about exams because they seem to have the opinion here that if you teach the subject the exams will sort themselves out.

I: Okay, that’s great. So moving on from there do you personally engage in any activities outside of school? That could be wider reading, watching television or listening to the radio that expand your knowledge of chemistry and general science.

M: I say I haven’t over the last four years, it has been, I say on a normal school timetable with everything you’re doing, especially if you start accepting any extra responsibility, I just haven’t found time at all. But the thing I can’t believe here is I got in at 8:15 this morning and there were 2 people in the office, if I got in at 8:15 at my old school everyone would be in and everyone would be staring at me like “why are you getting in at 8:15 you should really be there by 7:30” and then you’re at your desk working immediately. And then again people here leave at sort of like 16:30, I’ve never known this my entire life, normally I would be at work until 18:00, 18:30 go home and then possibly think about work more, so there’s not been anytime. So that has been one of the things I really want to do more of. The only thing I ever allowed myself was whenever the education in chemistry magazine came, I’d steal it and I would at least read the CPD section, that was the minimum that I did which feels like a pathetic amount, but that’s probably all I had consistent time for. But I’m hoping now I have a bit more time to read the whole magazine.

I: Yeah [Laughs]

M: [Laughs] and do things like that, but I have to say, honestly I haven't done much at all.

I: No, that’s fine, as you say it’s very difficult finding the time when you’re working those hours, my housemate is a teacher and he is in school by 7:30 in the morning, home 18:00/19:00 in the evening, yeah the last thing you want to do then when you come home is look over more science I guess.

M: But the other thing is, I think also department size has a big impact, I came from a department of 3 and because I was the chemist, people came to me for questions. Here I’m the least knowledgeable person in that room I would probably say, there are multiple people up there who have PhDs, they’ve pretty much all been teaching either way, far longer than I have, or have some sort of interesting life experience they did before coming into teaching, and so it’s really nice here knowing the least about chemistry possibly. I don’t know, but it’s nice having people to turn to like “well I don’t actually understand” or “oh this has always bothered me and I’ve looked it up and I can’t quite figure it out or whatever” so that’s really nice, so I'm hoping that’s what's going to be helpful.

I: Good. Okay so this next section is primarily on the A level curriculum and your opinions of it, so we’ve touched on this already briefly, but if you’re teaching a lesson and a student asks you a question that relates to content that lies outside of the A level spec, how do you approach the situation?

M: So it depends on who I have in the room. If I think everyone in the room can benefit from it, I answer it and we will spend time. I’ve never found A level chemistry to be rushed, I’ve never felt...At GCSE I felt If I don’t complete everything I need to in a lesson I’m never going to be able to get it all done, because you’ve got that element of you have to teach them problem solve, I’ve never felt it’s been that much of a rush at A level, and I’ve enjoyed that quite a lot. But I’m thinking of particular scenarios where my A\* student would ask a really good question and I have my D’s and E’s there and it’s not going to be helpful for me to take up class time to go through it, so I’ll often go “excellent question, I’ll come over in a second” finish what I’m doing and come over to them and go through it all with them one on one, would typically be what I would do. I try not to glance them off or say, “I can’t go through that.” There were a few times where I went “you’re beyond me” she was a person who said why a lot, so at points I was like, at one point I was like “the answer lies in quantum mechanics, I haven’t done it for a while, we can go into this but I can’t answer this now” [Laughs].

I: [laughs] yeah.

M: But I always try and answer it, I remember the first time, there were a few times where she would argue about something I was actually teaching, those were interesting intense moments where she would go “but you’re wrong” “But why do you think that I’m wrong?” at those points I’d have to hash it out in front of the entire class and explain why I’m correct, what my justification was because I couldn’t really go “oh I’ll talk to you in a second” because otherwise the others in the class would start to worry that I am wrong, so I had to just defend it .[laughs] That was really interesting

I: [Laughs] Yeah I can imagine, and how often do you find yourself teaching content then that lies outside the spec? Is that only when you’re asked or will there be times when you think this is really interesting as an aside?

M: I would probably never teach something that has no connection to what they’re doing in the spec, but because chemistry is so interconnected it’s often quite often easy to do. I think there’s certain areas where you can go just ask a really interesting question outside the spec really easily, one of my favourite ones is they learn nucleophilic addition and they can all do nucleophilic addition, so I go “well okay, well I’m going to give you a new nucleophile and I draw on an alkene” and I go “off you go” and they just look at me like I’m absolutely mad and I’m like “what’s the definition of a nucleophile? This thing wants a positive charge, off you go” and that’s one of my favourite ones because that completely gets them, and I’m like “you’ve got all the skills, just push some arrows, this is what degree level chemistry feels like sometimes you’re just pushing around arrows until it does something you’re thinking ‘That makes sense! Oh okay!” So there are certain points where I just have it in the course already, where I just go “I know this would be an interesting question”, electrochemistry is one, because once they’ve got the basics and they understand it, then that’s quite interesting. So we talk a bit about that scene in breaking bad where he creates a battery repowers the RV van, so we talk about that at quite a bit of length, and how does that work and or those things. The thing I'm trying to get better at is sort of, those sort of how do those apply in the real world sort of things because I have been a bit, I don’t know what the word would be but, sort of guilty of just teaching to the exam spec, so that sort of as much as I can link it or go a bit beyond or an interesting question, I will try to.

I: Do you think context helps the students?

M: Yeah, I think seeing that it’s actually useful is, especially with electrochemistry, being able to link it to that that’s more negative so that’s the negative electrode, that’s more positive so that’s the positive electrode now let's put this into the electrolysis sort of setting you already know which is real world, or let's put this to a battery and sort of talk that through, I think that makes that a lot more because otherwise can just be some numbers on a screen. I think also the one that really helps with a real world context is solubility of group 2 hydroxides, if you can draw out all of the enthalpy of solution diagrams for all of the things, and show well you know this one's insoluble, you know this one's soluble and you know as you go down, and explain the trend in solubility using the enthalpy of solution things, and actually physically seeing why it is, you’re connecting that back to that knowledge they already have. Well this one’s almost soluble, well why is that? Because its…

I: Yeah, of course, okay great. So we’re going to move on to some common misconceptions now, and the potential issues involved in both teaching and understanding them. So first of all we’ll discuss the topic, so in that pre-interview survey that I gave you I asked you to rate your most confident topics and your least confident. So you said that your most confident topics were acids, bases and buffers and analytical techniques, is that right?

M: Oh.

I: Have you done it the wrong way round? That’s fine, I’ll make a note of that

M: [Laughs]

I: So the worst topics you said are kinetics and transition metal chemistry.

M: That would be...Yeah those.

I: That’s fine, no problem as long as I know before I write this up, so those are you two most confident topics?

M: Yeah.

I: So what is it in particular about those topics that make you feel more confident in your subject matter knowledge of them? So we’ll start off with kinetics, so what is it about kinetics that makes you feel more confident?

M: I think teachers have quite a big impact and it was my university lecturer, so apparently my likes in chemistry are slightly niche because there are a 120 cohort, we signed up to our classes, I turned up to the kinetics class and there were 7 of us, by the time we took the exam there were 4 and it was weird, like I’d never had like a university lecture where there were so few of us, like they just gave us a tiny room and we’d talk things through. And the way he taught it was he’s obsessed with the peak district so he sort of put the sort of kinetics diagrams always to an OS map, and talked about sort of the idea of an intermediate where that and put that like and “oh, this is what this hill system in the peak district is there” and he’d talk it through and the idea of a ball rolling and all that, so I just remember that kinetic stuff really well and I think it’s almost meant that I can teach it relatively well as well because I kind of got really quite solid understanding of “Oh yeah the peak is the transition state, why is it a transition state etc” and things like that.

I: Yeah, that’s great, and what about transition metal chemistry, what is it about that?

M: Umm so one of my specialisms was organometallic chemistry, so I really like the transition metal sort of elements and did a lot of work on them, and I think also just the idea that with a lot of the transition metal elements there was also quite a lot of spatial element, to sort of how things work surrounding them in shapes etc, and that's always been one of my strengths because, again I can think in 3D so some people cannot.

I: Yeah, because I was going to say TM chemistry has been one of the things that a lot of the teachers have said they’re less confident with, so what do you think it might be, do you think it’s something to do with the visualisation that make it a difficult topic? Or one that teachers have less confidence with?

M: I think there’s also, there’s a lot of little things to trip you up if you’re not used to them because of course you’ve got elements in the d block that are a natural transition metal, you’ve got if you want to go into explaining anything you need to know what the shape of the d block is, and how it changes with various scenarios and things like that so, so that is not an easy element of chemistry, and I think also it’s something that you probably, I would love to know how many chemistry teachers have done biochemistry, because from meeting them, loads have either taken natural sciences or biochemistry and it means the physical side, or the inorganic side sometimes is just not as well covered and I, that was actually what I specialised in, I was all physical or inorganic when I did it later. I think it’s also familiarity because I’ve never had to learn my colours when learning my transition metals, I’ve already got those down like all the water sort of, all of the crystalline shapes I probably already know so it was all that stuff, it was relatively easy and I think in something with so many and so many colours, I think probably people don’t feel confident enough to answer the question about without looking it up first, but you have, there has to be an element of confidence of “No I know what the shape is of that, I know why it goes like that and how to connect it”.

I: Yeah, okay. And so the areas you feel less confident with then, so acids bases and buffers, analytical techniques. We’ll start with analytical techniques, what is it about that that makes you feel less confident in your subject matter knowledge?

M: So the analytical techniques, I was thinking much more...So NMR I’m actually very strong at but explaining how a mass spectrometer works, I’ve never been able to do it in a very eloquent….I remember being taught it multiple times and I can explain it, but as soon as I’m questioned my knowledge is very frail and they go...So it’s not, I can sort of, functionally I’m quite strong at “Here’s a mass spectrum” I can do that, “here's an NMR spectrum” I can do that, “Here’s an IR spectrum”, I can do that. The thing that I rate my confidence incredibly low at is if someone asks me “but how does the machine make that? How does the machine do this?” I’ve functionally used them in my degree, I can answer exam questions on them but I rate it as one of the least because I’ve fundamentally never understood how those machines work.

I: Well that’s it, I mean we use the tv probably quite a bit everyday, but we don’t know how it works [laughs] do we…

M: So that’s why I rate it quite low because actually as soon as a student will query what, why, how does that work, I have to go “I honestly don’t know, it’s a magic box that spits out this” and I understand this very well but it’s quite interesting because yeah I just never have understood it. But actually with the spectra I understand them quite well, but that is why I did not rate it because I just don't understand how it works. I remember once trying to teach how a NMR machine worked with spin and everything else and I got myself in a complete muddle, I just could not keep it in my head.

I: It is very complicated [laughs]. And what about acids, bases and buffers?

M: So that’s a weird one, so when I asked my other teacher what they wanted to teach, they wanted to keep buffers.

I: Right.

M: So they really had buffers down and I have answered quite a few questions on buffers but I know there can be some quite tricky questions there, but I’ve never taught it. Never taught buffers. So acid bases, absolutely happy with I can, I get, I cannot for the life of me do conjugate acid base pairs because I’ve not taught it, not really so I’ve not had that necessity that I need to get better at it, it’s one of those things that I have been working at over the summer. I’m pretty good at all the buffers exam questions now, but again I still can’t do acids bases conjugate base pairs just I always get into a muddle, so I need to make sure I’ve got that nailed before I teach [laughs]

I: And again another area that we found a lot of teachers are less confident in is electrochemistry, with their teaching and with their subject knowledge, so what do you think it might be about electrochemistry that teachers find that they have a lower subject knowledge or confidence rather?

M: I think it’s because there’s too many ways of teaching it. You look online, one textbook tells you this way, one textbook tells you that way and fundamentally they all don’t tell you what the numbers actually mean. If I’m honest I would have rated that my worst one before I went and taught it, and then I looked at chemguide and it has the most beautiful explanation of actually what the numbers mean in terms of how many of the atoms turn to ions and then therefore how much charge change is on there. And then once I explained that to students they got it, because it’s actually not that complicated but for some reason surrounding it is all of these sort of tricks to teaching it, which actually get in the way because you don’t understand it, and then the questions become really difficult because you fundamentally don’t understand why it’s happening or what's happening with it. So I think partly that’s textbooks and I actually actively tell my students “with this, no, you’re going off of what I’ve explained. If you absolutely don’t get it you can come to me and I will teach you a different way, If you’re happy with what I’m teaching you please don’t use the textbook because it’s trying to teach the anti-clockwise rule” and I don’t think that’s helpful, just learn what the numbers mean.

I: Yeah, and so with the topics we’ve just discussed, how do you, do you approach teaching the topics that you’re more confident doing differently to the way you approach teaching the topics that you’re less confident with? Or would you say that your approach is the same?

M: I would say my approach is different in the sense that I will be less willing to add in that extra challenge stretch thing because I’m worried that...So I will typically label the points to make sure I’ve got it right and then they’ve got it the point for areas where I’m not so confident because I want to make sure that I have managed to get that across in some way. Whereas with the ones I’m strong at, I’m typically I’m more confident that I’ve taught it in a way, I’m more confident in the way that I can test it, in the way that I’ve sort of captured every sort of imaginable question you could possibly have with this sort of area, and then we can do something a bit more interesting. Because I could probably do that quicker and get someone to the end results faster than with an area that I'm less confident on, I’ll probably force them to do more practice.

I: Okay.

M: If I’m honest.

I: Yeah [laughs].

M: [Laughs]

I: So are you teaching period two?

M: Yes

I: And thats in 10 minutes, is that right?

M: That starts at 10:10.

I: 10:10? Okay just so I know we’ve got enough time. So we’ll blitz through these ones then. So these next few questions are about the A level topic of kinetics, which you mentioned briefly. So as part of the A level reforms of 2015 the Arrhenius equation was reintroduced to all of the A level specs. How have you adapted to the reintroduction of the Arrhenius equation? Are you quite happy with that?

M: I was quite happy with that, the only thing that’s really difficult is how much that splits the class. If you take A level maths it’s “oh it’s Y = mx + c”, and they will happily do it. If they don’t know Y = mx + c all of a sudden it is one of the most impenetrable topic, because you are having to go back and like “Oh I think I vaguely remember this” and they don’t really know which ones the gradient of that equation, which ones the Y intercept and so it entirely cruxes on if they know y = mx + c. I think the actual teaching of what the equation means and all the elements of it is fine, but I think the fact of can you understand what this line is telling you, and what the points mean is the real problem, and maths students because they do that all the time, absolutely fine. And I find that really quite difficult having such a split class, I find this super easy, what are you saying? And that's the thing I haven’t quite mastered yet, is it getting them all there. I’d say I make them do quite a lot of practice on that one, because although I’m confident I want to make sure that they’ve got it and I’ve not quite figured out how to stretch the upper ones with it, normally I, once they’ve got it and done everything I normally my stretch will go back to rates and mechanisms because that’s a much easier section to make them just go off further. I’ve not really figured out like an Arrhenius question that’s more than the bog standard what you’re doing.

I: Yeah, so this next question it’s a nice visual one alright? So here’s a question we gave to a bunch of students, and on the reverse you’ll see how the teachers responded to the same question. The question, a sodium ion in the gaseous form is more stable than a sodium atom, true or false? So that’s how students typically responded and then if you flip it over you’ll see how a bunch of teachers typically responded, so don’t let the size of the bars deceive you, they are quite close in number. What we want to know simply is why you think those are the typical responses? So why do you think students responded one way with 70-30 A-B and why do you think teachers responded that way 47-53 A-B?

M: So I’m very careful, this is something I’ve always found quite difficult, and I know it’s an area where I’m just like I can’t quite eloquently explain it. So, I know the difference, it’s because this is exactly the words, so at GCSE you oversimplify it and you absolutely unequivocally say “an ion is more stable than the atom often because it has a full outer shell.” And I’d say these are quite close because fundamentally you can still get away all the way through a level, probably still thinking that, there’s nothing that will probably...I can’t think of any exam questions that will punish you that much for probably still using that wording. I know because I was unequivocally told multiple times at university that that is not true, but I still can’t really explain why that’s, sort of the whole idea with stability with the s p d and f and all that is quite confusing. But yeah I’d say that's a hangover from the GCSE, and then because I wouldn't say people, there’s no again easy actual explanation of it, People just don’t correct it, and they just leave them to thinking that. I pre-warn mine that I sometimes give if they’re applying to chemistry I give them a test of the questions they need a good answer to, and that's one of the ones that I give them, I’m like “you need to have a good answer to this one because a university lecturer will not be pleased” [laughs]

I: Of course. And so moving on to equilibrium we’ve got another similar question. This is pitched at first year second year undergraduates, so it’s quite a difficult question. So there’s the question there, you’ve got that equilibrium system and we asked a group of teachers what they felt would be if you add an inert gas neon with the whole system remaining at constant temperature and pressure what that would do to the equilibrium position. So we got the teachers to put in their initial answers and that’s what's represented by the blue parts, and then we asked them to discuss it with their peers and then we asked them to answer the question again, and that's what the red bars signify. So to begin with the majority thought there would be no shift, after discussion more teachers felt that there would be a right shift. So again I don’t want you necessarily to explain what the correct answer is, I just want you to say why you think the opinion shifted? As I said this is a tough question.

M: It is a tough question. Because if it’s at constant temperature and pressure, then the effect of adding neon should be nothing, so I would again, I would agree with the no shift. I can’t think why suddenly you would think right shift. Because, unless neon reacts with something, but its inert. I’m not sure if I’m honest,

I: Yeah, that’s fine. I’ll tell you why. So the bit where it comes into confusion is when you add neon, because you’re keeping the whole system at constant pressure, the partial pressures of all the other things in there are reduced.

M: Oh of course, yeah.

I: So that means that the equilibrium will shift to the right to counteract that. But again you know, that’s not an A level problem, that’s way beyond that.

M: No but that could be discussing Kp.

I: Yeah, but that’s it you need to consider Kp rather than just Le Chatelier’s principle or whatever to answer that question, and that’s what makes it difficult. But having considered those 2 problems that have just been presented on you, they’re reliant on things like Le Chatelier’s principle and the octet rule. Do you believe that the limitations of chemical models and analogies that we use should be taught at GCSE, or A level, or both? Or neither?

M: So, I would say it should be taught at A level, definitely at A level you should talk about limitations of models and I often do. And I also think it should be taught at GCSE triple.

I: Triple? Okay.

M: Because I think if you’re going to try and teach the limitations of models to someone who is never going to continue, or is going to probably not going to continue, that would be important but I think you’d have to get rid of something in order to put that in, but I that would create an interesting discussion. And also could possibly stop the whole “but you lied to us at GCSE” thing that happens immediately as soon as you go into A level. But yeah, you definitely need to talk about limitations of models. I’m annoyed I didn't think of partial pressures [laughs].

I: No no, don’t be annoyed, don’t be annoyed. As I said, loads of teachers haven’t realised that, and it’s as I said it’s a tricky question. We’re not trying to make you feel bad in your subject knowledge [laughs] Don’t worry about that. But, just a quick note briefly, do you often use analogies in your teaching when you’re teaching certain concepts, or will you explain them normally outright? Or do you try and think of an analogy to use?

M: I’m normally a little bit careful when I try use analogies, normally the way it works I will try and just explain it, just explain it using sort of as much as I can just trying to get them to understand. Normally I will layer it so I won’t automatically just use the analogy, because sometimes that can cause confusion. But if I have a class that aren’t getting it I will then go to an analogy in order to help them understand it, but I will try not to start with the analogy if I can help it.

I: Okay, excellent. That’s everything.

M: Okay.

I: Thank you very much for taking part.

**REBECCA INTERVIEW TRANSCRIPT**

I: Okay, so if you could please state your name for this recording?

R: [REDACTED]

I: And can I confirm that you’ve signed the consent form, and you fully consent to this interview being recorded and used for this research project?

R: I have.

I: Okay, excellent. So this first section of questioning is on teacher training, so it will primarily focus on the influence your teacher training had on your subject matter knowledge. So, which aspects of your undergraduate degree, if any, would you say helped develop your subject matter knowledge specifically for teaching?

R: Umm, my undergraduate degree was quite a long time ago, so I graduated in [REDACTED], is when I left university. But I did Natural sciences for 2 years and then chemical engineering for 2 years. So my chemistry knowledge wasn’t equal to a full degree, if you see what I mean.

I: Yep.

R: So I guess that my later undergraduate knowledge was more along the physical chemistry side of things, that were included in chemical knowledge, so the sort of enthalpy, entropy and things like that.

I: Ok, and then to what extent did your teacher training help to develop your subject matter knowledge for teaching?

R: I guess my teacher training was mostly refreshing, so I think at some point, and certainly when I was training it was mostly, you know when you’re doing a PGCE its mostly geared at secondary, sort of 11-16 maybe a slight extension into AS, so all of that I had come across before and was fairly confident with it once I’d had that refresher.

I: Yep, okay excellent. Did you personally engage in any self-directed activities to help develop your subject matter knowledge while you were teaching?

R: Umm, I, in terms of self-directed probably not, although, I’m just trying to think, it wasn't that long ago, I would say that I fully did all of the suggested activities, so all of the sort of doing A level past papers, GCSE past papers to sort of develop…

I: Yeah okay, I was going to say what kind of other activities did they suggest you do whilst you were on your teacher training outside?

R: Yeah I mean basically, it was mostly that kind of thing for the subject knowledge, it was doing example AS papers and A2 papers, I think I managed to do some example past papers for AS, I think I might have given up with the A2 ones because that was just a little bit further than I could find the time to do it, at that stage. But, yeah I would say I was probably quite conscientious and completed everything I was asked to complete, but mainly didn’t sort of go further in terms of finding further self-directed activities.

I: Of course, yeah. And what do you remember about the impact of the subject matter knowledge activities that you engaged in during your training, on your own confidence in your subject matter knowledge of Chemistry? Did you find that you became more confident?

R: Yeah, definitely, because even if you don’t know the answer initially, it kind of opens up there's a gap there you need to fill, so go away and fill it. And then that increases every time you’re exposed to something it increases your confidence.

I: Yeah, okay excellent. So this next section is going to focus on the role of subject matter knowledge in teaching, but before we get on to that, I just want to ask you, this is a very broad question, and I just want you to give all the ideas that you have...So, broadly speaking, what do you believe makes an effective teacher of any subject? So what qualities would we expect an effective teacher to have?

R: Well, that is a broad question [Laughs].

I: It is, yeah, so whatever, from your experience, from your beliefs?

R: Okay well, subject knowledge obviously we’ve been talking about already, but just subject knowledge on its own isn’t going to make a good teacher, but, can you be a good teacher without good subject knowledge? Umm debatable, I wouldn’t be a confident teacher without good subject knowledge, it depends on how far you’re going to go in terms of increasing the skills, the sort of self-directed learning skills for your students. So, in terms of qualities being patient because students won’t do exactly what you want them to do all the time, so you sort of have to encourage them, knowing the students is the most important. So knowing where they are at the moment, knowing how they learn, knowing what’s in the way of their learning, so what blocks them, what barriers there are and how for that particular student you can overcome that. And I think if you can motivate students to want to learn and want to go above and beyond what you’re delivering in class, so they actually are teaching themselves some of it, and resolving some of their own problems, then that's going to be a huge huge benefit.

I: Yeah, excellent. And, so if we take that just a step narrower, it’s still very broad but what about chemistry specifically? Do you think there’s anything in addition to what you’ve already said that when it comes to the teaching of chemistry, is something that makes an effective teacher of that subject?

R: Umm, obviously you’ve got the practical element, so I haven’t mentioned anything about, that’s nice because I teach in A level, I haven’t mentioned about behaviour management [Laughs] but there has to be an element of control, especially when students are doing practical activities,

I: Yes.

R: So I guess knowing when to tighten the reins and when to let them go a little bit because we want them all to leave with their practical skills as well as their knowledge, and what I really love about teaching here is the fact that they come in at the start of the first year, and you have to kind of tell them exactly what to do and then by the end of the second year you give them a sheet of instructions which might be very minimal, and they just know where everything is and they just go and get it. So, I guess that’s practical subject specific, probably not just chemistry. Umm, what else...Chemistry is incredibly concept based rather than concrete examples and I’ve had conversations recently about student’s feeling that even physics is easier than chemistry, and biology certainly there seems to be this impression that it’s easier to understand than chemistry. And I can see with the biology it’s very relatable, and I guess some of the physics is, but also physics tends to attract people who are good at maths, lots of maths in physics, if you can do maths you can do physics..

I: Essentially, yes.

R: ...to a certain extent. And chemistry kind of sits half in between them, and so you get the students who are doing physics, maths and chemistry and you get the students who are doing mainly biology, psychology and chemistry but no maths, and somehow you’ve got to cater to both of those groups, so I would say that being able to cope with students who might not have the best numeracy skills on the one hand, and on the other hand other students who might not have the best literacy skills, and try to deliver, try to get students to understand something that isn’t very relatable in real life. [laughs]

I: Yeah [Laughs] Yeah that’s very good. So, we touched on this earlier, so how important do you believe a chemistry teachers level of subject matter knowledge is in their teaching? So you said that it’s debatable, I mean I guess it depends on the level, so yeah, how important do you believe that it is? To explain your response.

R: Yeah, so, I said debatable because in an ideal world you don’t want to be delivering content really at all, but we’re not going to get to an ideal world, so, in reality it is very important, and even if it’s just in the point of view from your students will have confidence in you if they perceive that you have subject knowledge, and if you didn’t have subject knowledge they’re going to rapidly lose that confidence.

I: Yeah.

R: You want to be one step ahead of the students all the time, and I don’t know if you’ve had a chance to look at my responses, but, what I’ve found out through teaching at secondary 11-16 and at sixth form is that most of the students, I am always one step ahead of, and I know more them, but you do always get the students who are very very self-directed, doing wider reading, but by doing that they’re digging up questions that they haven’t found the answer to, and when they ask me, I haven’t got the answer to it either, so that’s where I feel the gap in terms of my own subject knowledge.

I: Yes, and so do you think a teacher should be an expert in their field?

R: Yes.

I: Yes, great.

R: But yes, I guess but what I was sort of going, going back to what I said debatable, yes they need to be an expert in their field, but do they always need to demonstrate that expertise in a classroom, in a direct way? No.

I: Yeah, okay.

R: Is that clear?

I: Yeah, yeah I do understand, yeah. That’s great. So you touched on this a second ago, so we’ll talk about an ideal world how you’d want to teach in a second, but do you feel your teaching of chemistry at this present time is limited by any external factors, so things that are outside of your control, so that could be school regulations, that could be the curriculum itself, the A level specification.

R: Um, yes the curriculum, no in terms of school regulations, I think that well, school regulations might come into it if there weren't the restrictions placed on teaching and the lesson content and everything by the specification and the time pressure to get everything covered, do all the required practicals, although we could discuss whether we need to do the hard practicals in the form that we’re doing them at the moment or could that be sort of widened and broadened a little bit. But certainly delivering the a level course within 2 years, and covering all the required practicals and covering all the ones that are suggested required practicals in case they come up in exams and student’s need to know about them, there isn’t much scope for, or there doesn't seem to be much scope for going broader than the course, just because there’s this time pressure.

I: Right, okay, and in an ideal world, how would you personally like to teach chemistry, so under what circumstances would you personally like to teach Chemistry, if you could change anything now?

R: Umm, probably to try to introduce more links to real life context, real life scenarios, make it a bit more, to make it a bit more vocational based and to make it a bit more relatable as we’ve been discussing the fact it’s so conceptual and hard to relate to...

I: Yes

R: I think that that would be quite handy, I think that in an ideal world that would be good, I’m trying to think what's stopping me from doing that at the moment other than time to sort of build it in to all of the lessons….

I: Yeah, well I mean time is a big thing though that's the thing. But going back to that, I saw in your survey you did that you spent 10 years working in industry, how much do you find that when you’re teaching you draw on the experiences of your work and make examples in say the lessons relevant, do you find yourself doing that often or?

R: I don’t actually, and I almost shy away from it.

I: Why's that?

R: Because I, part of me thinks this is going above and beyond what they need to know, am I just going to confuse them?

I: Right, I see.

R: Or am I going to give them something, you know the sort of, when you start doing A level or GCSE you know you’re like it’s all rubbish ignore all that level, and it’s kind of the same thing.

I: Right.

R: this is the information you need to know for A level, if I go beyond that in terms of bringing in stuff I know from sort of further, or broader, am I going to give them something that isn’t going to give them a mark in an exam. So I think probably a bit fear, I mean I do kind of use the examples, but not probably as much as I’d like to.

I: Right, okay. That’s interesting. So, next question do you personally engage in any activities outside of school or college indeed, such as wider reading, watching television, listening to the radio to expand your knowledge of chemistry? So do you read any magazines related to chemistry?

R: Shockingly, no.

I: No? Not at all?

R: I occasionally, do I for chemistry...No, I don’t think. Because I do things out of college to obviously relax because you need to.

I: Of course, yes, you don’t want to be…

R: And so I do read, and I do sometimes read sort of science related books and newspapers and things like that, if there's a chemistry related article in the newspaper I’m reading on a Saturday morning then you know yes I’ll read it.

I: Yeah

R: But I won’t go out of my way to find chemistry related things to read.

I: Right, okay.

R: Apart from in the holidays, but went I tend to do in the holidays is start things that I never finish because I go back to term-time and lack of time.

I: Yeah, of course.

R: So things I’ve started, not specifically chemistry, although one of them was, I started up I think I enrolled for 3 MOOCs in the last year, but they’re all kind of ones I’ve upgraded and waited to finish off because I’ve started them but haven’t finished them. So there was a practical chemistry one on there, so that's the one, but also some ones that are wider, sort of teaching skill based.

I: Right, okay, I see. So the next few questions are going to primarily focus on your opinions on the A level chemistry specification curriculum, so we touched on this again earlier, so you mentioned sometimes student’s may ask you a question that goes beyond the curriculum, what do you do in that situation? How do you approach those situations, so if they ask you a question you don’t know the answer, or if it’s beyond the A level specification and you do know the answer of course, how do you tackle that?

R: Umm, I’m very honest, I say “I don’t know” and I Google it.

I: Yeah?

R: Or, I don’t sort of do that while they waiting because you know what’s google going to say, I move on get them working on something else and then I’ll google it, and then I’ll go back to the person who’s asked it and give them the information…

I: And If…

R: Or suggest they need to…

I: And if they ask you a question off the A level specification that you do know the answer to, will you just tell them there and then if it’s the whole class listening? So during a whole class discussion one of the students asks you, will you then repeat it to the whole class, or will you tell them on an individual basis afterwards?

R: I would probably, if it was a whole discussion I’d probably talk to the whole class about it.

I: Yeah? Okay.

R: But I can’t think of many scenarios when that’s come up.

I: No?

R: No, no. Because I don’t think there’s all that many...Well there probably are, but I don’t think there’s all that many instances where I have known the answer, because my A level knowledge is quite, at the moment I haven’t really taught it for 2 years, it is quite kind of restricted to what I’ve sort of self-taught myself from the textbook really, and through teaching it and looking at past papers and all the rest of it.

I: Yeah, of course. So how often do you find yourself teaching content that lies outside the A level specification? I guess it’s not very often.

R: Not very often, It’s just the odd question here or there, I’ve got one student who is very able at the moment you know he’s kind of like definitely should get an A\*, it’s very rare that he drops marks in exams, in the tests that we’re doing, and he will ask me questions. He came up with one the other day, I bumped into him in the library he said, he was looking at the textbook and he said “Okay it says here ethanoyl chloride is the first Acyl chloride, what about ethanoyl chloride?” So I had to sort of quick google [Laughs] “It’s not very stable” I mean yeah, he’s the one who tends to be the person who asks the challenging questions at the moment, and most of the other students, they will occasionally ask a question which is outside of my comfort zone, but it’s mostly the odd individual here and there.

I: Okay, so what do you believe the scope of a chemistry teachers subject matter knowledge should be? So do you personally believe it to be an issue if a teachers subject matter knowledge is limited specifically to the specification?

R: Yes.

I: Yes? And why?

R: Yes, because you need to be able to stretch and challenge, big buzzword [laughs] And you can’t do that if you’re limited by the boundaries, how can you stretch someone beyond if you’re limited yourself there. You also need to, and I’m thinking obviously, I’m very focused on exams at the moment, but thinking about the different types of contexts that are going to come up in exam questions and not necessarily be the same context that students have seen before, and I think the more different examples that can a chemistry teacher can bring in through the teaching, rather than just what's in the textbook or what's in an exam question that they have seen already, that the more, the wider it can go, I think it’s going to be beneficial to the students.

I: Okay, perfect. So this next section, this is the last section, is on, it’s quite a hefty one though [laughs], this section primarily focuses on specific topics within the A level, and the potential issues involved in both the teaching of them and the understanding of them.

R: Right.

I: So I’ll make references to some of your responses out of the earlier surveys, so, in the pre interview survey you stated the topics you were most confident with were atomic structure, molar calculations and kinetics. So what is it in particular about those topics that make you feel more confident in your subject matter of them?

R: I think probably the fact that they are quite similar to GCSE, or it’s a development of GCSE chemistry. And having taught GCSE for 4 years and then moved into A level teaching, that, you know might of sort of built up my own level confidence with those topics, and it’s not a huge leap up to A level, whereas some of the other subject matter is completely, well I keep telling my student’s it’s not completely different from GCSE, It’s a gradual path from GCSE up to A level, but some of them are much more, much further away from what I was sort of confident of teaching at GCSE.

I: Right, okay, and how do you approach teaching those topics? So if you know “Right, okay my next lessons on kinetics” what approach do you take to planning that lesson and then being in the classroom and teaching it?

R: So in terms of planning in terms for my own subject knowledge?

I: In terms of planning for the lesson itself, so, you’ve already said you feel confident in your subject matter knowledge of them, so when you’re just planning a lesson on that topic, what do you do when you’re planning it? So how do you approach teaching it, do you just stand at the board and be like “Right my next lessons on kinetics, right I’ll be able to just do that straight away no problem” or do you need to look into anything?

R: So we’ve got, we’ve done sort of joint department planning, so before I joined here, [REDACTED] had already written the first year lessons, because it’s a new course, last year was the first year of A level examinations with the new specification.

I: Yes, that’s right, that’s correct, yeah.

R: So, my first year here was the first year the second year was being taught, if you see what I mean?

I: Yes

R: So [REDACTED] had already planned all the first year lessons, and then [REDACTED] and I were both teaching the second year last year, so we kind of co-planned and shared resources, but very much using the sort of pattern that he’d developed for the first year lessons. So starting off with an exam question, or something to kind of like gauge recall from the previous lesson, or prior knowledge or something like that. The sort of, the teachy bit in the middle if you like, but trying to minimise that, and with suitable exam questions, mini whiteboard tasks, things like that so that I can assess, we can assess how well the students are understanding things as we’re going along. I have adapted that slightly this year in that all of my lessons this year, and I only teach 2nd’s this year, but all of mine this year I have got them to pre-read from the textbook beforehand.

I: Right, okay.

R: So I’m assuming that they have some sort of level of prior knowledge, and I kind of, that process I guess...And it helps that I did the same thing myself last year when I was teaching it for the first time, before I taught every lesson or every block of lesson, I would go through the chapter of the textbook and make sure that I was comfortable with it. Sort of wrote out my own notes, answered all the questions myself and so on, and so I can kind of put my, at the moment, and last year, this year, I can put myself in the student’s shoes as to which bits they’re going to find straight forward and which bits they’re going to really struggle with potentially because it’s completely different to anything they would have done before.

I: Right

R: So when I’m delivering the lessons now, I don’t tend to focus a lot on, you know me standing at the front going through content because to a certain extent they should have already done that, and some of them some of them aren’t so much so they need a bit of hand…

I: Yeah, I was going to ask do you find that they do actually do the reading?

R: Most of them do, but some of them, there’s a small minority I would say who don’t. And I’ll come onto that in a minute in terms of how I deal with that.

I: Right, sure.

R: But if I know it’s a topic that they’re not going to have grasped, for example NMR, you know 3 chapters in the textbook full of examples, and they’ll come in and say “I don’t get that at all” and I’m like “That’s fine” but you know, “you kind of warmed up your brain a little bit about what it might be about”. You can come in here, you know you’re not going to...That you’re going to need to focus in class to be able to understand it.” So I think it’s still a helpful process, yeah in terms of, what I did after the Christmas assessments that we did, the Christmas mocks, was on the strength, on the basis of how they performed in that test, which was fairly in line with how line in all the tests, I kind of separated where they sit. So this is my teaching them, so I sorted out where they sit so I’ve got a couple, or a few who sit in that table and they’re kind of the ones who get it and I can more or less leave them to their own devices, this kind of notionally based front little row with the whiteboard, them not so much, this is my table that needs high support, and it tends, it’s not exclusively but it tends to be the people who don’t do the pre-reading, the ones on this table with a few exceptions, there's some that do all the work but still don’t get it and they still need support as well. And then the sides of the rooms are kind of like the halfway people, who, they kind of need monitoring but and more so than them but not as much as these people.

I: Excellent [Laughs] So, okay, going back to those topics, those were the topics you felt most confident with, so you stated that the topics that you felt the least confident with were transition metal chemistry, and analytical techniques. So what is it in particular about those topics that make you feel less confident in your subject matter knowledge of them? So we’ll start with transition metals, so what is it about them that makes you less confident?

R: Umm, lack of familiarity...So, the other side to what I said before about the ones I felt most confident really, lack of familiarity from GCSE.

I: Right, yeah I guess because both of those don’t come up much.

R: And also, I guess that that translates into the students. That they feel less confident in those areas as well because they haven’t encountered them before.

I: Yeah, that’s interesting that. And how do you approach, does your approach differ when you’re teaching the concepts you’re less confident with to the approach you take when you’re teaching concepts you’re more confident with?

R: I don’t think it does in chemistry, the reason why I say in chemistry is because I think that some of the content I’m teaching in applied science at the moment if I’m not, I probably do put more of it on the students to actually research stuff in the textbook if I’m not confident in it, but I think in chemistry I kind of make it my business to be able to deliver it confidently.

I: Right okay, so even if you’re not feeling so confident with the subject matter you’ll, you know make it seem to the students that you are confident in it?

R: Yeah, but at the same time acknowledging that I understand that it is tricky.

I: Yes.

R: So that they’re not thinking I must be really stupid because you know, she’s delivering it likes really obvious [laughs] So I do kind of give way to them when there’s something that I would find difficult if I was them kind of thing.

I: Yeah, okay, excellent. Um so now we’re going to focus on a few specific topics within chemistry, so first of all we’re going to talk about kinetics and the Arrhenius equation, so, as part of the A level forms of 2015 the Arrhenius equation was reintroduced to all of the A level specifications, did you say you taught A level before the new specs came in?

R: No.

I: Okay…

R: Umm no not really, in teacher training I did a little bit of AS teaching, but only a few lessons.

I: So I guess when it comes to adapting to the reintroduction of Arrhenius, you weren't already teaching that, okay, so that questions then not relevant. To what extent though do you feel that you and your students understand the mathematical processes that are involved in Arrhenius equations, so in terms of logarithms, use of natural logarithms, how are they, how are you with that? Do you understand the new use of natural logarithms in terms of mathematical process?

R: No, it's probably something I did once, because I did do further maths, I think that that the students who are doing further maths and doing maths A level are ahead of it, are ahead of me on it

I: Then the students who are not doing maths…

R: The students who are not doing maths, I don’t know, I probably dumb it down, probably because I don’t really remember what it’s all about apart from to make the scale easier to handle.

I: Yeah, so on your A level specification that you teach, are they given the two Arrhenius equations on their data sheet?

R: They are, yes, so.. [R walks off to get something] Yeah, but, no they’re given…

I: Both forms, the logarithmic form and the exponential form?

R: Yes, but they’re, what we kind of train them to do because the questions tend to be the sort of y = mx+c type questions, is we train them to break down the logarithmic form in to 1/t being the x axis and lnK being the Y axis

I: Yes.

R: So we sort of, this is how it’s written in the data sheet, but you need to separate those, split them apart from each, but they are given both I think.

I: Okay, and to what extent, I mean similar to the last question so that was about the mathematical process, but to what extent do you feel you and your students understand the application of the Arrhenius equation to further understand chemical kinetics? Do they understand why they’re using that equation?

R: Umm..

I: Or the relationship that it shows?

R: Yeah, I think they all understand...Well, what I hope that they understand, you can get the activation energy from it, the understanding of the frequency factor, is that what A is called?

I: Yeah, it’s either that or pre-exponential factor, it’s got loads of different names.

R: Umm, is probably less clear I think, because activation energy is something that is, they’re all quite, sort of comfortable with the concept of that, then I think that that’s probably the most obvious application of it.

I: Right, okay.

R: and using the gradient to calculate it and so on, but the weaker ones will struggle with that, and the ones who aren’t doing that will definitely struggle with it.

I: Yes, of course. Okay, so the next few questions, they’re going to centre on the A level topic of atomic structure and bonding. So I’ve got an example of a question for you, so this is the question, so we gave this to a bunch of students and a bunch of teachers. So there’s the question, a sodium ion is more stable than a sodium atom, true or false? And we found that 70% of the students said it was true, and 47% of teachers said it was true, so more teachers are going with false. I’m not asking you to answer the question itself, but I just want to know why you think those are the typical responses of students and of teachers?

R: So for students I would say that it’s all about the full outer shell, and the fact that sodium is going to be happier once its lost its outer shell electrons. And for teachers, possibly a concept that they’ve seen sodium as sodium, oh but that’s gas though, I was thinking about solid sodium. So, it must be relatively stable, you know, if sodium actually...Possibly you have to put energy in to ionise, so that it’s got a first ionisation energy so therefore the atom, the gaseous atom has to be more stable than the ion.

I: Yeah, and that’s exactly right, you know that is why the answer is in this completely hypothetical situation which can never happen would be false, but you know the difference between the teachers thinking it is true and false, as you can see is very very minimal. But this was a question designed to tease out those misconceptions, and as you say, with that the first question it’s likely because of that.

R: Full outer shell.

I: Yeah, full outer shell, things being happy, yes.

R: [laughs]

I: So the next question centres around chemical equilibrium, so this is a bit of a harder problem, so we asked some teachers at a conference last year, looking at that equilibrium system PCl5 being converted to PCl3 + Cl2 what the effects of adding neon, an inert gas while keeping the entire system at constant temperature and pressure, what the effect that would be on the position of equilibrium. So again I don’t want to know your answer necessarily, but I want you to consider why, so we asked….Sorry I should say that this pre-discussion and post-discussion refers to we asked teachers as individuals, and that's what the blue bars refer to, and then they spoke to one another, and after discussing it with each other, the red indicates what the most common answers were, so you can see that from most people saying we had no shift, we had more people saying right shift after they discussed it with their peers. So why do you think that might be the typical responses there?

R: So no shift being the most popular response?

I: And then right shift after the discussion.

R: So, you’re thinking, oh its constant pressure, I’m not changing pressure so it’s not going to shift in either direction, and I’m not changing temperature either. In terms of what else could be changing and probably the conversations that were happening, I'm just thinking this through, so you are going to get my ideas as well [Laughs].

I: Oh no! I would like your idea, no of course, I just don't want to put you on the spot! [Laughs].

R: That’s fine, umm you are changing the concentration because you’re adding something else, so you’re reducing the concentration of everything? So as a result it’s going to have more of an impact on that side than of that side, so, yeah, you’d probably have a conversation about Kc because you’re reducing the concentrations, the top of the expression is going to be reduced more than the bottom of the expression, so to restore the equilibrium you would need to shift to the right so things go back up and that goes down. So that would be a right shift.

I: Yeah, you can tell you’re a physical chemist [Laughs].

R: [Laughs]

I: That’s absolutely correct, and not many as I say, not many people that I’ve interviewed so far have been able to identify that, and it’s a reliance on Le Chateliers principle to just look at that as you said in the beginning, right okay its constant pressure, so nothing’s going to change. But as you’ve correctly identified, adding something else into the system, is going to concentrations or the partial pressures of those three species, and hence shift the equilibrium to the right, which is the right answer. Again, it’s another question that’s designed to tease out misconceptions amongst students in the past. So, final question now on misconceptions, you know what we just considered. Considering the problems that have just been presented to you regarding structure and bonding and equilibrium, do you believe that the limitations of chemical models and analogies should be taught at GCSE and/or A level?

R: Yes.

I: Both GCSE and A Level? Or do you think we should just leave it for A level?

R: No, at both, because I think that the longer that you allow a misconception to develop, so you know the sort of “the happy full outer shell” situation, then that becomes the norm, and that is incredibly hard to shift once students come out of GCSE and are going into more detail, more depth. And if they've still got that knocking around in their head when they’re sitting in an exam then they’re probably...And if they’re under pressure they’re probably going to revert to what feels like the right answer, what feels comfortable to me and so a misconception that’s been allowed to take hold is a dangerous misconception.

I: Yes yes, and it’s interesting to note that structure and bonding obviously is more physical chemistry topic, equilibrium a more physical chemistry topic, do you find in your teaching its the physical chemistry topics that have more misconceptions associated with them amongst your students? Or do you find that it’s generally across the board, it isn’t actually specified to one area?

R: I think it’s across the board but at the same time, I think there’s more physical chemistry content than organic chemistry. A lot of organic chemistry is the application of some physical chemistry concepts, so I think that where you have misconceptions, there's lots of misconceptions in terms of direction of electron movement for example, Im not sure where they develop because we don’t do it at GCSE so that must be developed while they’re learning at A level. But I think, no I think, thinking about it is probably is predominantly physical chemistry where the most misconceptions lie.

I: And there is any reason you think that might be? Because of the abstract nature of it I guess?

R: Yeah, the organic chemistry at GCSE is quite limited.

I: Yes it is, that’s true.

R: And lots of physical chemistry is taught, all the basis is, atomic structure.

I: Rates.

R: and rates yeah, equilibrium, so that’s probably why organic chemistry at A level doesn’t have so many misconceptions because there isn’t, there aren’t those oversimplifications being taught at GCSE, I guess the only bits being taught at GCSE are, there probably are areas where it’s simplified.

I: Yeah, I mean in terms of what you’re…

R: Alkanes, alkenes, polymerisation.

I: A bit on alkyls now…

R: Yeah, and esters.

I: But even then it’s very limited it’s only the triple science that does it.

R: Yeah, and I don’t think that I’ve had to sort of, unteach or undo anything that.

I: No, that’s it because you don’t cover any of the reaction mechanisms at GCSE, and that's the fundamental of it really, at A level, maybe a few reaction conditions but that’s not going to be.. That’s a case of rote learning that’s not a case of having to apply a concept.

R: I would imagine that university lecturers have to do undo misconceptions, things that are taught in organic chemistry at A level [Laughs]

I: Oh yes, no I’ve done a lot of work into that already, yes [Laughs] That’s very true. And one final very quick thing I want to ask about is that the topic of electrochemistry, so you put that at number 6 of 10 of the topics in the list?

R: Yeah, which order did it go in?

I: 1 is the best, 10 is the worst.

R: Ok okay, yeah.

I: Or least confident I should say, so you put electrochemistry in the middle which is, I think the best that anyone rated electrochemistry, so there’s a lot of people who are not very confident with electrochemistry, so can I ask how confident are you with electrochemistry, and how confident do your students tend to be with that topic?

R: Umm, I don't have a problem with it, my colleague hated teaching it [Laughs] and probably one of the reasons I’ve got both A2 classes, or both second year classes this year is because of that hatred.

I: Right [Laughs] We find its a topic that a lot of teachers seem to dislike and struggle with, or lack confidence in, and we’re trying to gauge why that might be.

R: I think that it's, it seems to me quite logic based, the titrations are horrible, the redox titrations and very complex, and I had one of my more able students last year sort of bursting into tears in a lesson when we were looking at lots of past paper questions on redox titration, but I don’t think it’s, I think its yeah, I think it’s logical, probably because I am more confident with the physical chemistry.

I: I was going to say, did you encounter it much in your degree or in your work in industry?

R: No.

I: It’s only been since you came to teach the A level that it’s kind of emerged?

R: Yeah.

I: Okay, no that's interesting, just as I said based on the interviews I’ve already done, it seems to be one of the least confident areas, I think it’s averaged at 8 or 9, you know people hate it, most people put it at 10, I think you’ve brought the average up by putting it there [Laughs]

R: [Laughs]

I: But no, okay that's excellent, thank you for your time.

**ARTHUR INTERVIEW TRANSCRIPT**

I: Ok, if you could please state your name for the recording.

A: [REDACTED]

I: Can I confirm that you've signed the consent form and you fully consent to this interview being recorded and used for our research project?

A: Yes

Interviewer: Ok, cool. So this first set of questions will primarily focus on your teacher training and its influence on your subject matter knowledge. So which aspects of your degree, so that’s your undergraduate degree, if any, helped to develop your subject matter knowledge for teaching? If any.

A: Subject knowledge to help for teaching?

I: Yes.

A: All of it? All of it. I don’t use so much of the corrosion stuff that I learnt because that's been taken out of the spec. But yeah, I use all of it. I actually go back to my notes and use them to remind myself at a higher level of the concepts that I’m teaching. And I’ve still got those books I produced to help me gain my degree, and I do use them, and I even show them to some students to say this is how I got my first class. This is the sort of way I approached it, and I use that to show them and all the past papers. I don’t keep all the past papers I did, but I did keep some of them, and I say this is what i do if you follow the same approach with your studies. I always say you have a high chance of gaining a really high grade. Although that's not subject matter directly, indirectly, I actually use it, even hard copies with my students but as far as everything I learnt in my applied degree, I use everything more or less.

I: Okay, so, you undertook a PGCE?

A: Yeah.

I: That's right. So to what extent would you say your teacher training addressed subject matter knowledge development during your training period? Please provide an outline of that.

A: Hardly any at all. I did do a physics enhancement course. I did 18 months. So, you know because at the time there was a huge, and there still is, a need for physics teachers. So they were recruiting physics enhancement teachers, so I did 6 months. I did a lot of subject knowledge in that. Chemistry, they did somethings with me, but it was such a low level I didn’t really learn anything, at all.

I: Okay, that's fair enough. Did you engage in any self-directed activities to develop your subject matter knowledge? In that time.

A: During my teacher training?

I: During your teacher training, yeah.

A: No, I don’t think so, not with chemistry, it was all pedagogy and stuff like that.

I: Okay. What do you remember about the impact of the subject matter knowledge activities you engaged in during your teaching on your confidence in your subject matter knowledge? So you said for physics, did that help with your confidence?

A: Well yeah, as far as chemistry, zero, because I mean I was a medicinal and analytical chemist. I’m not being arrogant when I said this, but I was very confident with my chemistry, especially organic. But with physics, absolutely. The six-month enhancement really developed my subject knowledge of physics, but I haven’t used it since I haven't taught any A Level physics, although I would like to. But chemistry, no I was always very confident with the chemistry.

I: Okay, so the next section is on the role of subject matter knowledge in teaching. So I’m going to ask a few questions that will primarily focus on what you think makes a good teacher, and how a teacher’s subject matter knowledge can influence that. So, broadly speaking now, not in terms of subject matter knowledge, just in terms of everything, what do you believe makes an effective teacher of any subject?

A: Discipline, organisation, self-motivation, an inspiring character - obviously that's quite difficult to achieve. Modelling the way to answer questions and just making planning lessons the priority above all else. Also, being very strict and methodical with your approach and have a very systematic routine. let the students know what they are doing when they come in the classroom, what they are doing during the classroom, there’s clear boundaries set. I don’t care what students you’ve got in front of you, whether they’re disobedient, difficult year 10’s or very compliant, quiet year 13 chemistry students, you have to have that approach and that will get you students on board. Also, I think it really helps that you drop in stories of what you used to do. Any aspect of what I’m teaching I can relate it to a job I was involved in that wasn’t a teacher and I can make it very relevant. And a bit of humour to it really does engage students I think, they respect you for that because they know you were a real practising chemist. I think a lot of them, especially the ones that are really focused on chemistry and want to do chemistry, you know if you’ve got an A Level chemistry class of 24 students, typically you might only have 2 or 3 that will go on to study chemistry. I do know from feedback 1 or 2 students I have taught have changed their mind about chemistry and want to study it because of the influence I have had on them. That is direct stem from my experience as a medicinal chemist and relating it to what they know. I have an advantage because of that.

I: I was going to say, do you think personally, in your personal opinion, if you do have a background in working in chemistry for a few years, then you're more likely to be able to teach chemistry more effectively or make it more relevant than say, somebody who has just come out of university?

A: Yeah, I think it’s helped me personally because you know 17 years I was in industry, different industries. But if I take a step back, I think it may be unfair to say it makes a teacher a better teacher, because, I am sure there are graduates that could come out and be fantastic teachers and fantastic without that life skill, that life experience. But, it’s certainly helped me, and I do think it’s an advantage, but I wouldn’t say that would stop any very young graduate coming and teaching. Teaching is a skill, and it requires good management, and I think my subject knowledge is a different part of that job and my experience is a different part of that job which a graduate can’t have, they can’t have had that. I have talked to other teachers about this, and another teacher that also came from industry and we’ve both used it to our advantage and we’ve both been very successful because of that. But just because somebody can come from industry with that experience doesn’t mean that they are going to be any good in front of a class, they are 2 separate skills. I would say it's helped me, but I don’t think it’s necessary.

I: So you say it's more about using the things you’ve got available to you to your advantage in teaching?

A: Yeah, but it's certainly progressed my career and helped me get some very good results, but you’ve just got to be disciplined, that's all you’ve got to do. That’s the first thing, if you’re not planning lessons properly, and you stand up in front of A Level kids, most of them brighter than me, you will get found out. You’ve got to plan and be organised and they respect that, whether you’ve got experience or not. If you do that, and you show you’re on their side, and you show there’s things you’re not sure about, you gain the respects of the students. You don't have to have experience to do that, you just have to have the right approach and mentality. Maybe, somebody with a bit more life experience could be better at that than somebody who has come straight from school and university? I wouldn’t say that, but some people argue that.

I: Okay, is there anything that you haven’t mentioned that you believe specifically makes an effective teacher of chemistry? So that was about being an effective teacher generally, is there anything you think you would like to add to that in terms of teaching chemistry specifically as a subject?

A: Me personally?

I: Yes, you personally.

A: I’ll just repeat what I said again. All that experience I gained as a medicinal chemist. Running and maintaining an NMR, developing methods on NMR, mass spec and organic synthesis. Purification techniques, chromatography data analysis, drug design. All of that is just so useful to me and I can talk to students about it, explain the problems to do with medicinal chemistry, the pharmacology, the pharmacokinetics, how drug development works, all of that stuff. Plus I can talk about industrial chemistry, although its 90’s now, how large scale industrial companies work, my experience with interviewing and employing employees and relating it to their qualifications. Just giving them advice about how to make progress in industry in general. Telling them the difference between an approach a student may have, if they have that same approach in industry that they would get sacked. When a student is underperforming, I can relate it. You’re not going to get a job if you’ve got 9 GCSE’s at A’s and A\*’s, and you’ve come to A level and you haven’t changed your approach, and you’re finding it difficult and you’re being lazy, and you come out with 3 E’s, you’re not going to get an interview at a decent place. They’ll see two contrasting characters on your results, and why have you done that? We wouldn’t interview people. I’m not saying we’re not going to give people a chance, but there are other people with better. And they look at you sort of like *“Uhh, oh yeah”*. So again, I think that my experience as a medicinal chemist really does help my teaching, predominately the organic and analysis obviously.

I: Okay, perfect. So how important do you believe a chemistry teacher’s level of subject matter knowledge is in their teaching?

A: I would say at A Level, on a par with your ability to manage a classroom environment of 24 kids. I wouldn’t say it’s the most important but it is very important. But I still think the most important thing for any teacher is first and foremost generating a learning environment where students can make progress both in and outside the classroom. That again requires first and foremost good planning, discipline, organisation and routine. You can have the best subject knowledge in the world, but if you haven’t got a class under control, pointless. I think it’s less important if you weren’t in A Level. In secondary, I think the most important thing by far is classroom management, you need it. But I would still say it’s the most important thing in an A Level class, but subject knowledge is right up there.

I: Yeah, of course. So do you believe that a teacher should be an expert in their field?

A: In A level chemistry?

I: Yes, in A Level chemistry specifically.

A: I believe they should have a good minimum of a 2:1 or first in a Chemistry related degree, yes. That’s the minimum, absolutely.

I: Do you personally feel that your teaching of Chemistry is limited by any external factors? So that’s things you don't have control over.

A: Such as what?

I: Things like time constraints or the syllabus.

A: Oh, okay. It would be very easy for me to say, yes of course it is. We could all do with more time, but I manage the time I have quite well. I think when I first started teaching A level I was spending colossal amounts of time planning. So somebody new to the subject, even if they’ve got fantastic subject knowledge, still has to spend maybe several hours planning one lesson. I was doing that, but once you’ve gone through the syllabus and you come back to it, you spend less time. I’m at the point now where most lessons with all the resources I’ve built up through very good planning in the early days, I don't really need to do a lot anymore. There are certain topics where I still have to sit down and not thoroughly plan but go through and refresh quite thoroughly because I forget, or I’m not confident with it. I don’t want to show that to the students, but I will if they start asking me difficult questions, I’ll quite happily say this is a topic that I’m probably least familiar with but let's talk about it. The constraints I have now is not the time, but it was in the early days. Now it's just everyday stress and pressures of trying to get students to reach SLT’s expectations of their benchmark when quite clearly they don't have the mental health or maturity to do it, and yet they still expect you to do it. That stresses me out, that's the constraint.

I: That's the primary one?

A: Yeah, we have to get results, all students on a piece of paper, so in August we’re judged on them. But there are some individuals who shouldn’t or are not fit to study and they just keep pushing them through, when I don't think that's fair on the student or the teacher.

I: Okay yeah, fair enough. So is there anything you would change? So in an ideal world, how would you personally like to teach chemistry?

A: Umm.

I: If there’s nothing you would change that’s fine.

A: No there’s nothing I would change, I do like the linear, I have no problem with the linear but it just, and I’m talking about this institution, we have lower entry requirements than other institutions around the area even though our principal is trying to sell us as a higher achieving college. The thing is we will always get, and I have no problem teaching kids with lower Alice scores or average GCSE scores than other colleges, I’ve got no problem with that. But the problem is the students come in, and they can’t quite access what we’re trying to do, no matter what you do with them or they’re going to come out with an E and they just bash their head. There is no alternative for them because they pick 3 A levels, the weaker kids are told to pick 3 A Levels, all of them are now because it’s linear, apart from the maths and further maths and the odd student who wants to do 4.So you know, by the time they get to the end of the first year, or they start doing second year stuff and they cannot access it at all, then they really struggle and there’s no alternative for them. So I would like to change, and this is more the college, I think they need to pick 4 levels, so they can drop one at the end of first year no matter what. Because some kids have got no options after the first year, because they’ve got nothing to do.

I: Okay, so is there anyway your approach in your practice would differ? If you could make any changes. Or do you think you’re happy with how...

A: The way I teach A Level, we teach it so that if a student wanted to sit the AS and leave, then they can, but obviously we can't devote class time like we used to prepare them for those 2 exams. The practical endorsement I think is a positive change, because there’s none of this prescriptive, *“Let’s get them through this”* ISA controlled assessment, *“Let's make sure we all do the same thing and say the right colours”* and all that stuff. But just recently, the last monitoring report did become a lot like that where they were looking through a book and they were picking up discrepancies between the tracking spreadsheet and what we were awarding them in the book. But it got to the point where it was like, well how is this going to benefit the teacher and the student? I mean they are showing competency in skills, and he was looking for evidence in books that I didn't think was necessary or wasn’t aware we had to do this all the time. It highlighted that actually this practical endorsement for large centres can become a bit of an administrative nightmare. That then is starting to eat into my time planning lessons, as I have to go through all the books and using his words in an email and verbally *“tick boxes”*. He also likened it to an OFSTED inspection, he said treat it like an inspection. It wasn’t a pleasant experience because of all the bureaucracy of it, I thought we were trying to get away from that, but it seems to have come back. It is is a shame, but in the end of the day why go through all this tracking spreadsheet nonsense if it doesn’t contribute at all. I think they should just trust the centres do practicals, and leave it there. If it's not going to contribute, we go through all this process. I don’t think that's necessary anymore, I think it's counterproductive to what we’re meant to be doing.

I: Okay, well that leads us nicely to the next section. So we’re going to be focusing on your opinions of the A Level chemistry curriculum. But quickly, before we get on to that, do you personally engage in any activities outside of schools, such as wider reading, watching television or listening to the radio to expand your own knowledge of chemistry?

A: I read the New Scientist, but I don’t read it cover to cover, I skim through it, I look at the jobs in there. Education Chemistry, the RSC publication, Chemistry World - I’ll always pick that up and skim read it. But I don’t really have time to do anything else with a family and this sort of job. During term-time I’m in here at 07:30. But I do finish straight away and go home. But then I work at home, I do other things, I do private tutoring and that takes up a lot of time. But that also helps my teaching, as I learn other specs. I do one-to-one tuition with different kinds of students, that really helps pinpoint weaknesses in students I didn’t perhaps realise. I know that’s not further reading, but it does contribute to my teaching. Private tuition when done properly, really can help cement the way you teach and explain things.

I: Excellent. Okay, so you mentioned this briefly earlier but, if a student asks you a question relating to content that lies outside of the A level specification, how do you personally approach that situation? Can you give an example of when this occurred and what you did?

A: There’s lots of examples, A level students who are interested and if you inspire them will always ask questions. Students will ask questions about my old job and medicinal chemistry. So for example when we do oxidation of alcohols, I will say, “*nobody does this in medicinal chemistry, nobody gets dichromate out”*, so then somebody will ask *“what did you do?”* I’ll then get my book out and show them Dess-Martin periodinane and say this was 8 years ago now but this is a much kinder reagent, it’s not as toxic, it’s very clean, you can wash it, you’ve got your product and high yields. And then I'll show the book and say you’ve got all these different reagents people develop and it's so much cleaner, but we can’t talk about this until you understand the basic process of oxidation. NMR, if a student asks a question about that I can do 2D NMR, I can talk about that. If a student asks me any question I will endeavour to try and get them to answer it, or we will talk about it. I don’t just say no I don’t know, I’ll say yeah I’ll find out or I’ll direct them somewhere but I do use a lot of my knowledge. Also, even back when I was a lot younger as an industrial chemist. If I can link it to large-scale industry, if we talk about phenol, I know so much about that, where it was made - Swansea! [Laughter] I’ll link it to the price of oil, you know all the time I use everything I’ve learnt all the time, and they love it. Most of them really want to know about that, there was a great big chemical factory in [REDACTED], that’s where I used to work. They’re all like “*really?”* Yep, there were great big tankers going down [REDACTED], 10 a day filled with phenol and formaldehyde going right through this housing estate. They had a hundred tonnes of it in molten phenol, and when they built the houses they had to dig 8 feet down to check the leeching and a student went *“I used to live in [REDACTED] and I didn’t know that!”* But again, that is directly because of my experience, so somebody who doesn’t have that experience wouldn’t be able to latch onto that. But then, a good postgraduate student, if they wanted to come into teaching would have a lot of knowledge about research and they could use that.

I: Cool, so how often do you find yourself teaching content that lies outside of the A level specification?

A: I’m very lucky, I haven’t done that yet. Not since I’ve been teaching A level. We do run BTEC, but I haven’t done a BTEC course. I would then have to do Biology and Physics, but that’s around AS level. But I haven’t done any of that, not since I was at school, I did biology and physics GCSE.

I: Okay, so what do you personally believe the scope of a Chemistry teacher’s subject matter knowledge be? So how much do you think they should have? Do you believe it to be an issue if the teacher’s subject matter knowledge is limited to the A level specification?

A: Absolutely, yeah. I believe any A Level teacher of any subject has to have a good solid degree. And relevant experience, which is probably a bit of a golden ticket, a big ask, is also very helpful. But no, you have to have a degree, you have to extend and challenge students, and I can’t see how somebody with just A Level chemistry can do that. Maybe they can if they further read, but I personally would want them to have a degree, I think it’s essential.

I: So you think it's primarily an issue if teachers only have up to an A Level in Chemistry because they wouldn’t be able to challenge their students?

A: Yes. But at any level of teaching you need at least the next level up qualification. At least to be able to challenge and extend students! Because if you stand up in a class and they are very engaged, you’re not going to challenge them are you? You’ll find it very hard to stretch and challenge them, and that's what some students need, whether they realise that or not.

I: Okay, cool. So this final section leads to these questions which will primarily focus on specific topics in the A level and the potential issues involved in both teaching and understanding them. In the pre-interview survey you stated that organic chemistry and analytical chemistry were the topics where you felt the most confident in your subject matter knowledge, what is it about those topics that makes you feel more confident in your subject matter knowledge of them?

A: Just using my work experience in drug design and synthesis. Working out synthetic routes to make novel compounds, purification of those compounds by various techniques, column chromatography, identification using: TLC, HPLC MS, HPLC IR, NMR, Proton NMR, Carbon NMR, quantitative carbon NMR. I’ve done all that, 2D NMR too! Then as an analytical chemist I did all sorts of wet chemistry, so I do know a lot about inorganic, but I find that more difficult to teach because I have to keep reminding myself of all the content. Organic, I mean I really enjoy it because it's really abstract and I’m very confident in it because of all my experience with it. I used to run 2 NMR Machines, I know how to run them, maintain them and I can talk quite in depth about the analysis of spectrum. Maybe not about the mechanics of how it works, although I can talk basic about it. But again it comes down to my experience.

I: Okay, and how do you approach teaching those topics, in terms of the planning and then executing a lesson?

A: So NMR, I would not focus on how it works really. I would just talk about... Look the keyword is Nucleus, it's about the nucleus, I would put some nuclei on the board and say these would have NMR spectra, and these wouldn’t. *“Can anyone say why or why not?”* And get them to say they have odd nucleon numbers and that's it. I’d talk about a compass in a magnetic field, what does a compass do in a magnetic field? It points north. If you put a nucleon with an odd number in a very strong magnetic field they’ve got a magnetic spin, what are they going to do? They’ll line up, so all we do then is turn on a radio and sweep along the bandwidth and they all listen to different music. That’s all they do, we listen to different radio, I like Radio 2, you like Jack FM, so we all vibrate differently at different radios. And then you start, maybe put ethanol up, so I’ll put a displayed structure of a molecule up, get the data sheet out, and I’ll get them to construct the NMR, not me. After that I’ll put it under the camera, and they can all do it, they just look at it and go right draw a line so they draw a line, and then we build up. There's TMS, what's this? Why did we use deuterated solvents? And then click, there's some kid who goes *“Oh that's got an even nucleon number”* and yeah that's it, you get them to do it. And then you just keep building up, and the molecules get bigger. But I do carbon NMR first, then proton NMR, and you introduce two more bits of information: splitting pattern and the integral. Then again, you get them to do the spectra, you don’t show them. Let them build it up, make their mistakes. There's a couple of cards we use where they look at simple low resolution NMR and they work out some splitting patterns. Then, once they’ve done that, wash them with questions! Build them up. So again, the organic mechanisms one I don’t show them, I write rules on the board, things like between species electrons will move from high electron density to electron deficiencies. So we put the rules up and then we discuss them, there’s usually four rules I use like in a polar bond the electrons will usually be pushed onto the more electronegative. And we use these rules, and then I’ll put up two molecules on the board and then I say “*what do you think is going to happen?”* I’ll then use the camera to show the mistakes, and build up. So don’t tell them, get them to think. So when they come like the second years now, revising, when we did mechanisms today almost all of them did them without even thinking, even out of context ones.

I: That's really good.

A: I do still use, but I haven’t used it this year, I use your video, I had used them 2 years in a row, but it's very difficult for me to get feedback from them directly as I always leave it to the end, so they finish the spec and the I usually give it to them like next week, before easter. Tell them *“Have a look at this, reflect on your mechanisms”*. But then we’ve only got 5 weeks left and it’s just solid prep, so...But things like that are very good, and I also use this guy called Mackem, a youtube for OCR? I’ve looked at his videos, and they’re very good for that purpose, so I’ll always use it as pre work, but I never show any videos in the class. Some students you know, you set it as pre work *“have a look at this video”*. I don't set them questions on it, because I don't want to set them work or me work to take in, so I don’t know if they're actually watching it. Most of them are, you can tell the ones who are because when you start doing problems they are ahead of the others. But pre work videos are good, but I don’t think they are as good as people have hyped them up to be, but then maybe I don’t use them correctly. But some students tell me they prefer to watch the videos after the lesson, if it works for you, that's all it is.

I: Okay, sure. So one thing you did mention briefly, so you were talking about the radio frequency thing, so that was a use of an analogy. Do you find yourself using analogies a lot in your teaching?

A: Yes I do, yeah I do. I try and make it comical as well, so there is danger that with the misconception. When you talk about how things work, like the NMR, you’ve just got to remember that all these kids need to do is interpret spectra. So as long as they’ve got some appreciation as to what is causing these signals, so like the analogy I’ll use for say carbonyl carbon nuclei or protons in electronegative environments attached to oxygens, I just say think of somebody stood up there and that oxygen is pulling their pants down, exposing the nuclei and shifting it down field. And when you’ve got two oxygens attached to a carbon, it’s like *“whack”* you’re pulling it right down, and that carbonyl is right up there and they’ve taken the pants off and they’ve thrown them away. They like that, and they can see it. It's very difficult, I remember when I was learning NMR I had no idea what he was saying, I can remember him, he was talking about *“This is the equation for ppm”* and he was doing all of this stuff and it was like *“what are you going on about?”* But when you start doing the spectra, it’s very logical and actually quite simple. I mean the n+1 rule is simple, isn’t it? But the stuff behind it is very difficult, so I avoid teaching that, it's not necessary. It’s not because it’s not in the spec, it’s because it's unlikely they’ll ever need to know it unless they go on and do, I don’t know, chemical physics? Who knows, but I do use a lot of analogies and you try and humour them.

I: Do you find yourself using those analogies with the topics you know better?

A: Yes, so if we look at electrochemistry, do I have any analogies for that? I don’t think I do really. But then it's such a dry topic, Isn’t it? Again, you just say its movement of electrons to more positive potentials, so I draw lots of diagrams for that with arrows, look there electrons, its going that way. There’s a half equation, there's the other half equation, draw the arrow it's going that way. You’ve got these other techniques like the anti-clockwise technique and all that, but no, I don’t do any of that. It's just there's the electron, which was is it going to go? Is it going to go to the more positive one, or the more negative one? What charge is an electron, what charge will it be attracted to, positive? There you go, that's it. So something I’m less confident in, I try and keep it as simple as possible.

I: Okay, so that leads on nicely to the next question. So we were just talking about the ones you’re most confident in. So you stated that chemical equilibrium and electrochemistry are the topics you felt least confident in your subject matter knowledge. What is it in particular about those topics that make you feel less confident in your subject knowledge?

A: It’s just I forget it all. It's not that its difficult, it’s just that I have to re-read everything. Maybe it's because I have a lack of experience in that from my jobs. But if I’m going to teach redox potentials, it's not so much now, but in my early days of A Level I really did have to do all the exam questions and even then I’m like I don’t even know why this answer is this. So if I’m thinking that, they are going to be worse off. But it's all the factual stuff like colours of the transition metals and shapes of complex ions, it's not so much a problem now, it really isn't. But some of the harder questions, and how to answer them and gain the marks, you have to remind the students to state which is the more positive potential, you have to state which is going to be oxidised and reduced and which way the electrons are going to flow. Christ, you may as well then work out the cell potential just to cover everything. So you know, it's doing things like that. I mean organic chemistry, you could argue that's even more abstract because it's just like these are these dots flowing about these letters. At least with electrochemistry you’ve got some numbers to deal with. It’s not that I’m completely afraid of the subject, it's just that I have to refresh my mind every time I do it, quite thoroughly.

I: So I was going to say, so how do you approach teaching those topics you’re less confident with? You have to refresh beforehand?

A: I will plan as if I haven’t done it before. I won’t write out what I’m doing, I don't do any of that but I will do some exam questions, and *“go oh yeah I remember that”*, and I will use PowerPoints for that. I try not to use many PowerPoints, I don’t really use that much, but I will have perhaps a more structured approach to the lesson and identify clear goals of where I want to be, which you should do for all lessons. I’m not saying I do that, but I just have to make sure that’s where I need to be, that's where the students need to be. So just more thorough planning and doing my own exam practice.

I: Okay, so, if you reflect on the approaches you take between teaching the concepts you feel less confident with to those you feel more confident with, the main differences between those approaches is you say primarily the amount of time you put into planning the lessons. Do you think you will ever feel more confident in those topics or do you think it's just the nature of them?

A: Well yeah, I am more confident in those topics than I was 5 years ago. 4 years ago when I first started teaching. And this year, again, less time planning. So it’s a lack of experience, I mean, the degree I did at [REDACTED] we did loads of electrochemistry, all the corrosion and all this stuff and I remember thinking, what are we doing here? But I got it all right, I passed with flying colours, but I always remember that being very difficult. So maybe that's a reflection of what I thought of that subject matter when I was learning it. I didn’t quite enjoy it, I certainly didn’t understand it, but I mean I still got through it and got very good grades, so that's just transpired into where I am now. But yeah, I am much more confident, It’s just I have to remind myself between the differences between a fuel cell and an electrochemical cell. I don’t find it particularly interesting.

I: Okay, so the next few questions are going to centre around the A level topic of kinetics. So what support do you get for subject specific CPD, just generally?

A: So in the early days they sent me to [REDACTED], when [REDACTED] did a 2 day A Level Chemistry, I forget what they’re called, enhancement course? They were very good for somebody who is new to the course. I think they were superb and I did 2 of them. So you know the college would also do them, but I don’t need to go anymore. They send me on exam board CPD, which is sometimes very useful when you change spec. And there’s the [REDACTED] meetings which we’re allowed to go to, I think they’re really good and I get a lot of them, well, I’ll get something out of those meetings. Every meeting I’ll take something away and think *“I’m going to do that”*, and I actually do do it. Other times you go to other meetings and you think *“I’ve heard that before”* and it seems quite good, but you don't quite believe in it. You can’t beat talking to fellow practicing teachers, who are teaching, not who have been teaching. You just cannot get that, and the only way I can get that is through the [REDACTED] meetings. They are essential.

I: That's great. As part of the A level reforms in 2015, the Arrhenius equation was reintroduced to all A level specifications. How have you adapted to the reintroduction of it to the A level syllabus? So, was it on the spec you were teaching before the reforms?

A: No, but we used it when we did Salters B and we did the project which is 30% of the second year, or 40? I can’t remember. We always did a kinetics project, I know you could have done anything with them but, to keep our resources under control and to manage delivering that with say 120 students, we gave them the choice of 5 kinetics type projects. To give them opportunities to access the higher marks, I can't remember how they used to set the criteria but, we used to teach the Arrhenius before we did the kinetics so they could access it and implement it in their project. So we were doing it, but not to teach to an exam, to teach to improve their project.

I: Okay, and do you feel confident teaching that concept?

A: Yeah, again I just have to sit down and think y = m x + c etc, but I don’t have a problem with it. I know where the students go wrong and how to correct that, but not as confident as the organic though!

I: Okay, to what extent do you feel you and your students understand the mathematical processes in Arrhenius calculations? So, shifting round the logs?

A: I must admit I don’t teach them logs or anything like that. I mean in the actual data sheet they do that for you, they give the Arrhenius and they give the logarithmic, they take the natural and logs and lay it, it's there. So all you need to do is go y = m x + c. So that's the extent I need to do. So you know the kids that don’t do A Level maths, as long as they know which buttons to press, because it's in the data sheet.

I: Okay, and to what extent do you feel you and your students understand the application of the Arrhenius equation to further understand chemical kinetics? So, the actual use of it, and what it tells us.

A: So when we teach it, I get them to link about what is activation energy and where have we seen it before, and then we go back to enthalpy profiles. And then I say to them, what will the sign of any activation energy be and well it's going up so it’s positive. Ok, so whatever you come out of this graph, what will the sign of activation energy be? Positive, remember that! So we link it back to enthalpy profiles first year, I link it to Maxwell-Boltzmann distribution curves as well, where the activation energy is - especially when you add a catalyst. So I try and link it back to that, as all they have to get is the activation energy, graphically or by rearrangement but I haven’t seen questions like that. The one I do struggle with is the pre-exponential factor, which has the same units as K. I do read into that, and I do try and explain it to the kids, and I think we say it must link to the number of molecules to the right of the Maxwell-Boltzmann distribution curve. I think that's what we say, I think I’m right.

I: Yeah, I think that’s right.

A: But do you know what I mean? In the question the students go well why has it always got the same units as K? And I’m just like, that's a good question, and then I think you need to know the maths around all that, and that is my limitation. But, I’m not going to spend half an hour going through that when they don’t need to do all that, which you know may highlight a weakness. But when you’ve got a class where maybe half of them don’t do A Level maths, you have to draw a line at a point. I’ve got one kid who could happily show everybody and he wants to, so sometimes I’ll go “go on then” and some of the kids are uninterested, so you know you can use your maths students for this stuff, and I’ve got some very bright students who can do that. So yeah, I do try and link Arrhenius to first year chemistry and also key stage 3 maths, as that’s where they do y = m x + c. I used to teach key stage 3 Maths and we did y = m x + c in year 8, that's when they do it. I’ll remind them about that, and I might even do a y = m x + c co-ordinate thing, and ask whether they remember doing that in year 8, and then go now we’re going to transfer it to this, with a negative gradient. Again, they struggle with a negative gradient, *“why is it going down?” “Why is it negative?”* It’s going down. Then they don’t change the sign, even though they’ve just told me its positive.

I: Right, okay. So the next question focuses on the A Level topic of atomic structure and bonding. So I’ve got a couple of graphs here, this is a question we pitched to some teachers and some students about a sodium ion. So this is how teachers responded, that is 47 and 53 those are quite different in size, so just be aware of the numbers there. Why do you think that these are the typical responses of students and teachers to these questions?

A: So what, that's students?

I: So that’s students, and that is how teachers responded. So teachers were 53 and 47 in favour of false, and students are 70% it’s true.

A: So student’s are probably thinking that it has a full outer shell as a sodium ion, but it’s a gaseous atom, it hasn’t. So they are saying all reactions want to get to a full outer shell. The sodium ion is more stable than a sodium atom, so if the sodium atom is more stable than a sodium ion, why would they say that? I don’t know. I’m thinking Born-Haber cycles. You’ve got energy on the left hand side, the gaseous atom on, hang on….Atoms, to gaseous atoms, to gaseous ions. So maybe, more of them are thinking about the Born-Haber cycle, so when you do the Born-Haber cycle and go to the top, you’ve got gaseous ions there don’t you? And the gaseous atoms are there, so maybe that’s why.

I: So this is a completely theoretical question as it is very difficult to measure, but what do you personally think is the correct answer?

A: It would depend on the context, oh no wait, that’s a gaseous ion.

I: Yes, they’re both gaseous.

A: Yeah, I was going to say, if that was a solid or an aqueous then that's different. So I’ll go for the atom.

I: Yeah that’s right, so in solid and in aqueous it would be different but ionisation energies are always positive, you have to put energy in to remove electrons, but as you've correctly identified yes, we think as well students are seeing the full outer shell means that…

A: Well, that's how teachers teach it to begin with.

I: Exactly, and you can seen that, I mean it’s only 53% to 47%, it’s pretty much half and half with true and false there.

A: So am I thinking along the right lines with the Born-Haber cycle?

I: Yes, exactly yes.

A: I’m using that to visualise that it’s higher up in the energy cycle.

I: Yes exactly that, so this is the explanation that [REDACTED] has written out for it. Essentially yeah, because we typically talk about things wanting a full outer shell, or that they need a full outer shell to be more stable and these..

A: But when it becomes an ionic solid, it is more stable

I: Yes, it is far more stable, that's the difference.

A: Well, generally, it depends on whether its endothermic or..

I: Yeah! Okay so final couple of questions relate to La Chatelier’s principle and chemical equilibrium. So I think you were at the post 16 teachers conference last year, were you?

A: Yes

I: So you might remember this question. So the question relates to, it’s down here. So you’ve got this system down here, would be the effect of adding neon at a constant pressure or temperature? So you’re not changing the overall pressure to the system, okay? The blue indicates how people initially respond to this question, and the red indicates how people respond to this question after discussing it with fellow teachers. Why do you think that these are the typical responses? So initially people thought that there would be no shift and after discussion they thought the equilibrium position would shift to the right. So I’ll give you a bit of time muse over that, as it’s not an easy question.

A: So you’ve got 1 mole going to 2, constant temperature and pressure. So if you stick in more moles, even though it's not a reactant...Constant pressure and temperature...I’m thinking it's going to shift to the right.

I: Yeah?

A: Because you're sticking in more, it’ll shift to the right. You can track that change, but it’s not a reactant though.

I: You are along the right lines.

A: So the majority thought there would be no shift initially?

I: So the majority thought there would be no shift, if you add the inert gas, there would be no shift.

A: But then the majority changed their mind to say it would go to the right?

I: Yes.

A: You’re increasing the number of moles. What’s this?

I: That's the number of people who responded.

A: Oh okay, so what do you want me to answer?

I: So I’m just asking why you think people started off with saying there would be no shift and then changed their mind to say there would be a shift to the right?

A: Why people would do that?

I: Yeah

A: Because they’re sharing their ideas?

I: [Laughter] And you think they're being more convincing?

A: I don’t know, I guess it depends who you’re sat next to. Maybe you were discussing with somebody who’s a physical chemist. I mean I’m not a physical chemist, I’m an organic chemist. That’s a hard question.

I: It is a tough question.

A: You are increasing the number of moles, but you are not going to react...Does it shift to the right?

I: It does shift to the right, yes.

A: Why?

I: So the reason is, what you’re doing is adding it under constant pressure. So the pressure of the system stays the same. So by adding neon, and keeping it under constant pressure, what you’re doing is reducing the partial pressures of all the species involved. And because there’s 2 moles on the right, and one mole on the left, it's going to shift to the right as it has more significant impact on that side.

A: Oh right, so to keep Kp constant?

I: Yes exactly

A: Oh, okay.

I: So, that is a tough question.

A: That’s the same as when you ask kids with the Haber process, why does Kp stay the same when you increase the pressure? You just cancel the pressures on the top and the bottom. Yeah, I think...yeah.

I: Exactly, it’s just a strange way of wording it.

A: Where has this question come from anyway?

I: It came from a research paper that was written in the 1990s, which was written to tease out misconceptions in undergraduate, first year chemists.

A: I have to say, why would anyone want to waste neon in that reaction? Why would you do that!

I: [Laughter] Exactly, it's just because its an inert gas! That’s what they’re going for there! So finally, some final comments on misconceptions with models. Having considered those problems presented to you do you believe that the limitations of chemical models and analogies should be taught at GCSE and/or A Level? So we spoke about the structure and bonding, so we spoke about saying how something is more stable if it has a full outer shell. Is that necessarily the case? Do you think we should also teach the limitations of a model? Do you personally teach any limitations of models when you use them in your teaching?

A: Yeah I do say that, but I can’t think of anything off the top of my head. But I do often recall myself saying, because students can question things. Especially, I think students can find it quite difficult when you’re talking about hydration enthalpies and lattice enthalpies and enthalpies of solution. If they start looking at the data, it can get really confusing, the patterns. Sometimes, I can't think of specifics, but i try and avoid it. Because I can’t understand what’s going on, there’s lots of different data, and it’s confusing me. So, that’s in hydration enthalpies. I can’t remember the specific examples. What other models?

I: So I guess, organic mechanisms are an example of a model in themselves? The drawing of them.

A: Yeah, I mean when you’re drawing them it is odd, 2 dots going around attacking the back arse of a carbon atom. It’s like, really? I don’t see any misconceptions with that though, I enjoy it!

I: I know, it is joy! [Laughter]

A: Yeah that is very abstract, using letters, dots and arrows to show why this reactant forms this product. When you really think about it, there’s a kid there who’s like got average GCSE’s, not the strongest, he or she is probably sitting there, mind blown.

I: Of course, you’ve got to suspend belief a little.

A: Which is why I do it the way I do it. Get them to talk about it and produce their own mechanism, with these sets of rules. One thing they find very difficult is when water acts as a nucleophile or Ammonia, and you get a positive Nitrogen or Oxygen atom. They don’t like that, they ask why don’t you show a dative covalent bond? You can do if you want, but all the electrons are shifting about to allow this hydrogen to leave. They talk about that but for some students in some classes, I have got this rule out. I can’t remember off the top of my head, but it’s to do with the number of valence electrons and non-bonding and bonding electrons, you can actually calculate whether its a formal or a partial charge. Some students ask when is it a formal or a partial charge? And you can say well, count the number of bonds, so if Nitrogen has got 3 bonds its Delta minus, but it ifs got a fourth one, its a plus. Lot’s of them accept that, but some of them want to have a rule. I remember this rule to calculate formal charges, but I can’t remember it off the top of my head, but it works! It’s a very simple rule!

I: Yeah It does work, I can’t remember off the top of my head, but I do remember.

A: Yeah, that right there is where I’m trying to use my subject knowledge to explain things.

I: Yeah, of course. So going back to that, do you think we should teach limitation of models if we use them?

A: At A level, yes.

I: But not necessarily at GCSE?

A: I would be selective with that. Why would you do it with any student unless they were going on to do science? Because I think you would inherently just confuse them even more, but I think with students who are doing triple science, even then you need to be selective, because how many students doing triple science go on to do Chemistry? When I taught triple science at [REDACTED], and I had 32 kids in there, I had about 4 chemists in there who went on to do it. You know, if you start teaching limitation of models to some kids in that class, I just think you would confuse them even more. So you’d have to be selective, but definitely at A Level.

I: Okay.

A: I think that’s the first thing you should do, I often say, “Right, this full outer shell nonsense, don’t think like that”. That’s not what drives some of these reactions forward, it’s not. You know, we’ve got to consider entropy, enthalpy, free energy. All sorts of things. You won’t get it and access it until the end.

I: Do you think that, and you said that you mention that, do you think that's a result of experience? Did you always find yourself doing that?

A: Doing what?

I: Actually highlighting the problems with these models.

A: No, so when I first started teaching, I wasn’t really aware of that, limitation of models. That was brought to me, probably because I started teaching secondary, I don’t think I was really aware of it. I used to say things like...I was aware the way the full outer shell theory was incorrect, but I didn’t really consider it as a problem. Not until I started teaching A level and I started going to the [REDACTED] meeting. I remember when I first became a teacher, I started in a May half term, they said go on this course, a June one. You were talking about things there, I was like “Oh yeah, Christ”. Also [REDACTED]’s CPD, I remember a lot of it was about misconceptions and models. But no, I wasn’t really aware of it until A Level, even though I was a practicing Chemist. You won’t until you start teaching it.

I: Of course. Okay, great, so that’s all of the questions I have for you today. Thank you ever so much for giving up your time.

A: That's alright.

**RICHARD INTERVIEW TRANSCRIPT**

I: If you could just er please state your name for the recording

R: Er I’m [REDACTED]

I: and can I confirm that you have signed the consent form and you fully consent to this interview being recorded and used in our research project?

R: Ah yep.

I: Excellent. So these first few questions are going to focus on your teacher training and its influence on your subject matter knowledge. So, before you undertook your teacher training you know undertook your undergraduate degree, um which aspect of your degree, if any, helped to develop your subject matter knowledge, specifically for teaching?

R: Eh so it’s probably going to be first when I was working in the labs, that was probably the first opportunity I actually had to teach. So I would’ve been at the start of my postgraduate degree, and I would’ve been supervising year one or foundation year students during their labs. And that's kinda I think well I wouldn’t say it necessarily focussed a particular skill I was wanting to impart, it probably focussed a desire with going into teaching in the first place. Rather than, I always thought I would go down the research route and that’s the first time I actually thought no this is pretty cool, it’s something a bit different.

I: And how did that help to develop your subject matter knowledge for teaching, I guess there's the…

R: I think well probably it’s probably the specificity of the lab instructions that you give in terms of method and actually interpretation of what is expected and even at a high level you can’t assume anything, and yeah that has been something that has held true, in terms of simple things like setting up a titration or setting up a gas collection experiment instructions for setting up a titration would certainly not be sufficient you have to actually even experience and have to actually guide them through what it all looks like and do the maths and do the (X) with the burette or whatever else so yeah I would definitely say the specificity of instructions in terms of guiding them as to what's expected

I: I see okay, so moving on from there to your teacher training so during the teacher training you undertook the GTP is that right yeah? To what extent did your teacher training address subject matter knowledge development during your training period

R: I think it was rather than subject matter per se I think it was more about how you might teach that subject matter and the importance of how you approach that subject matter so there’s one that is always cast out which isn't necessarily a chemistry questions which is ‘the difference between respiration’ and breathing for example and one in chemistry is ‘what’s an acid?’ and very frequently at year 7 the linguistics that you're putting in that actually develops the opportunity for misconceptions later on and it’s just the opposite of an alkali well yeah so yeah i would say more around the pedagogical impact of your definitions rather than chemistry subject knowledge specifically I think there was an assumption that your chemistry knowledge was sufficient and I certainly remember the year before I started a level teaching spending my summer going through the books and making sure I was up to scratch cause I wouldn't say that was something that was provided in my teacher training and as I say it was more about pedagogically how you support the student to overcome these potential pitfalls.

I: Okay that leads on nicely to my next question because what I was going to ask is if you engaged in any self-directed activities to improve your subject knowledge say you hit the books what else?

R: It's more around less no so hitting the books definitely lesson observations of other teachers in terms of how they support in terms of what was similar and different about the style of teaching cause I think I had assumed that these kids want to be there therefore maybe it can be more on the science is really interesting rather than sort of differentiation or scaffolding and very quickly realised that that wouldn't be successful umm and yeah so definitely lesson observations are my -- headteacher at the time was a chemistry teacher um so yeah lesson observations were a big thing along with sort of when I first started in that September it would be team planning of lesson plans and maybe take a 15 mins and gradually build it up and yeah that was helpful.

I: Okay great and what do you remember about the impact of those subject matter knowledge activities that you engaged in on your confidence in your subject matter did you find that it increases your confidence quite a lot?

R: I think looking back now yes but initially i would probably say no because actually I realise that I had to be very careful around what a definition was so to give you an example one of our trainee teachers this week described sodium chloride as made up of atoms now he said that to a year 7 student because they don't know what an ion is but it’s just not true to say that sodium chloride is made up of atoms because that is wrong so that student although I wouldn't say to that student NaCl is made up of ions now shh cause that doesn't help.

I: No.

R: Equally it doesn't help to tell that student that it’s made up of atoms either so I very quickly realised that actually I need to be meticulous and with a fine toothed comb around the language that I use and language that I’m confident in why I’m using the words I’m using in the context that I’m using them so one that quickly came to difference for me is the difference between a base and an alkali and I probably in hindsight used those two words interchangeably for quite a few years in my teaching which probably okay maybe didn't hinder them in year seven but by the time those kids got to year 12 and 13 at a levels it probably would’ve hindered them so yeah i think initially it was probably actually this is I wouldn't go as far to say quite scary but yeah i need to ensure that i was clear about the linguistics I was using.

I: Okay excellent cool so that’s the first section, the next section is on the role of subject matter knowledge in teaching and just general teaching so before we get onto that specifically broadly and you can be as broad as you want in your answer here ‘what do you personally believe makes an effective teacher of any subject’?

R: Ah passion I think enthusiasm, interest, somebody who is knowledgeable so for me in science and I would have to say that I do this less than I used to but somebody who’s aware of what’s going on in science not like oh isn’t it great that we know that this curly arrow does in a mechanism but actually where is that currently being used and why do we care why is that going to be a benefit to me in the future and so yeah someone who definitely keeps science education specific and someone who keeps up with the research and that could be a challenge because of paywalls and things like that and yeah I would say enthusiasm and someone who’s keen to keep up with CPD and I think actually in science it would be someone with a critical eye like one would expect to have if you were doing scientific studies or research exactly the same when your teaching approach so for me your teaching approach would be pedagogy in the flipped classroom rather than just accepting that as gospel because someone who I respect someone more senior actually was critical eye over well what’s the evidence for this and I think that’s helpful in science.

I: And yeah cause the next question was what do you believe makes a good chemistry teacher specifically is there anything else that you would add to that with respect to specifically chemistry?

R: I think again it's going back to the clarity of the linguistics and the scientific specific knowledge so obviously its key and i would say chemistry specifically have an ability to effectively use models and an awareness of students challenges and actually visualising what chemicals do and I would say also an awareness of the limitations of those models um so simply because I take four sticks and four balls of two different colours I think I’ve built methane somebody else might think vie built four sticks two different coloured balls so I would say an awareness of limitations and the strengths of each of the teaching tools that you have because there are specific challenges in chemistry that don’t exist in other subjects for example in maths one doesn’t have to prove that two plus two is four, it’s just gospel but in chemistry one does have to prove that methane is tetrahedral and has a particular shape and behaves in a particular way so an awareness of all the things to-do that I think .

I: So you said that you spent a bit of time working in industry, so do you find that whenever you're teaching you find yourself drawing on industry?

R: yes I would say less so now than when I first started cause that was 20 years ago so one of the brilliant advantages but simultaneously disadvantages of sciences education is that it’s so fast paced um so actually what I was doing in industry 20 years ago is so old hat now that it’s not considered really that valid or effective and um but yes so in terms of something like what I was working on which was a new drug so in terms of organic synthesis in terms of why are we wanting to make that drug why do I want that amine group there why do I want an alcohol group why do I care that this reaction happens definitely but in terms of more this is where the current application of this is less so what have previously been conducted is probably not its current application if that makes sense.

I: So how important do you believe a chemistry teachers level of subject matter knowledge is in their teaching so do you believe a chemistry teacher should be an expert in their field? Or…

R: I would say in chemistry education specifically subject matter is definitely important however I think there are tools in place that can overcome that and it depends what you it’s probably not the best answer but for me it depends what your end goal is if your end goal is to get a student an A grade then subject matter becomes less important how to get the student an A because so for example looking at curly arrows you do not need to understand what a curly arrow means and how to use it at a level chemistry you cannot learn those mechanisms and understand nothing and still get an A um so an ability to actually this is just the rules just learn it its effective in that strategy if your aim is to get that child an A if your aim is to get that child to engage be enthusiastic then that’s not effective so me yes I believe that science subject knowledge is incredibly important and somebody should be the expert in room however if your aim is simply grade orientated one can get away with certain loopholes and certain just rule sets that you just learn.

I: Do you believe that it’s an issue if teachers are grade orientated?

R: Yes on the face of it, yeah.

I: Why?

R: That’s because that's what their performance is graded on that’s what their pay scale is graded on and so we are still relatively new into the new specifications so it’ll be interesting to see what happens with the new specifications um but so far the way that questions in certain topics certainly the new specification has asked those questions has still allowed for a ruleset teaching tool rather than an understanding of what the teaching umm and teachers are cause that’s what’s going to come up in the exam and if it’s not in the specification they need to know specifically how to apply it xyz then they can get around not being able to do that.

I: So do you feel personally that your teaching of chemistry is limited by the external factors such as those you mentioned like the specification?

R: So yes definitely I think the yeah so the specification would be the big thing but I think the so the changes into the new specification as I said were relatively early days into that yeah so the intention was that we could overcome that issue and student going towards uni degrees in chemistry would have a more sound knowledge of these concepts and be able to apply them from day one yeah were still relatively new into that so we can’t give any firm conclusions of that and but yes we are restricted by the past papers because at the end of the say we need to get the kids to be able to answer the past paper questions and yeah it’s interesting that a thiol might behave in the same way as an alcohol to make a thioester but unless that’s going to come up in the specific exam, why are we teaching it to the kids and interestingly that did come up in the exam last year and they flunked cause they weren’t able to see that the sulphur had a lone pair paired in exactly the same way as an alcohol um so teachers at the moment we’re slightly constrained and handcuffed almost that we have to prepare them for applicational questions but we don’t know what the application questions are going to be and because it’s not specific around the specification so we’re trying to persuade parents and senior leaders and other teachers in your department so one of the conversations we’ve been having at the moment is required practicals for GCSE and trying to get them to do a chromatography on different protein structures and we had a massive backlash because well the classic chromatography experiment is pens so why would you do anything different there are still I think hopefully it’ll get better but there still a slight restraint in terms of what the reading of the specification by both students and teachers leads to in reality I think.

I: And in an ideal world how would you personally like to teach chemistry, what would you change, if you could change anything what would you change?

R: I’m going to go for the radical answer and say change the specifications and I think for me actually the although I never taught it because it was quite difficult to get an A grade the old AQA practical exam was quite an effective tool for teaching and measuring ability in chemistry so they basically got a couple of powders and gave them two hours to identify them or you’ve got an hour to make x or whatever it might be and I think that was actually quite an effective cause at the end of the day it is what chemists actually do on a day to day basis and I think there is because of the fear factor I mentioned about the linguistics and the importance of the correct scientific literacy early on that then limits the ability that you can teach things later on in life so saying that ‘oh oxygen wants to gain two electrons cause it likes having a full outer shell’ that is an effective teaching tool to get low ability students to understand but it’s wrong so I think for me I would go incredibly radical and I would not have science as a required subject at GCSE I would make it optional and then that would give us the freedom to actually really focus on the oracy skills and linguistic skills that we need so it’s not difficult to explain to that student why the full outer shell is not challenging it’s just that we do it in a bad way it just limits us to doing proper chemistry later on so yeah that’s probably what I’d change.

I: So moving on from there do you personally engage in any activities outside of school to expand your knowledge of chemistry that could be anything from reading listening to podcasts watching tv and if so what do you do?

R: Education in Chemistry regular blog magazine with current ideas for teaching and there is you may know the person who does the subject but there is current research that’s the summarised and made into a teacher friendly manner this is what it actually does which is really useful, the second thing I would use would probably be twitter there are a number of academics who post educational journals this is really interesting that this person found this and there’s also a number of teachers who post I did this with this particular tool and found it useful let me know what you think those would probably be the two main uses I do also use the chartered teachers website to get access through paywalls to educational journals um and sort of RSC journals or RSC membership as well those would probably be the main things um and then just in terms of lower down the school YouTube channels and there’ll be educationalists that do programmes on Cbeebies for the primary school kids that they’re quite interested in.

I: Okay, that’s great, so these next few questions leading on quite nicely from the last section, they are going to talk about your opinions of the A level curriculum, so something that we haven’t already asked and your teaching of the A level specification. So first of all, if you were teaching and a student asks you a question relating to content that lies outside the A level specification, how do you approach that situation?

R: I think it’s, to be honest, the honest to that is it depends on the class, and it depends on the question.

I: Right, okay.

R: The reason I say that is so for example, I mean thinking of one off the top of my head, but there will be mathematical skills in kinetics for example, but a student who is prominent in maths my ask about a natural logarithm calculation or method to draw a graph or something like that, and I may so happen to have students who are in the class who don’t do A level maths and don’t understand what a natural logarithm even is. I would probably not shoot that down, but I’d probably say “that’s a great question, but its off the specification but why don’t you come ask me at lunch” so we can go through it. If it was something, so if it was something around so for example organic synthesis and somebody asked me a question about like, “okay so why are we continually using amines in this structure?” that’s not on the specification but I probably would answer that because I don’t think it hurts, I think it’s, yet again it kind of depends on the dynamic of the class, if I’ve kids in there who I know are struggling with organic chemistry I probably would shut that question down.

I: [Laughs] Yes

R: Yeah so I think depends on the situation really.

I: Yeah, and have you, how do you approach the situation if you are asked a question that you personally don’t know the answer to?

R: Be honest, I think that’s, that is the actual truth. That’s a great question, I honestly don’t know the answer. I would probably say “Let’s look through it together” and have notes and say well “this is what I might think, I’m not sure if that’s correct, I’ll come back to you and look it up later on”. But yeah that certainly has happened.

I: Oh yeah, of course.

R: Yeah, that’s probably the normal route I would go down.

I: Okay, and how often do your find yourself teaching to a full class content that lies outside the A level specification?

R: Uhh, rarely, so it would be probably the application of why do we care? So for example this year I was teaching my year 13’s GC and HPLC and it was around the time they were looking at Bradley Wiggins and his doping scandal was coming out and should he have been banned? So we framed the lesson around that, in that why was he not banned? Why has he not been stripped of his knighthood? He took these drugs, how can we prove he’s not gone over the limit. Now it’s very unlikely that they are going to be asked a question about Bradley Wiggins and in his drug habits in the exam but on the specification is stating how we can measure how much of the quantity is there, what’s the advantages of GC and TLC, so as long as it is very clear this is how it’s linking back to the specification and this is why we’re doing it to make it slightly, I wouldn’t say more engaging or more relevant, but more aware of you know the sort of the news around us and the application then that would probably be the only content where I would spend a lesson as such doing that. But again it would be dependent on the style and class of students that I had in front of me whether I would do that.

I: Okay, so what do you believe the scope of a chemistry teacher’s subject matter knowledge should be? So do you think it’s an issue if a teachers subject matter knowledge is limited to just the A level specification?

R: Umm, I think if there is no specialisation then yes, I think that’s an issue. However, If there are clear areas of expertise then for me less so, so for example with me from a very early stage in my undergraduate degree I focused more on the organic side, so sure I can teach transition metals to A level, because I’ve learnt it but ask me to talk about bi-dentate ligands and the application of the electron configuration and anti-orbitals and...I did it in my degree because I had to, but that was 20 years ago now [Laughs]

I: Of course.

R: So yeah, the ideal scenario would be a department where there are different areas of expertise.

I: I see.

R: And yeah, and that, I think it can be a good thing that you’re expressing that actually we don’t know all the answers as scientists and actually this is how we go and research it, this is what we actually do when we don’t know an answer, and modelling that as well I think can be a learning gain in just in terms of a life skill.

I: Yeah, okay, excellent. So this final section on the interview is going to focus on specific topics in the A level and the potential issues in both teaching and understanding them. So I’m going to have to refer to that survey you filled out yesterday. So if you can just give me a second to locate it. There we go. So your most confident topics, the topics you that you were most confident in your teaching of were organic chemistry and analytical techniques. So what is it in particular about those topics that you make feel more confident?

R: I think it’s, with analytical chemistry I think it’s, there is an answer that you can get, nobody is going to argue if you get a sharp peak at 1700 that you haven’t got a carbonyl peak, that’s just a written rule, that is just fact. And even with more complicated molecules that you can look at, there are systematic rules that you can apply in terms of symmetry for an NMR for example, or you know number of bonds and coupling or, there are a series of just written rules that you can apply that work.

I: Yeah.

R: I think with organic chemistry, it’s probably, ironically it’s probably exactly the opposite, so for me I was never happy with the scenario of “well, it just works, just accept that if you reflux the backside of something, with a potassium chromate it will oxidise it, so if you’ve got a primary alcohol it’ll oxidise it to a carboxylic acid” “Just accept that.” I was never really happy with why, why I should accept that? Why, okay, that just happens, right just accept that it happens. So therefore that led me to an understanding of organic chemistry happened to be the area where different disciplines were applied into it, why did I need to reflux it? Why wouldn’t it just work if I heated it to 40C, you know, why did I need to use a particularly strong oxidising agent, why wouldn’t it work if I used something with a lower Ecell value?

I: Yeah.

R: Umm, so, ironically, it was probably now I would say it’s the topic I’m most comfortable with for those reasons, because I’ve done that initial “right, this is why when I take an amine in these conditions and react it with a haloalkane I make a substituted amine, and this is why in these conditions if I do that I make an alkene, and this is why in certain conditions it’s going to react as a nucleophile and in certain conditions it’s going to react as a base, this is why.” Yeah, so things like Gibbs energy, things like, yeah considerations of different topics I think KA synoptically link them together I feel more confident if a student asked me a question such as “Well why does this happen?” I’m able to answer that. Probably the challenge for me in organic chemistry is what we mentioned before, as the, well you can just learn this mechanism and not understand anything. But yeah.

I: Yeah, and how do you approach teaching those, do you just you know, “right I’m teaching this topic” you know how do you go about preparing for those lessons? Do you prepare any differently to other lessons?

R: Yes, I think it’s in terms of looking at, and again this has happened probably more prominently since that thiol question that we’ve mentioned earlier, looking at molecules and splitting them up and saying “okay what would happen if I put this in here? What would happen if I put that in here?” and so for example in bonding you know if I got a student to draw I don’t know...Thinking off the top of my head, if I got a student to draw water I would expect them to know that a molecule that’s two bonds and a central still being oxygen it would be the same shape, I probably wouldn’t have expected them to know that if they’ve got an oxygen and they replace that with a sulphur, that’s going to mechanistically react in a similar way.

I: Yeah.

R: So yeah I’d probably be going into more detail around what impact does this make by making each changes, or for example when teaching year 12’s curly arrows, I probably would throw in molecules they’ve never met before.

I: Right, okay

R: With a lone pair to say, okay what happens here? Does it still work? Obviously that requires a lot of scaffolding, you’re not going to do that from day one, but it’s probably something where I would feel more confident to extend them and extract them, and it seems to be one of the topics not in the new specification, but it seems to be one of the topics where the exam boards (………) are saying “right, okay an alcohol reacts with this but how does a thiol react?”

I: Yeah, okay. And do you find yourself using analogies in your teaching for those topics?

R: Probably, if I’m honest, I try to avoid it. But, yes probably. But I think yeah one has to be again, one has to be careful about the (.............) being used and an understanding of what actually happens in the chemistry. But yes I probably do.

I: Yep, okay. Umm so moving on then to the topics that you said were the least confident. So you stated that it was transition metal chemistry and electrochemistry. So, we’ll start with electrochemistry, what is it in particular in electrochemistry that you feel less confident in your teaching of it?

R: I think it’s probably an explanation of the order in which you balance half equations and then working from that there are a variety of routes that having looked at in chemistry in topics I’m not sure I still, so the anti-clockwise rule I’m not sure I still understand that now [Laughs]. I can add half-equations together to work out an overall ECell I have my method to do it, and there’s a textbook method that I look at every year and I’m sort of like “what?”

I: Yeah.

R: And again I have my route for balancing a half equation, and the textbook might have a different way of doing it, in terms of the order that it’s done. So I look at oxidation numbers first then add electrons then multiply then cancel out and then sort out of rules about the order of which you add protons and add water molecules either side doesn’t matter. Yeah there are a number of different routes kids find in textbooks and on the internet that’s different to the way I’ve done it, so that’s probably why I find it more challenging.

I: Yeah? Okay, and what about transition metal chemistry?

R: I think in terms of transition metal chemistry I think it’s around again its one of those topics well it’s just “learn it”. Copper (ii) complexes make blue complexes just learn it, but I was never really happy with that and I’m not sure I’m completely concrete in terms of electron excitation and the colour wheel and electrons moving down from higher energy orbital level to lower energy orbital level.

I: Is that on the specification?

R: No, but as I’ve said, for me I like to know why things happen. So it’s not necessarily that I can’t teach a topic, it’s that, yeah I can teach the topic, I can tell them that copper complexes are blue, iron (ii) complexes are a particular colour, I can get them to learn the different colours of the different complexes and what happens in precipitation reactions with hydroxides, I can just get them to learn that, I’m not sure I can get them to explain why that happens. I’m not sure I can explain why that happens and therefore I’m less confident in it. Why deprotonation happens in particular ………………….ligand exchange………...it’s its colour.

R: That’s probably one of the topics that having tried to dig deeper, I just got to a stage where I’m just like, right, just learn it. And I’m not sure that I’ve ever really got beyond that, and it’s probably for that reason, as my role I decide who teaches what topic, and I’ve not taught it for about 4 or 5 years now so it’s probably again a topic that if I went back to ito now, I’d have to go back and review all the books again, whereas there are other topics that actually do you know what I’ve taught those recently, yeah.

I: And how do you approach teaching those topics, would you say your approach differs to teaching the more, the topics you’re more confident in?

R: In terms of the topics I’ve ranked lower?

I: Yes.

R: So I think there is, it tends to go to more of a ruleset, so it is, for example with, excuse me...With the Arrhenius equation it is, right “just accept that if you do a natural log of this this happens, just accept that. You don’t need to know why it happens, that’s maths, just accept that this happens”. I probably would still teach like that. In kinetics I think it’s probably, sorry in equilibrium rather, I probably would have previously put that even lower but having looked into research, and the reason I probably would have put it even lower it’s because up until very recently we taught Le Chatelier’s principle, and yeah, it’s a load of bologna.

I: Yeah, we’ll get on to that in a minute [Laughs]

R: It simply works by sheer coincidence, and I have found that for myself, although I don't teach it in the specification, for myself being more familiar with things like reaction quotients and how to calculate a reaction quotient, helps my explanation on why Kc is more useful than something like Le Chatelier’s principle they’ve met earlier on. Whereas there are particular topics, so in kinetics for example I would have a look at, ok, harder questions where okay, there is a ruleset where you keep one concentration the same and change the other and see the impact of the rate and work out the order, or what happens if you change both the concentrations, ands throwing in questions like that because they’re coming in more prominently. So I think there are certain topics that would be probably reactionary to what's happened in past paper questions.

I: Right, I see okay.

R: And there are certain topics that I would be more confident in how I’m teaching, so more mathematical topics I’m probably more reactionary to what’s happening in an exam context versus okay, are there now examples where there changing both the concentrations simultaneously and asking you to workout the overall order, are there questions where they’re giving you one order, one reagent and asking you to work out the order of the other reagent and suggesting a mechanism. Are these kind of questions actually propping up? And if they are propping up I would probably be reactionary and teach that sort of stuff if, if they’re not I probably wouldn’t throw it in as much.

I: Right.

R: So I would say those are some of the topics I had to change, rather than a desire to change if that makes sense.

I: Yes, that does yeah. Okay, and do you find yourself using analogies to teach those topics?

R: Less so because the answer that you frequently get is a mathematical answer…

I: Right, yes.

R: So if you double the concentration and the rate doubles it is first order, and that is just, if you do reagents over, sorry products over reagents and plug in concentrations you get a fraction, you just get a number and I think there are certain times you might use rulesets in terms of Kc having a particular numerical value and what that means about the actual reaction, but in terms of analogies, probably less so.

I: Okay, cool. So we’ll move on, you mentioned briefly there chemical kinetics, so we’ll have a brief chat about that, so as part of the A level reforms the Arrhenius equation was reintroduced, how did you adapt to the reintroduction of the Arrhenius equation to the syllabus? Were you comfortable with it before or?

R: Yes so I think it’s, it’s one of those questions where I was probably more comfortable than I otherwise would have been, but that’s simply because of the context I found myself in. So, the school I was in at the time before the specification changes were doing an Edexcel course and they had to be able to calculate the activation energy from the graph, but not actually use the Arrhenius equation, so, or not learn the Arrhenius equation or not know what it meant, they just had to say “right, okay this is a graph, calculate the activation energy”. One of my science teacher’s at the time was the head of science, sorry the head of science and the head of sixth form, she wasn’t particularly happy with that so she taught it in the lesson even though it wasn’t in the specification.

I: Oh right, I see.

R: So for me that particular topic wasn't such a massive change as it would be for some. Having said that I would still probably being honest struggle to prove that from the Arrhenius equation that if we do natural logs we end up with Y = mx + c graph, and therefore I say right “this is the Arrhenius equation, this is what a logarithm does, this is what a natural logarithm does, if we take this natural log from here this is what we end up with” and those who are mathematicians in the class say “yeah, that’s right” and those who are not mathematicians think, most of them accept that that happens, and obviously logs to base 10, they can see from, so for example pH, now if I take log to the base 10 of -2, so they can see how that works, and therefore for them to say natural log does the same except to the base e, you probably don’t understand what the base e means but they can see that the same principle applies.

I: Yeah, okay. So do you feel confident teaching Arrhenius?

R: Umm, I feel confident in getting them to the stage they need to be.

I: Right, okay.

R: Which might be different in that chemically understanding the Arrhenius equation, if that makes sense?

I: Yes, that does yeah.

R: So I feel confident, I think it’s one of the topics we have to be careful about the order, in terms of academically in the year of when you teach it, and I would certainly make sure we teach pH before we teach kinetics, so that they have the experience of using logs and what a log actually means. This year, actually coincidentally, we moved it to, the school that I’m currently at don’t do AS levels…

I: Right, okay.

R: So we’ve therefore moved some of the year 13 content into year 12, one of the topics we moved was kinetics and it’s not surprisingly hasn’t been massively successful for that reason, because we’ve taught it before we’ve taught what a log is and before those who even do maths know what a natural log is. And yeah, it has therefore been more of a struggle to get them to see this is the relationship.

I: Right, okay. So we’ve gone through all of that, what support do you get for subject specific CPD from your school?

R: So there is an annual budget that we get, there is on our, on my annual review documentation there are targets I might wish to achieve, and therefore there would be a favourable approach to CPD which meets those targets. So if my target is to up the number of students taking A level chemistry in the first place, then opportunities to liaise with outreach officers or things like that would be looked upon favourably. If my target was to increase the number of C to B students then that would be the CPD focus that I would look at. It’s probably, I probably have more of a justification to look at research, and how that actually impacts the students. They can see how it impacts the teaching that I do but how it specifically impacts the students is more of a question I have to answer, so why going to certain, why is that going to improve the grade outcomes of your students? If that’s the target, that’s a question I would have to justify.

I: Okay, I see, great. So we’ll move on now to focusing on some questions around structure and bonding, which we have discussed briefly. So I’m going to show you a question now, you may have seen it before, if I can find it….So this is a question, so the question is, it’s a true or false question, a sodium ion is more stable than the sodium atom? True or False? This is how a group of students responded to the question, 70% said true and teachers responded 53% false and 47% true. So, I’m not asking you to give me the right answer, but I want you to comment on why you think student’s responded like this, and teachers respond like this?

R: Umm, because with students at GCSE they are taught, and I still teach this, that if they have outer shell electrons they have a choice, so sodium has one electron, it can choose to lose one electron and make an outer shell or it can choose to gain 7 electrons and make a full shell. And I do still say to the kids “which is easier?” lose 1, or gain 7. “Oh, lose 1’s easier sir” and I use the words stable as a result of that, but then, therefore that can mean a misconception that’s placed in their head. With the teachers there is an awareness of Born-Haber cycles taught at A level and in the Born-Haber cycle there’s awareness of vectors and vector diagrams and what an arrow represents in terms of endothermic and exothermic nature, and therefore is an awareness, or should be an awareness that going from sodium gas to sodium+ gas is an endothermic process and therefore that requires energy, and therefore the stability implications of that. Probably the reason why it’s not 100% is again that GCSE content of simply without any knee jerk reaction which is more stable sodium or sodium 1+,I mean there is a colleague of ours who asked me that question a couple of years ago at VICE and as a knee jerk reaction I didn’t draw a Borne-Haber cycle, and I was like “Oh yeah, of course”. You can almost revert to that GCSE mindset of, okay empty shell, full shell that’s what's stable. “Okay, loses an electron to get stable therefore sodium + is more stable”.

I: Yeah, great. Okay. So moving on then we’ve got a question about, a similar type of question about Le Chatelier’s principle and equilibrium. So I need to explain this a bit. So the question is down there it’s regarding this equilibrium system. What would be the effect of adding some Neon an inert gas at constant temperature and pressure, so that's keeping the entire system at constant temperature and pressure even after Neon’s been added on the equilibrium position. And teachers who took part in this were invited to then discuss the answer, they had to give an answer on their own and then they were invited to discuss with each other what the answer might be and then they are asked to give an answer again.

R: Right, okay.

I: So the blue bars indicate what they said before they discussed with their peers, and the red bars indicate what they said after discussion. So, initially the majority thought there would be no shift, but after discussion we saw that the consensus shifted towards thinking there was a right shift. Again I’m not asking you for the correct answer, I’m just asking so why you think teacher’s initially responded that way and then changed their minds?

R: I think initially there is a perception perhaps that adding a gas that doesn't obviously take part in the reaction is therefore not going to impact the position of the equilibrium. And again there probably using a La Chatelier’s approach rather than a Kp approach in terms of what they’re expecting to happen in the equation.

I: Yeah.

R: There was a percentage of people that had a shift to the right in the position of the equilibrium there was a percentage of people that had a shift to the left position of the equilibrium, one might expect that during the discussion you could justify those answers and one would hope that they would have started using Kp in their explanations somehow and therefore that caused the shift. Again, there is a ruleset that isn’t particularly well understood even at GCSE, and there is, the sort of classic analogy of running up the escalator but the escalator is travelling downwards…

I: Yes

R: To be honest I’ve never really grasped that, it’s not a particularly helpful analogy.

I: No [Laughs] Nor have I.

R: So, I mean my analogy that I do in that one is I say “A Teenager, so whatever you ask them to do they say “Screw you”, it does exactly the opposite” but yeah, I think in terms of some of the teachers would have then used Kp as a justification and done an actual calculation in terms of the Kp value, and therefore said “okay, this is then what's happened, and this is then the impact on the position of the equilibrium”.

I: Yeah, that’s exactly what happens, good stuff. So, baring that in mind and we did touch on this earlier but I want to hear more of your thoughts on it now, do you believe that the limitations of chemical models and analogies that we use should be taught at GCSE and or A level?

R: Yes..

I: Both GCSE and A level?

R: Yes.

I: Explain why you think that.

R: So I think, so for example there is a, the classic one that I would probably think of at GCSE would be around bonding, but also, so there was a scenario we had recently with a trainee teacher who I supervise who said to a student “Oh a covalent bond is a shared pair of electrons” that's what it is. Now that’s the model but then afterwards I had a discussion with that teacher and said “well why don’t those electrons repel each other?” and then actually, I’ve never even thought of that as a possibility, of course the electrons would repel each other if it was just a pair of electrons, so then what's a covalent bond? And actually that then leads to potential misconceptions around things like electronegativity, things like reactivity at A level where if we actually gave them a more concrete definition and concrete limitations of what these models do and what they say, that, i think would be helpful at A level.

I: Yeah?

R: So what we’re doing at the moment I think, we’re saying okay, something like a covalent bond is a pair of electrons, the assumption then is that they’re static, that is just yeah, that is completely scientific nonsense, but that would be the assumption. I mean, there has been research, I have not personally done research into this, but there has been research into this, students don’t appreciate that the electrons move, and then even in electronegativity at A level, around a carbon-hydrogen bond for example they don’t appreciate that one millisecond both electrons could be completely over to the carbon, so how do they understand what a temporary dipole is? And how do they understand what impact that actually has on the chemistry of the molecules? How do they understand what a London force is? How do they understand whether ionic compounds have London forces or not? Do they? And therefore what’s gravity and you know…

I: Yeah [laughs]

R: So, yeah definitely, I think models are really useful, they help us with an explanation but they are limited. I think us being, yeah that’s chemistry and an appreciation of that earlier on, I mean when I went to school and my A level started and they said “well forget everything you were taught at GCSE, this is the truth” and then I went to uni and they said “yeah forget everything you were taught at A level, this is the truth” and obviously a 14 year old child is not pedagogically developed enough to understand the Schrodinger equation or antibonding orbitals, but they are pedagogically developed enough to understand that there is a limitation to the model that they’re using, and as they go through they’re going to use more advanced and more developed models. So for example with my year 9’s, I’ve just taught them bonding. I don’t teach them 2,8,8 because yes it’s a model but it works for the first 20 elements, the periodic table is 100 and something elements long, so I don’t...I teach them first shell has 2, second shell has 8, third shell has 8. “Where does that come from?” “Oh look the periodic table, on the first row there’s two, on the second there’s 8, how many does the fourth?” and I get them to actually come up with a better molecule themselves, they’re much happier with that.

I: I’m sure they are yeah!

R: So I would argue, i mean they are topset, but I would argue if you asked most of my year 9 topset to draw the electron configuration of bromine they would draw 17 electrons in the outer shell.

I: So based on that, do you think that we should be only teaching limitations to the higher ability groups, the ones who may go on to do A level chemistry? Or do you think we should teach it to the lower ability groups as well?

R: I think there are scaffolds that we can use that are helpful, I think for me there’s a difference between differentiation and pedagogical theory. So a low ability student, I mean I would argue a low ability student can't count the number of boxes in a row of the periodic table.

I: Yeah.

R: However, there are, I think we focus too much on relying on models to lower ability students, and using models more for lower ability students as if, so for example there’s one of my colleagues who was teaching that topic to a bottom set year 9 group, and she used counters. So her focus was not on how many electrons are in the outer shell, it’s what charge the resulting ion would be, so she had protons and electrons and neutrons and she put them all in and got them to work it out, and of course they couldn’t do it because they didn’t realise the neutrons were neutral.

I: Ahh.

R: And her analogy was “Neh” for neutral, well yeah but electrons are negative, so why are they called “e”?

I: Yeah.

R: So, there are models that we use that don’t necessarily always stack up, and because for us it was, yeah okay that makes sense, like if I have 8 protons and 8 electrons, I can use a number line and I end up at 0, that makes sense to me.

I: Yup.

R: And six-year-old children would use a number line so surely my lower ability year 9 group know how to use a number line, but there’s a limitation in the linguistics of the model they’re using around “Neh” for negative, so I think it's, we have to be careful around our reliance on models rather than actually saying that we shouldn’t identify the limitations of models full stop.

I: Right.

R: So it’s, yes a higher ability student is going to be happier, this teaching method that I’m teaching you is limited and the differentiation in making how we express that, rather than not expressing it at all.

I: Yeah, okay, excellent. Well that’s all the questions I have. Thank you ever so much.

**JENNY INTERVIEW TRANSCRIPT**

I: Okay, can you please state your name for the recording?

J: Uhh, [REDACTED]

I: And can I confirm that you’ve signed a consent form and that you fully consent to this interview being recorded and used for our research project?

J: I have signed and consented.

I: Okay perfect, so this first section is on your teacher training and its influence on your own subject matter knowledge. Okay?

J: Okay.

I: So, first question. Which aspects of your undergraduate degree, if any helped you develop your subject matter knowledge for teaching?

J: For teaching A level chemistry?

I: Yeah, for teaching A level chemistry.

J: It was mainly the units I did in chemistry, so although I did biomedical science, I did a unit of Physical chemistry, inorganic chemistry, and organic chemistry, like the first units the Chemistry students were doing. And there’s the crossover material, so I did quite a bit of genetics, proteins and so when we do the kind of biochemistry in the A level I’ve got little stories and little connections I can make, because that's what I studied as a degree.

I: Yeah, of course, yeah. So, to what extent did your teacher...So you did a PGCE correct?

J: Yes.

I: So to what extent did your teacher training address subject matter knowledge development during the training period? If at all.

J: Umm, it did a bit. So we had lessons in Biology, Chemistry and Physics. But it was secondary science aimed, and um, I’ll tell you the truth I was pretty strong. So I was one the stronger candidates, I’d done all three sciences at A level, which not very many of my colleagues had done. And although I’d had quite a big gap between teaching and umm sorry, my degree and starting teaching, I seemed to have retained it fairly well. So initial tests, they gave us initial tests, I came kind of, I was top in the class on those.

I: Nice.

J: Generally I was, um...It was reassuring, but I felt fairly confident at teacher training, but it was only up to GCSE level we were looking at.

I: Right, okay. And with those initial tests, the purpose of those was it to see if you needed any subject enhancement?

J: No, I think it was to scare us that we didn’t know it and that we’d forgotten it all. [Laughs]

I: Right, okay. [Laughs] So while you were training to teach, did you engage in any self-directed activities to develop your subject matter knowledge? I mean you’ve already said you were quite strong so..

J: Yeah I bought textbooks, I did a bit of reading around. I always...It was one of the things that was noted when I did start teaching so, I’m sorry if I’m jumping to another topic..

I: No that’s okay.

J: That my colleagues who, sometimes we would be supporting each other’s lessons, they’d go *“I always learnt something new in your classes”* because I would I’d go quite in depth and I would research, find all the stories, rather than just teach a certain topic I’d try and find stuff around it because I feel I’d be a far more interesting teaching it If I had a bit more than just, up to exactly what they needed to know and no further.

I: Yeah, and where did you find those bits of information?

J: Umm, internet, textbooks, the RSC website is great - it has stories about Nobel prize winners and those kind of things. Umm, so they were my main sources.

I: Okay, great. Umm so..

J: New Scientist! Sorry. [Laughs]

I: Oh yeah! [Laughs] That’s fine. What do you remember about the impact of subject matter knowledge activities that you engaged in on your training on your own confidence in subject matter knowledge, in chemistry specifically?

J: Yeah, so the chemistry I don’t remember massively. I think the main thing was practical skills. So that was maybe, not so much the skills themselves but how to teach them, how to organise your classroom. Those were the bits that I think were weakest. Because I never had to think of it in terms of “*Oh my god I’ve got to teach people how to use a Bunsen burner and not set fire themselves.”* So practical I think was a bit that was really useful. I remember being quite impressed by the guy teaching it, he seemed very confident and on the ball, more than the other two subject teachers actually.

I: Yeah, okay so you said that you undertook a degree in Biomedical sciences, when you first started teaching did you feel that was, compared to other people who had undertaken degrees in straight sciences, Biology or Chemistry, do you think it was more of a, do you think it was a hindrance in terms of your subject knowledge? Or do you think it was more of a strength in terms of…

J: Um..

I: Or a bit of both?

J: Well, I’d been able to choose, there was quite a bit of flexibility in units, so the units I’d done, I’d done Chemistry units, I’d done pharmacology, lots of cell biology, genetics. So, it didn't really feel that different to the people who’d...No, that's not true. It felt like I was better across subjects because I hadn’t just done a pure one, I’d spread it around a little bit.

I: Yeah, that's good, cool. So this next section is on what you think makes a good teacher, and how a teachers subject matter knowledge can influence that. Okay, so very broadly speaking now, we’re talking in terms of everything, what do you think makes an effective teacher of any subject at all?

J: Umm, okay so there’s lots of things in my head now.

I: Exactly yeah, so everything, just spew it all out! [Laughs]

J: Okay so, subject knowledge I do think is important, enthusiasm, empathy for your students - so being able to anticipate and understand where they’re going to have problems.

I: Right, okay.

J: You do sort of have to, in a way be able to multitask, when you’re teaching you’ve got to be thinking about what am I going to teach, how am I going to teach it, but you’ve also got to think how are all of these students coping with it. So, being good at, spotting their body language, and spotting when somebody’s not with you, and keeping track of them. That’s something that's been important. Umm, confidence is something I wish I’d got the hang of earlier on. So walking in with the right body language, acting as if you own the space, because actually I’m not...People don’t always believe this of me but, I’m really not a naturally confident person, I had to really fake it. I spent about five years going what would a teacher say, how would a teacher behave, because it wasn’t natural to me. So, if I could go back and talk to myself at the beginning, you know I’d be like *“work on this, this is really important”*. How you present yourself, and how you hold yourself and all of that, there is a bit of acting, and a bit of drama and a bit of showmanship.

I: Yeah, of course.

J: You know, I’ve got a little stack of naff chemistry jokes and stuff like that now you know [laughs] And interesting stories, so a little bit of entertainment as well.

I: Okay, so, broadly speaking again, what do you believe makes an effective teacher of Chemistry, specifically? Okay, so we’re talking A level now. In addition to what you’ve already said, what is it about teaching Chemistry?

J: Okay, so Chemistry, you’ve got to be able to enthuse them. So you do have to be enthusiastic about your subject, because they can tell if you're faking it. So it never works as well if you're teaching something you don't have some enthusiasm for. You have to be good at processes and explaining processes to do them, so breaking things down to smallest parts and then building it back together. Again, communication skills are important. Having it so your students aren't afraid of making mistakes, I think is really important. Because you often have very bright students who have rarely made mistakes up to that point, and then you get a massive step up to A level, and they start making mistakes. They can often be the types of student who don’t react well to making mistakes because they haven’t up to that point, and teaching them that it’s okay to give things a go and it's okay you don't get it the first time, it's how you react to that, that enables you to progress.

I: Yeah, of course.

J: So, I think that’s quite a major thing in chemistry because it’s pretty much the hardest A level, so there's a balance there that you’ve got to build up their confidence and their resilience in a way that other subjects don't have to, because they don't come across these real challenges in the same way.

I: Yeah.

J: Repetition is quite important, so you don't just practice it once, you've got to practice it repeatedly, again I guess that's more of the resilience part. Being able to communicate, having good communication skills as these are complex ideas, putting them in a way they can understand and for me especially, because I’ve always had students with many different languages coming in, they may not be very aware, hold on they may not have heard of this word before or if they look up saturated in their dictionary it’s going to...

I: It’s going to give them something different.

J: It’s going to give them something different, so over time I’ve learnt what those words are going to be, or what those issues are going to be.

I: But that’s come with experience of teaching, rather than knowing it straight out of teacher training.

J: Yes, well experience is an important part of teaching. Teachers get better the longer they’ve been doing it, I think. At least for the first few years.

I: Yeah okay, so you’ve already touched on this very briefly. Just how important do you believe Chemistry teachers level of subject matter knowledge is, in their teaching? So do you think a teacher should be an expert in their field? To what extent do you think…

J: Yeah, I think it is very important. You need to know a little bit beyond what the students do. I’m aware there are a couple of topics I don’t feel as solid, electrochemistry being one. Where I feel like I’ve not got the same, when it comes to the physical chemistry, because my physics was always quite strong. I can take that further with them if they ask me difficult questions, I can cope with it and I know what the next step is. With obviously with the organic, I’ve got quite a good background with the organic and the biochemistry, but I really feel the lack when those topics that I don’t have as many extra bits I can add to it.

I: Okay.

J: And I’ve not got anyone to ask for help, so if I get stuck it’s a real problem. [Laughs]

I: Yeah, I can imagine. [Laughs] So, do you feel that your teaching of chemistry is limited by any external factors? That’s things that you don't have any control over, yourself.

J: The fact that we’ve had so many changes hasn’t been great. So every year I’ve had something new coming in.

I: So is that in terms of, is that within the school or is that...

J: So the specification changes, *“oh we’re doing practicals differently”* and that kind of thing. There is always a little bit of limitation with money, the technicianing hours, so they keep squeezing our technicianing hours for instance. We’ve been fairly buffered by the fact of the international school, but that's effectively collapsed recently.

I: Oh right..

J: So it’s become more of an issue. 6th form colleges get charged VAT that schools don't. They took away, there was additional funding for science students, like a little bit of premium funding they took that away. In that respect, kind of money wise it's been a bit, we don't buy them textbooks anymore, we give them online access to a textbook. They've got the access, but we know they don’t use that as they would a paper one. Because of the faff, or because they don't want to sit and read a book on a screen, they quite happily look at other stuff on screens but somehow reading a book less so. Yeah, there's definitely been monetary, technicianing and...myself! I’ve got larger classes, lots of different subjects to teach, its time, students coming in and out during the year, students who haven’t got any practical skills, all of these things do have an impact.

I: Yeah, okay. What would you change about those things? So if you had full control, what would you change? So you know…

J:[Music in background] Perfect background music! [Laughter]

I: Yeah, I know! [Laughter] So what would you change about those things?

J: If I could, definitely smaller class sizes. Trying to do practical classes with 22 students with students in there with Asperger’s, who don't have any background in practical skills, it's occasionally quite stressful for me. I’d like to be able to actually have one session a week where I didn’t teach the whole class, I just had a small class of the people who are struggling, so I can focus on their issues, and theoretically I could do that, but if you set the main class work, and you try and focus on the small group you always end up getting called back to the main group, or you’re having to deal with them. I think small group tutoring is really effective, but there's no way we could do it in mainstream, the way it's set up at the moment.

I: Okay, so what are your opinions in respect to the, so the new specification change a couple of years ago. So now obviously they have their exams at the end of the two years, unless they’re doing the AS of course. Do you think that is a better or a worse system, in terms of…

J: I think for our students, what's worrying for ours, to give you a bit of background, we’ve got a lot of international students, and we’ve got a lot of students who are quite borderline. So we give them a chance when they may not have necessarily been allowed on the course at other colleges, partly due to the area that we have, and partly due to the fact that a lot of the students can get poached by competing colleges. Now, some of those will go on and fly, but some of them don't realise what they’ve bitten off. Back when we had the January exams, that gave them a chance to realise how difficult the course was. Because they can go through kind of, slightly deluded “oh well, I know I didn't do well in the in-class test, but I didn't revise for it. I’ll revise for the actual exam”.

I: Yeah.

J: And things like that…

I: Of course, of course.

J: So giving them an actual exam, in some cases it did mean we lost students but it also meant that we had students that turned it round completely. I had a student that failed the initial one and went on to get a B overall.A Student who got an E in the initial one and is now doing a PhD in pharmacology at [REDACTED] because she went on and got an A. But she needed that “*oh crap*” kind of moment, in order to realise *“i’m not doing enough, this is what it’s like and this is what i’m going to have to put in to achieve at the end”*. In a way, we also, if students are struggling, we do put them in for the AS. And it could be argued we are doing that for our results, but we’ve never worried too much about that. Instead, for that student, the worst-case scenario is they do two years of the course and come away with nothing, which is a potential outcome. Because those students, they are better off getting an AS and switching, and doing in environmental studies in a year, which they quite often can do very successfully, or switching and doing BTEC in a year, because it's something we can now do. Because a distinction in BTEC is going to get them further than an E in chemistry. And that can be a tough conversation to have, but it's in the best interest of the student. So taking away the automatic AS has removed the stepping off point for students. It may be better off for the bright students, they are fine, they go through the 2 years no problem. But what about those that were...You know, they used to fail the AS, now they’re going to fail an A Level...That leaves with the end with nothing, they’ve got nothing at the end after two years. On a personal basis for those students, for those types of students, it’s not been a good thing

I: No, and has it impacted your teaching in anyway?

J: Yes, so, I try and push them really hard early on. I mean, quantitative is normally the first thing we do anyway but I don't sugar coat it. I try and make it tough, I give them a test at the end of the month, first month in. And I go “*look, you’re not on the right course*”. If you can't do well on this first test, its not for you. Look, there can be tears and tantrums, *“but I wanted to be a doctor”* which is often an issue, *“I wanted to be a vet, i wanted to be a pharmacologist*” and you have to kind of go *“well that’s not going to happen”* If you can't do it for the first test for one month’s worth of material, it’s not going to work for 2 years’ worth of material.

I: Of course.

J: And we do shift them, and that has occasionally been blocked for various reasons, but so far I’ve never had a student that I wanted to move that has stayed on the course and succeeded. And that’s not through lack of me trying…

I: No of course.

J: So over the years, that’s just made me more confident I’m doing the right thing for them, regardless of my results. I try not worry about that, I worry about the individual students, as the results are going to be what they're going to be at the end of it anyway! [Laughs]

I: Exactly [Laughs] Okay, so this next..Oh no! Before I move on to that, I want to ask, so you said that you worked in film and tv production?

J: Yes.

I: So, for how long did you work in film and tv production?

J: 3 or 4 years, I still do occasional bits on holidays and weekends. So I work on the odd multi-camera, that's where you’re filming a live concert or a live event – [REDACTED] last year!

I: Oh nice! [Laughs] You just wanted to put that in there? [Laughter]

J: But I did, the last time I was working in it full time, I was working for the BBC on a TV show called Doctors. But i wasn’t working directly by the BBC, I was hired by a company. And the BBC shut down when they moved from Pebble Hill, and I wasn’t hired back, but I told I wasn’t going to be because I was a girl.

I: Right…

J: I got very disillusioned, I also was suffering back problems which I still do when I rest up. I can’t be doing this, you know 30 years down the line, you know I can’t still be doing this. So, I kind of wondered what to do for a bit. I went for teaching because of my strengths, which I think are interpersonal skills and I like problem solving. In a way, I thought teaching had both of those things, I’ve got my creative side, I get to come up with resources, come up with interesting ways of doing it, I like a bit of a challenge. Reading around, people might..you know teaching’s not easy, its varied, there's always new students, new things happening. Whereas the idea of say going and working in a lab and just doing the same thing, you know running I don’t know how many PCL plates just filled me with a kind of horror. [Laughs]

I: Oh I know, that’s why I’m doing this! [Laughs]

J: That's why I went. You know, I’ve always ended up teaching and helping. There was an actor on the show, quite young and he’d ask random questions and I’d try and answer them. *“Why is the sky blue?”* And I’d go kind of “*well, that's due to the light scattering and”* [Laughs] I think I’ve always had that me, I did teach English in Japan for a year after uni, so I’d had a bit of a background in teaching, so I knew a little bit about what I was getting into, but I didn't know the whole thing…

I: I don't think anyone does [Laughs] So do you feel your work in film and tv production, do you think it's had any influence on your teaching?

J: Yeah, it's made me more confident. Every now and then I’ve tried to, so if students need to learn a technique, sometimes I’ve got them to film it on their phones and edit it, things like that.

I: Yeah I remember you saying that before, yeah.

J: We’ve done stop-motion animation of reaction mechanisms, and those kind of things, I think maybe that's me coming in from a different angle. So, yes occasionally it informs. But if often forms quite a different part of…

I: Yeah of course, I can imagine yeah. Cool, so we’ll move on now to the next section. So these questions primarily focus on the A Level chemistry curriculum, and the content on it. So we spoke very briefly about you engaging in activities outside of schools, so to develop your own subject knowledge, and make it more interesting for the students. So at the moment do you still engage in those activities? Do you watch television…?

J: Yeah, so this year has been a bit.. We were talking before the recording, I’ve got unexpectedly teaching first and second year BTEC and a unit in digital media, and also something called IT skills, which are all brand new courses to me. I’m the only one, on all the units I teach I’m the only one teaching them. So this year has been phenomenally hard just to do the basic teaching. Yeah, I’ve found it quite depressing, I feel like I haven’t been doing that in a way I normally would. I’ve still been, I read education in chemistry, and every now and then I have been trying to...I put myself forward for the practitioner qualification, in part because I felt I was stalling in that area which is a bit ironic as in you’re meant to be putting yourself forward for it when you’re doing well at it. But I thought it would spur me on to push myself on a bit more in that respect. So, just recently I’ve been reading a bit more about, educational papers, I’ve been getting a little bit more inspired. My poor colleagues, *“[REDACTED] keeps talking about education”* If you come in here talking about this, which, certainly in our college we felt, a little bit in the sciences, bearing in mind there’s only 4 or 5 of us, 4 full time effectively, we’ve got one chemistry, one physicists and two biologists, no well three part time biologists effectively, sorry.

I: Wow, yeah.

J: And we felt quite neglected, a lot of our CPD has been on how to do essay skills, and how to do class discussions. It’s felt like it’s missed all of the things we find difficult.

I: Right yeah, I see.

J: I’ve recently been getting quite inspired and like *“oh these are things the things that are meant to work in our subject”* and challenge some of the things we find difficult. So, just recently I’ve been getting quite, I have been reading a bit more and getting quite excited, which is good because I was at the point where I was going to leave the UK and teach in Dubai, because I was getting so overwhelmed and sick of this.

I: Wow.

J: Sleepwalking through teaching and never feeling like I was doing a good job.

I: Oh wow, I see.

J: Hopefully next year will be better [Laughs]

I: Yeah, fingers crossed! [Laughs] So, in lessons, if a student ever asks you a question to content that lies outside of the A level specification, how do you approach that situation? So can you give an example of if that has occurred, or when that has occurred?

J:Yeah so, we had one recently. I had a student go *“Oh, what do metal gases look like [REDACTED]?”* And I was like, *“right okay, I’m not sure, I would imagine because they’re so hot they would be glowing and like in flame tests”*. So I did the kind of, *“I’m not sure, I think it might be this, look it up and find out!”* And they looked it up and went *“Oh, you’re right!”* and a neighbouring student went *“Of course she’s right, she’s a Chemistry teacher”* [Laughs] No, no, no, that was just me guessing based on some bits I know. There’s no, no-one is an expert on everything, I’m quite open on that I don’t know it all.

I: Right, okay.

J: So if it’s something new, that's interesting, I really like it when they ask me things that are a bit beyond, because it shows that they are really engaged, as opposed to I’m doing this because I have to do get good grades

I: Yeah, like only learning it for the exam, yeah.

J: I think it’s a really positive thing, but I’m quite open that *“I don't know everything, guys.*  *Maybe it's this, what do you think?”* It can be quite nice to have a little, quite good extension for them to use what we do know, to try and work out what it might be, and then send them off to go and find out. Hopefully, they are interested enough to go that bit further with it. Yeah, I don’t pretend I know everything, I think that’s a bad habit to get in to. Plus, I think they’re fairly confident that I’m pretty solid, that most of the time I do get it right, it's very rare that, you know if they ask it's very I get it wrong. Usually I match the answer to the mark scheme, quite rarely I might go *“Oh, okay yes”* I didn't quite realise what the question is going for. They don’t seem to take that as any kind of reflection on my ability, because I don’t think it's a good idea to pretend you are the fount of all knowledge.

I: No you can't can you, no exactly. So how often do you find yourself teaching content, as in teaching to the whole class, content that lies beyond the A level specification?

J: Not very often, I like to do wave-particle duality, because I like to mess with their heads [laughter] So, I kinda go you guys don’t need to know this but we kinda teach that electrons are like these little balls whizzing around but actually it's quite more complicated than that. You know, these electron shells, it's not like a ball like this, it’s a wave function. There’s little gifs on wikipedia that show the wave function in 3D, which are great. So I do a little bit of that, and go you don't need to know it, but its really cool and you can...This year I did it, and somebody missed the lesson, and I said “*it's alright you missed it, it's not the end of the world because it’s not on the spec”*

I: Yeah.

J: *“Yeah, but it’s really cool what you missed, you know, completely blew our minds”*. So I like putting the odd bit in there and going look this is not what we’re covering but if you take it further, this is..you’re going to be coming across stuff like that.

I: And that's it, do you think that helps the students to engage with the content by including those things?

J: Yes, well it also, I, I think they need to stretch their brains a little bit, like it’s, they find it hard and they find it challenging but then certainly later on I go *“look, just think about how hard you found the first year stuff, and you can do it like that [clicks fingers], that’s how much you’ve developed and grown”* and it’s one of the enjoyable things about teaching that age range because I really feel like they make..They’re doing such a hard subject that they really develop, in a way that when I teach them the other subjects I don't feel the students are pushing themselves and developing so much, and that them learning that they can cope with this difficult stuff is really important for them to appreciate that this is beyond what I understand, beyond what I can cope with but I can head in that direction.

I: Yeah, of course. Finally, in this section, so what do you believe should the scope of the chemistry teachers subject matter knowledge should be? Do you believe it’s an issue if a teacher’s subject matter knowledge is completely limited just to the A level specification?

J: Yes, yes. I find it a frustration as sometimes I do want to be able to...My technician who is a far better chemist than me, she’s a chartered analytical chemist who has had kids and of course Chemistry is not very family friendly. So, she is getting paid like a cleaner just because it fits around school hours, which is just bonkers.

I: It is.

J: So I’m going to lose her once her kids get a bit older. And, she’s been brilliant, so every now and then I’ll go, *“I don’t know what to do with this”*. The Cambridge technical qualification that we’ve dropped had ran stuff that hasn’t ever been in the A level, and I don’t know where to find this stuff, and she would research and bring out these papers and like *“Oh my god! Goodness.”* And they were well beyond the scope of what the student would be but it meant that I could get my knowledge to where it needed to be. So without her occasional help, I’d have nothing. And that is a drawback. I could really do, you know it would be really, I try go to the contemporary chemistry evenings when they're on, but for me I would really like someone to teach me some of this stuff and be able to go to the odd lecture and just go *“Ohh, okay thats where it’s all heading”* because the odd subject I am really limited, it’s quite hard to get any further beyond it. The main one I think, being electrochemistry, which is maybe on my mind at the moment.

I: Yeah? I’ll come to that in a second, don’t worry. You’re not the only one who doesn’t like electrochemistry, by a long way. So we’ll move on now to this final section. So this is a bit longer. So these questions are focused on specific topics in the A level, in terms of both your teaching and student’s misconceptions. So, in the survey that you did before the interview you stated that atomic structure and molar calculations and energy calculations were the topics that you felt the most confident in your ability to teach?

J: Yeah, my maths has always, I’ve got very strong algebra...I did the physics A level, I did pure mathematics, so you know, that, no problem. You just jiggle it round and…

I: So I was going to say, yeah, so it's just because your background in maths and with algebra, that's why you’re so confident on those topics?

J: Yeah, I think that's it.

I: And how do you approach teaching those topics, so If you know you’ve got a lesson on those things coming up, how do you approach teaching those topics?

J: I like to work via...I really dislike the whole triangle thing. Too many, they do too often at GCSE.

I: Oh, I don’t like that either!

J: Because, it means the students have never practised rearranging and it’s like they imagine algebra stays in the math lesson, but that's not what they're using here. I quite often use *“Look at the units and work from the units”* so, I’ll give them a number of things like miles per hour, how would you calculate that. You know, if the units are in Newtons per metre squared how are you going to calculate that? So we get them, if they can derive the formula from the units, then they don’t have to memorise these formulae. *“It’s in grams per mol, so I must do mass in grams divided by number of moles”*. If we can get them going down that route, it becomes a lot easier for them. I try and kind of...I’m always saying find the mole, because normally once you’ve got the balanced equation, normally your first thing is to find out the number of moles of one of them, in order to then use that equation in order to find out the moles of something else. I do tables quite often so that you get the information from the question and pop it into a table so you’ve got the information summarised because students often re-read or forget bits on the re-reading. I try and get practicals in quite early, again I feel this year I’ve not done as good of a job as last year, because my brain...I wasn’t thinking about it as much, but I quite like towards the end of a topic go *“right, okay, here’s some copper sulphate, go find out how much waters of crystallisation it is”* and I don't give them a method and/or I’ll give them a very limited amount of things and go *“go look at that for yourself”* and I’ve found that's been really useful for them because they get used to *“right, step one”* and they do this, *“step two…”* and they’re not thinking about why they’re doing any of those steps, so if it’s possible for me to do that I do try and put it in. I do it with vinegar as well, I go *“here’s some vinegar, go found out its concentration. You’ve got 0.1M Sodium hydroxide…”* I do a bit of a *“your homework is to find out what’s the acid in vinegar, find out the reactions it’s going to have with sodium hydroxide, find out what concentration you expect it to be, are you going to need to dilute your sodium hydroxide so…”* I give them like a pre-thing

I: Yeah, that’s great

J: And then I let them make mistakes, because its vinegar and relatively low, dilute sodium hydroxide, I let them screw it up a couple of times and be like *“why didn’t that work, why’s it only been 1cm3 , which one will you to have dilute in order to…”* So I have been trying to do a bit more of that. It takes more time…

I: Of course, which is the disadvantage, but you know…

J: Yeah, which can be the problem but I think they get things better. So it's something I want to try and put more in.

I: Yup, so coming back to what we were talking about earlier, just as you started I just remembered, so yeah it can take more time to do that. Do you find with the new A level spec that time is an issue in terms of teaching the content, or are you able to fit everything in?

J: Yeah, so both has been the case this year. So, first year I’ve got like six weeks to do the whole of the organic, and I’ve never been behind before, this time I’ve somehow fallen behind. Whereas i finished, I went to a chemistry meeting and they were going *“oh we’ve almost finished”* or *“I have finished”* so I’m just revising for the second year. But I did push through the organic. There’s so much rote learning on the organic, I thought, you know what I’m going to push through the stuff where its, you've got to repeat it and learn it, and there aren't any concepts to learn it's just, *“this will make this if you add this”* and *“this will make this if you add this”*. I push through that fairly fast, thinking we’ve got so much to revise, my plan next year is to mix it up more. So, I’m going to go back to the order I used to teach it, so for the last two years I’ve done all of the kind of physical and inorganic and then I’ve done all of the organic. Instead, I want to do first bit of organic, little bit of rates, then come back to the next bit of the organic. And interleave it, because every time we come back to the organic they have to relearn the beginning bit. I think that will help them keep their knowledge up, rather than, *“well we haven't done any physical chemistry since October, because that's when we finished it”.* So now you’ve got to kind of learn it as this massed practice, and from what I’ve been reading, it’s much better to stagger it through. And i think it used to work quite well. I just kind of went *“my brains too full, I’ve got so much to do, I’m just going to do it in the order of the book.”* -for the first time through. I'm kind of realising maybe that's not ideal. So, that the plan, but this lot are stuck with what I’ve done.

I: [Laughs] Okay, so coming back to that pre interview survey. So you said that the two topics you felt the least confident in your subject matter knowledge were transition metal chemistry and electrochemistry. What is it in particular about those topics that make you feel less confident in your subject knowledge?

J: Well I, for instance with electrochemistry, it always, things like if you’re talking about the half-cell the cathode isn’t the cathode it would be if you were doing electrolysis.

I: Yes.

J: It’s like, it’s got the opposite charge. The fact that conventional current is actually going in the opposite direction of the electrons. I think possibly me having a bit of physics is actually making it worse for me because I’m aware of…

I: I see, yes.

J: You wouldn’t normally, I don’t think, if I hadn’t done the physics I wouldn’t care about the way conventional current went. So a lot of things are the wrong way round as you’re talking about cell and not circuit, so that is not great. I do teach it a little bit differently, so I don't do the anticlockwise rule, because to avoid that, I was aware that exam questions weren’t always given with most negative to most positive, so instead I say *“right, so the left..As we go across the page, the left hand side is negative and the right hand side is positive”*. *“And if you have your half cell, you should have your negative one on the negative side and your positive one on the positive side.” “And if you write it out and you have a positive voltage it's all going to go that way, the positive direction, and if it's negative it's going to go in the negative direction , and your most negative half equation will go in the most negative direction.”* So that’s how I teach it, and I think it works, but I’m worried that there may be misconceptions that I’m enforcing, because I’m only teaching up to A level, and I’m aware that GCSE teachers, students come in and they’ve got misconceptions because their teachers only knew up to the GCSE level, and I kinda go “Yeah, but that's not quite the case, that's not always the case” I'm concerned because I've come up with my own little method just for A level, I might be enforcing issues that I’m not aware of, because that's my limit. And I’ve found it quite hard, I have tried to read beyond a little bit, but it's not something that's particularly easily available, if you see what I mean.

I: Yeah, and what about transition metal chemistry?

J: Transition metals, I just feel like, again I feel like my ceiling of knowledge is with the A level, and I know little things about things, and the odd little...I sometimes go to the RSC industry chemistry and industry lectures and I kind of pick *“Oh people are doing this, and this”* but I just, I feel like there’s a massive drop off in my knowledge as soon as i get beyond the spec, plus, all those bloody colours. Trying to memo…[Laughs]

I: [Laughter] Just remembering, rote learning…

J: Yeah, I think it was the first year I did it, the textbook was wrong, they had chromium as being yellow and I was looking through Vogel’s trying to work out what colour it should be, and comparing it to the colour I was actually seeing, and going *“but what am I meant to be teaching!?”* And I was finding it really hard to work out what it should be and I think that is also partly why I’m insecure because I had that first year, and there’s like no-one I can ask, I asked the exam board, and you’re really bloody vague with me as well, and I need an answer. So this whole grey blue violet, I’ve also got a theory with some of the colours, we don't do the flame tests anymore, but I think that sodium is red/yellow, because orange wasn’t such a common word when we did the flame colour. Orange wasn’t a word.

I: No it wasn’t no, I think it came about in the late 16th century I believe. And it wasn’t very common then.

J: Because what is yellow/red, you ask someone what yellow/red is.

I: Orange [Laughter]

J: Orange! So, you know, you're going to students *“Yeah, I know it looks bright orange, but that’s yellow-red.”* [Laughter] So thinks like that, the whole colour thing…

I: Yeah, with those exam answers you’re better off never saying one colour, you're better off saying bluey green, just to kind of hope that the…

J: Yeah but then the other ones they go if you put more than one colour, you know…

I: It has to be...It’s difficult.

J: And some of the new... it would change! So well we changed specs and they’ll go *“Oh no no, we’re not saying it's this colour, you must say its this colour.”* We also have the weird thing that (Unknown) colour interesting but that different cultures, the points that you go from blue to green is actually slightly different in different cultures. So, I would sometimes go round and ask my Chinese students if they think that’s blue or green, and they would invariably call things green that would we call blue.

I: Wow, that's really interesting! Yeah, and it becomes very difficult, yeah.

J: I think that might be where my dislike of it has come from, I’m a really, if I don't know the answer I’m really quite pedantic, I’m really pedantic, let's be honest. And I will chase it up, exam boards have had me kind of like, with these new qualifications that have been a bit vague “*What do you mean by this!?”* and you know I’ve been really..Because I feel like I’m letting down the students if I don’t know for sure. So as a result of that kafuffle, I think that's maybe why I don't like transition metals. Because I want there to be an answer.

I: Yeah, okay, but It’s too wishy washy. Too vague, it doesn't have...

J: It’s too wishy washy, and also...Learning all the bloody colours! [Laughter]

I: Yeah [Laughter] Okay, so how do you approach teaching those topics that you’re less confident with?

J: Yeah, so I often, I have to often put the subject matter together myself, so like a mind map of it, ones I can colour in and stuff like that. For instance, transition metals is the only time where I need a cheat sheet to remind myself. The rest of it, I can do off pat. I do not need an aide memoire i can just do it [Clicks fingers]. Yes, I have to have a little colour sheet, because *“do they call it violet, or do they call it grey green, or do they want it as…”* So I think I’m also aware transition metals is enormous, and they give us a little slot of it but…

I: Yeah, exactly.

J: It’s just huge, and they kind of picked a random little corner in those. Sorry, I’ve gone back to why I don’t like it.

I: That's fine [Laughs]

J: So teaching it, I try and get the practicals in first, so I think rather than telling them the colours, I let them see it first. And then I tell them what they ought to have seen. Little colouring in sheets, we do, there's a lot of rote memory for these ones. So lots of white boards, quizzes, that kind of thing. I do make them a nice colouring in mind map and stuff like that. Yes, I guess I chunk it up because, I have to in order to remember it. So I figured they probably need the same as me. They don't tend to ask me a lot of questions beyond the scope of it though, which either means they're not coming up with it, or I’m not teaching it in a way that is making them interested in taking it further.

I: Yeah, what about teaching electrochemistry?

J: Electrochemistry...Yeah, It's interesting I’ve just tried to do a little revision video on it and its had me very much thinking about how to do it. We’ve revised half equations first, oxidation, reduction, introducing how they measure standard hydrogen...Sorry, standard electrode potential, and then how we use that to predict...The difficulty is often that step up between *“okay you've just got two, and there's one electrode potential”* to when you’ve got like seven or eight equations, and then you can have *“first this one happening first and then this one happening”* that’s quite tricky. The difference between the idea that something can be feasible or not actually happen.

I: Oh yes, that's a confusing…

J: They don’t like that very much. And again that's terminology, so chemistry words like spontaneous and feasible aren't necessarily meaning what they mean outside. So yeah, that’s how I approach it.

I: Okay, so if you could just take a second to reflect on the approaches that you take on the content you feel less confident with to those you feel more confident with, what differences are there in your approach for going in to those lessons?

J: I think I’m more prepared. I do worry, looking back that maybe with the ones I’m less confident on that I don't stretch them enough. Maybe I’m not giving them enough of the really tough questions, perhaps because…. I mean I can do them all, but I’m not as natural as my acid-base equations, or pretty much anything else. I really have to go *“right hold on”* and go back to first principles every time. *“This one’s more negative…”* You know, or its in order of...I really have to work right the way back from the beginning. Which is how I’d take it through with students, but yeah maybe my lack of confidence means I’m not pushing them as much. I’ll have to think about that.

I: Yeah that’s interesting, there we go. Right, so the next few questions are going to centre on the A level topic of kinetics. So, as part of the A level reforms of 2015, the Arrhenius equation came back to a lot of the specifications, pretty much all of them actually. It was on a couple of them beforehand, but now it’s on all of them. I guess with your mathematical...I guess it's been okay?

J: Yeah, so I did Edexcel for the first few years, which had…

I: Oh okay, yeah It was already on there, yeah.

J: It was already on there, so for me I dropped it and it came back again. Same with Kp. So, it hasn't really bothered me. [Laughs]

I: No, that's okay, no that's fine [Laughs] So you feel confident teaching that and everything?

J: Yeah, we just go back to equation of a straight line and...The students, it is clear that the students who are more mathematically minded, and the students who are doing physics find it a lot easier, the other ones, it’s a case of trying to find as many practice as possible. *“You’re going to have to practice this guys, it may not be automatic to start with but you can do it.”*

I: I was going to say, yes, so to what extent do you feel both you and your students understand the mathematical processes involved in the Arrhenius..

J: Yes, so I’m happy with it, having the fact that there’s a natural log in there is, I slightly skate over it for those, of course if they're not doing mathematics they don't come across natural logs. But they’re already given it in the form, you know..

I: Oh are they? So the *y = m x + c* form.

J: Yes, which, I mean i haven’t taught it for a little bit, so must mean that's going to be coming up soon. So they just, they’re not really having to derive all the way from first principle, how take them through how to derive it from first principles, but they don't need to. But I like to do that because i want those who are doing maths and physics, and who enjoy the physical chemistry to appreciate it. Because, especially if they’re going on to do chemistry, they don’t get things like that given to them. So, at least seeing it, but again they’re not going to have do that repeatedly. And then, it's just the case of the equation of a straight line, and working through and reminding them, Try and go back and kind of like do short and multiple choice questions, so they’re not always having to draw a whole graph but going *“okay, we did this last lesson, here's a sketch, what does this intercept, what's that going to stand for, what’s the gradient going to stand for”* so just reminding of them a few times. As opposed to “*you've got to draw the graph”* Because it takes so long to get the point of doing the calculations…

I: Of course.

J: We need to do that a few times, but they also need to practice without the whole lot.

I: Yeah, okay, so what support do you get for subject specific CPD, if any?

J: Nothing.

I: None? At all?

J: Nothing

I: Is there a reason for that, or…?

J: No, well having said that I’m allowed to go to the (REDACTED) scheme, but within colleges. They don’t understand what I'm doing, I think they just leave me to it. Which is a shame, I’d like to be able to do more, but, you know.

I: Right, okay, yeah. So the next few questions are going to centre on the A level topic of atomic structure and bonding. So I’ve got some little, so there’s a question up there, and they’re both the same question, and this shows you how students responded to the question and how teachers responded to the question. So, just be aware that this is a small gap between them its 53 and 47, even though it looks much bigger than that.

J: Yeah, you’ve...Uh….

I: Yeah, so, as I said, this is the question. A sodium ion, one sodium ion gaseous in form is more stable than one sodium atom in the gaseous form. Why do you think these are the typical responses of students and teachers?

J: In part, its due to the way they teach it. So, we kind of teach it as if a sodium atom wants to lose it, rather than it’s only a small amount of energy to remove an electron, compared to removing an electron from a chlorine atom, so it's easier to provide that. That's now how we teach it, we go *“it wants to lose an electron”* and we don't really dispute them of that at A level, because it’s convenient. And there's quite a few things where it’s convenient and we just skate over it because..Which, I think I said before I’m quite pedantic, and I do try and point this out. In fact, I do this as a class, I go through this it’s from Chemical misconceptions…

I: Yes it is, yes.

J: So I do do that with the class. I go through and we do true and false to try and reduce it, bit because it's so convenient, even if they get it in the lesson I’ve done that, I think that they will switch back to what works for them, unfortunately. So, yeah it’s okay, it’s convenient, and it is drilled into them at GCSE and that's what I used to do myself, you know.

I: Of course, yeah.

J: I didn’t use triangles, but there was quite a pressure to use triangles “because it will get them through, it will get them the grade”

I: [Laughs] Exactly.

J: So, that's why I think, because of convenience.

I: So, do you think it's the same reason as to why, it’s pretty much 50-50 between teachers…

J: Are these post-16 teachers?

I: Yeah, these are post-16 teachers, and that's the split. So why do you think there’s that split for teachers?

J: Again, possibly because they teach...I think some of them maybe have never thought about it. When I first started teaching i was a bit sheepish about the fact I only had biomedical science. I thought everyone else is going to have a chemistry degree, and we went around the table and they all biochemistry pretty much.

I: Oh right, okay.

J: So actually, not many of them had a Chemistry degree, and as I said my physics has always been quite strong, so I think my, because I’ve got strong physics, I’ve always been a little more aware of things like this.

I: I see, yeah.

J: I genuinely think some of them are not aware of it. Because if you’ve done biochemistry…

I: Yeah, where is that going to be…?

J: You’re not going to come across. So I think you’ll find there's a surprising number of A level chemists, chemistry teachers, who aren't pure chemists which, perhaps, focus more on organic or something. And partly I went through chemical misconceptions to ensure that I wasn’t messing up my students.

I: Well that's good! [Laughs] As you said, that's more evidence of you engaging in things to enhance your subject knowledge. We’re almost there now, don’t worry. Only a couple more. So this next one is on chemical equilibrium. So this is how teachers responded to an equilibrium problem. So the problem is given there, you don’t need to worry about that *n*, that's how many people responded to it. So this is how a group of teachers responding to a question regarding chemical equilibrium, the blue indicates what they initially responded, and then the red indicates what they responded after they spoke to other teachers in the room about it.

J: Ahh, Hmm…

I: Okay? So initially the majority of the teachers said that there would be no shift, but then after discussing it with their peers, the majority thought that the equilibrium would shift to the right. So, I don't want you to answer why it’s correct, or what the answer is, I just want you to give me any ideas you think as to why this is the response and why it caused it to change?

J: I think it's quite a tricky question.

I: Yeah, it is.

J: And I think it shows that we’re all quite, possibly unsure. So the fact that so many changed is because we weren't sure. Quite easily kind of swayed by other people’s discussion of it. Interestingly enough I think I went along to this one, and I came away going, *“I’m not…”* I spent a long time trying to work out stuff on equilibrium and I really wish I could have someone to talk to about it, because I, I think for a while I was teaching it in a particular manner, and I stopped teaching it that way because I was worried effectively teaching my students misconceptions.

I: Can you remember that how that was? So, how you were teaching it?

J: Yeah, so I was basically say I don't like Le Chatelier’s principle, because I don’t like saying it wants to move, or it wants to adjust it. So, I would say it's things like, if you heat it, it's going to speed up both reactions, but it's going to speed up the endothermic...It will have more impact on the endothermic reaction. So, that was how I was explaining all of these, if for instance we had this equilibrium you’ve got in front of me, if we increase the pressure, imagining the PCL5 is kind of falling apart, well increasing the pressure doesn’t affect that because It's not colliding with something in order to break apart, whereas if you increase pressure the two on the right hand side are going to be colliding more often, so you're going to speed up the backwards reaction more than the forwards reaction. And this is not, you don't have to explain this in the exam, you can use Le Chatelier principle to explain why, but Le Chatelier’s principle is not explaining why, it’s the application of a thing.

I: Yeah exactly, of all the principles behind it.

J: But I’ve never really been taught Le Chatelier’s principle at anything beyond A level, this is me kind of coming up with stuff i’m crap on. I’m kind of coming up with stuff, and I may be wrong so I ought to not, unless I’ve got someone I can really talk to about this, who really understands it, I need to not do that, in case I’m messing my students up, a little bit. I spent ages trying to find something out there that would kind of confirm I was getting it right or wrong, but I just couldn't find anything.

I: It's very difficult to find it spoken in ‘simple terms’, if you like. It's one of those areas that’s been identified as teachers are struggling, because of Le Chatelier’s principle, Le Chatelier’s principle tells you what happens rather than why.

J: Yeah, and I hate that it says explain why, in the question, because it’s not! You’re applying Le Chatelier’s principle, that's not...The fact that you’ve got more on the right hand side is not why!

I: It’s just...yeah.

J: In my head I thought it must be due to relative rates.

I: Yes. So, okay…

J: I’m not convinced i’m wrong yet, but until I can be sure I’m right [Laughs] I can’t…

I: Well I know someone who I can put you in touch with who knows a lot about equilibrium, so I will make a note of that.

J: [Laughs]

I: Just do that...Right, there we go. So yeah, have you got anything else to say about that?

J: No.

I: Okay, so one final question then, having just considered those questions I’ve presented to you, on structure and bonding, and Le Chatelier’s principle, do you believe the limitation of chemical models and analogies should be taught at GCSE and/or A level? Because we don’t really discuss…

J: Yes! Well I do my best to, I say, this is a simplification, that this is convenient. But! [Laughs] with things like...I did go to the talk about La Chatelier’s principle, there are cases when it’s not correct, but I've always said, in a way, I don’t like this. It's a good way of predicting, but it’s not, this is not an explanation. This is a, somebody has come up with this, and it works in the majority of cases, but it’s not a reason. So I do try and do that as much as I can. At least when I’m aware of it, which I am occasionally. There are points where I can go *“Ermmm and it gets more complicated and this is enough for you guys”* or occasionally I explain it to them, or explain as much as I can, and then go *“However!”* This is all you guys need to do. Because i'm pedantic [laughs].

I: Yeah, of course [Laughs] And do you think we should be teaching those limitations at GCSE as well as A level? Because there is a lot of models we teach in the GCSE.

J: Yeah, I certainly...Yes. certainly, bright students can cope with that. I used to have, I can remember a year 7 class I had that I would kind of begin introducing very very...They were phenomenally bright this group [laughs] I must admit, but, top set kids and I'm sure there’s school's out there where it's not unusual to have top sets so bright, try and take it a little bit further for them, go *“Look, okay we’re using this but in real life this is just…”* But only a little bit of it. Our brains can't cope with...How do I explain it, I sometimes say that “*We like to explain the world in things that we can understand, so we can see things and so that we can touch things. And we can only understand the world, through the way that our brain sees it”* So we try to explain these things in terms of things we can understand, in terms of the way we understand the world. But a lot of this is beyond that, it’s beyond little balls of matter and things like this, at this level they don't behave in a way you’re going to be able to explain in terms of what you can see and feel and touch. The fact that that's really hard and you find it really difficult, that's okay, because you know, everybody has that problem.

I: Yeah.

J: So yeah I do, I do try and let them know it's harder than we’re telling them. More complicated.

I: Okay, excellent, that’s everything, that's all the questions I have. Thank you ever so much…..

**GERALD INTERVIEW TRANSCRIPT**

I: So if I could just ask you to please state your name for the recording?

G: [REDACTED]

I: And can I confirm that you’ve signed the consent form and that you fully consent to this interview being recorded and used for our research project?

G: I have, yeah

I: Okay, perfect, so this first sections regarding your teacher training, and the influence that it had on your subject matter knowledge for chemistry, okay? So going back to before your teacher training, which aspects of your degree, if any at all would you say helped to develop your subject matter knowledge for teaching?

G: Not much I think, in terms of teaching obviously if you’re teaching A level, that's at a much lower level than your degree, I think that after doing a chemistry degree, you have that more detailed knowledge of things, rather than the more general aspects of what's required for A level teaching, I think the amount of time I spent solving the Schrodinger equation at university for various things has had no impact on how I teach chemistry at A level or similar things but, I, yeah...I don’t know whether, I went to [REDACTED], I don’t know whether the undergraduate course there is, I think it's vastly different. I think it has changed since I was there, they were, they basically required you to know all your A level stuff straight away, and then went straight into some complex stuff. I think it was a more traditional sort of chemistry course, yeah I don't think, I wouldn't say that much at university helped me, when I first became a teacher in terms of delivering the A level.

I: Right, okay, and to what extent did your teacher training address subject matter knowledge development during your training period?

G: So during the PGCE, obviously doing a science PGCE, in terms of the chemistry I was pretty confident in doing that, there were people also doing the chemistry aspects, so we were split up into the three sciences, so there were about, maybe a dozen of us doing chemistry and i felt my subject knowledge was one of the best if not the best, I think there were some who had been doing material science as a degree, they hadn’t done a pure chemistry degree and so the chemistry sessions were what i sort of i was expecting. There were also some people who had come into teaching a lot later, so maybe into their 30’s or so, the oldest one may have been nearer 40 and obviously there knowledge of the A level chemistry was 12 years out of date and they probably haven’t revisited it because of their career choice and not having used it so that was beneficial to me. What was beneficial to me was doing the biology, because i didnt do biology GCSE, I think that helped me, especially with organic chemistry to remind me about actually what an amino acid is and how you put together condensation polymers as I hadn’t really done much of that before, in terms of chemistry knowledge, there were sessions put on which obviously were compulsory in terms of your chemistry but I felt that I pretty much knew it already.

I: Yeah, and was it just sessions they put on to go over of the content or did they employ any particular activities?

G: So it was going over the content and based upon that doing practicals etc, so the common things you might expect to have to do, yeah that's quite a few years ago now. Yeah so we had a few, we had more in chemistry obviously than in physics and biology but we were drafted out to different experts around the university sort of helping us do the teacher training for that and I think we had to come up with a few ideas of how we would teach things and then we were given feedback on not only subject knowledge but also how you got that information across, so at no point were there any concerns raised with me about my subject knowledge, but there were for others because they hadn’t, as I said before, they either had done a chemistry degree many years ago or had done a related degree but not specifically chemistry.

I: Right, I see. Okay that's great, and did you personally engage in any self-directed activities to develop your subject matter knowledge while you were training? Which weren’t formerly part of your training. Or did you feel pretty confident in your…?

G: Uh, no I felt pretty confident I think. Most of the time, in terms of the training obviously the most useful thing was when you were in a classroom in a school, and someone gave you feedback on the lesson, about “did you think about introducing it this way, or a different way?” But normally you would plan that with a teacher beforehand, especially the first few months, they gave you what they would do, and then obviously they took that away and try to get you to, allowed you to make your mistakes. So there were certainly times when looking back on it, I wish I’d done something else, but that happens now when I’m teaching anyway, it’s a natural thing to do, go “Why did I do it this way?” and I keep trying to change the way I teach various topics and try to keep it fresh rather than relying on PowerPoints and whatever but I think overall I didn’t, there was nothing that I did on top of what was required of the course.

I: Okay, excellent, and what do you remember about the impact of the knowledge activities that you engaged in during your training on your own confidence on your teaching?

G: Um, pretty much what I expected. I’d only left school 5 years or so beforehand, or whatever it was, it was what I was used to when I was at school and I think, yeah I think it was pretty much what I expected.

I: Okay, excellent. One last question regarding that, so you went straight from your degree into teacher training, yeah?

G: Yep

I: Is that that correct?

G: Yeah

I: Okay, and you went onto do a PGCE so you stayed in the university, did you go to a different university?

G: I went to [REDACTED] so, I started, I did my undergraduate in [REDACTED], then PGCE in [REDACTED].

I: Right, okay, do you find that, do you feel at any advantage or disadvantage to colleagues who have spent time working in other jobs aside from teaching?

G: So working with colleagues sometimes when you’ve got someone who’s been working, so someone who’s done a chemistry degree then working industry then coming back, they have at some points some very specific examples they can use as “this is what I studied, and in my profession this is when it became useful”. How useful that is in terms of teaching, I’m not sure it is that useful, it just gives the pupils that they teach why we’re studying things, which is always a good idea, but I think for most of it, a Chemistry course it does not change very much, it’s not like if you do History and you have to study a different period or English where you have to study a different novels or maybe if you’ve done one before I think there are some people who went on, we’ve got a couple of people who’ve done a PhD and obviously that narrowed in on some specific area and they like to drag that out if they can do but I think, for some colleagues who went off and did something it’s useful to show kids sometimes if you do a chemistry degree there are different jobs rather than just going into teacher or becoming a chemical engineer or whatever they might not be aware of that, but in terms of actually helping them teach, I think it’s minimal.

I: Okay, excellent. So we’ll move on to the next section now, and these questions will primarily focus on what you think makes a good teacher and how a teachers subject matter knowledge comes in to that. So we’ll start really broad, what do you believe makes an effective teacher of any subject?

G: Nice, nice very broad question, I could go off on any tangent here.

I: Yes, so this is for any subject, not specifically to chemistry.

G: So the key idea is to be able to get across the message as succinctly as you can, and therefore to do that you have to have first of all, a good subject knowledge. The kids have to believe that you know a lot more than them, so that when they ask a question you’re not going “Uhh, umm”, you have to be able to give them an answer pretty much straight away, so your subject knowledge has to be key. But getting across, I think the struggle is Chemistry if you get it it’s fine, if you don't get it its inherently very difficult to pick up, if you’re a bright pupil and you can understand it, happy days, everything's really quite quick, if you don't get it, you really have to, it is a big struggle and half of the job is changing it from something they’re unfamiliar with and putting it to a familiar-ish idea. Therefore the problem with that is you lose a lot of the science behind it, I using analogies is great but sometimes you extend them too much and it just gets a bit messy, but without having an analogy for most things, a lot of pupils can’t access that information. So, my belief is you should have a really strong subject knowledge but you should also be able to relate it in 3-4 different ways, so if a pupil is looking at you with the confused expression you can try something else. You can, you know what they are thinking and that only comes with experience after a while, and it also comes from making mistakes, so you should be pretty happy that if you try to explain something and it goes wrong “that didn't quite work out how i intended” I think having a bit of humility and sometimes making mistakes is important, you should not always feel you need to know absolutely everything, but I think after teaching it for a few years you expect the questions, still every year someone comes up with a question that you’ve never even thought of, and you go that is quite interesting and i’m going to have to go away and look at that, but, just being, varying your subject knowledge and being able to relate to your pupils, that's two broad key ideas.

I: Yeah and would you say there's anything else in particular for chemistry, that you would add to that?

G: Umm, you’ve got to be strong at maths and physics I think, you have to have a very precise eye for detail, you have to be able to see those little mistakes that pupils make, and often that is being able to look at a piece of work and immediately spot the error they’ve made, again that comes with practice but an ability to look at an equation straight away and realise there’s something wrong or halfway through a maths problem they’ve transposed some numbers over, and being able to see that, because it’s not entirely obvious, if you’re drawing out a mechanism, being able to very quickly check where the arrows are going etc, I think that the key for Chemistry is the precision is really important and you should not let them away with a waffley answer you want them to write less but being more precise.

I: Yeah, okay excellent. Um, we touched on this just know briefly when we were talking about what you believe makes an effective teacher, so how important do you believe that a Chemistry teachers level of subject matter knowledge is then in their teaching? Do you believe that a teacher should be an expert in their field?

G: Yeah.

I: Yeah?

G: Yep, again when we talked about at university, I think you just have to know, you have to know the syllabus pretty much all of it straight away before because there are so many bits that build upon other areas, you have to have when you are teaching A level chemistry, you have to have a very very sound knowledge of everything because when you start talking about energetics you still have to have some concepts of bonding and what's going on, you do have to be aware, because a lot of the time it can, it’s not immediately obvious what the answer is, I think quite a lot of time at GCSE especially it’s portrayed as being black and white, it's one thing or the other thing, but when you come to A level there’s a sort of merging that you suddenly tell them that things have an ionic with a but of covalent character, you have to be able to hold quite a few ideas together at the same point, which makes you the expert and the pupils not so much. But yeah having a fundamental very strong knowledge it’s critical I think. Obviously after being in charge of mentoring people for their first year of teaching, it’s clear that some just really struggle with it and we’ve also had who’ve got a PhD and have got brilliant knowledge but can’t get that message across in terms of the way they deliver that, so you have to be an expert in what you’re talking about and pupils have to believe that, but obviously you’ve got to get your message across as well.

I: Okay, excellent, so do you feel that your teaching of chemistry is limited by any external factors? So that’s things that you personally don’t have any control over.

G: Umm…

I: So that could be the school or the A level spec, anything like that.

G: Umm, time, time’s the big issue, so we have to deliver in terms of the A level we have to deliver the curriculum across those 2 years when talking to other colleagues we seem to be about average in terms of the time we’re allocated by the senior leadership team, I know there are some schools which have less, I know that there are some schools who have more, we seem to be about what everyone else gets. But time is the critical one, unfortunately there is no time to sort of, there's no time to go and investigate something more exciting, there’s sadly no time for pupils to do there own independent research. We do the AQA exam board, it’s pretty much mapped out for you by the exam board week by week, this is where we expect you to be, so yeah time is always the constraint, I’m fortunate enough that our school we don’t have any constraint on doing practicals in terms of budgeting, equipment we’ve got fabulous equipment and setups and labs, so that’s not an issue for me. Textbooks, photocopying not an issue, we sort of get what we want. Umm, other external influences… I’m lucky enough that everyone in my department except for a (..............) have got a Chemistry degree so i’m not limited by having only me to teach the A level etc, I’d say the only, if we had a magic wand we could wish for to have an extra period a week, would make it a lot easier to finish the course at hand, plus we could do more exciting things.

I: Yeah that's it, because I, next question was going to be in an ideal world how would you personally like to teach Chemistry? So just another period….

G: I’d have more time, more time to do stuff I think, it’s a practical subject, we do all the practicals we do all the AQA ones because obviously you have to and we do other ones as well, but It’s just delivering that, it’s delivering what is required because at the end of the day our parents and the kids want their best results and that's determined by how well they perform in an exam rather than what funky stuff they’ve done in Chemistry club or whatever. Yeah, just more time.

I: Yeah, and do you just of out interest, do you offer the AS to your students or?

G: No, we did, we obviously before the last curriculum change when it was AS going to A2 we obviously everyone did the three modules required for the AS and then the other three for the A2. We did in the first year of change we allowed pupils to do the AS and then obviously those who didn't carry on they got a qualification but those we did were superseded by what they got at the A level, now though pupils choose 4 subjects and they end up doing 3 A levels, but there will be some pupils who will drop out throughout the lower sixth, there will be some who will still carry it on but will they not take the formal As exam, so we don’t offer it.

I: I see okay, I was going to say when you did offer it did you find there was even more time constraint there?

G: Yes, but then, so this time now which we would normally not be teaching they've got, so the second half of the summer term they because no-ones doing that now they’ve got a longer exam week and then they’re all going to be doing their UCAS and then they’re going to be going off doing various trips with other subjects, this idea of having slightly more time, yeah you do get more time because you don’t have to stop in a month beforehand and hit them with past papers, so it has been easier, the As, but exam probably but a bit more into it but yes I think we’re lucky compared to some subjects that there hasn't been that much change, we haven’t been that affected by it.

I: Great, so this next section of the interview will focus on the A level curriculum and your opinions of it in Chemistry, before we get on to that though, just a quick question, do you personally engage in any activities outside of school, so that could be wider reading, watching television, going to museums etc, to expand your knowledge of Chemistry?

G: I read education in chemistry, I look at RSC resources when they send it out, obviously the school’s a member and I hold that membership, things on TV there aren't that many chemistry related they’re more general science, I think we need the Brian Cox of the chemistry world, we’ve had the Attenborough for Biology and Natural History, we’ve Brian Cox for physics, we’re still waiting for someone to do that. There’s obviously Peter Wothers and a few others have done their chemistry lecture and I watch those every year but it’s still I think Biology is much more accessible to most people, physics is a bit funky and people like to think Chemistry is slightly missing out there on that face on the media. I wouldn’t say I do much more, I sort of BBC News Science things like that, but not many of them are chemistry related. I probably should do more [Laughs].

I: No no we’re not telling you that, no, it’s just out of interest there. But yeah we’ll move on to the A level curriculum now. So again we touched on this earlier so if a student asks you a question relating to content that lies beyond the A level specification, how do you approach that situation? What do you do if a student asks you? And if you can think of an example that would be great.

G: Umm, so normally that would be someone who is probably going to be applying for Oxbridge or medicine or something that, or has an interest in doing that. We put on, there are two sessions a week for the sixth form, so two 35 minute lessons where they can drop in and they can come to it’s normally me, come and see me and talk through ideas. So normally we would be doing things like the Cambridge chemistry challenge the lower sixth one, or the chemistry Olympiad we would do questions like that. If a pupil in a class asked an interesting question I would always, even if it’s completely off the topic, I will always try to give a 2 minute little answer, and then say to them that’s as much as we’ll probably go into but if you’re interested you can come back and chat, obviously as soon as you say those words, if you want to come back and chat, generally that kills it off at that point [Laughs] Because they would show how interested they are. But, as I say most of the time it’s within a non A level timetable session that they will come in and we do extra questions and normally from that I’ll be suggesting to them, like the Olympiad questions are very good because they’re clearly outside of the curriculum but they have to have the curriculum knowledge to answer the first bits and then they extend them. And then we do lots of practice interview questions for like an Oxbridge interview so you’re trying to get them to have a very good knowledge of their syllabus but also try to throw in a completely obscure thing and they have to think as a chemist in 3 or 4 different ways to do. So something as simple as “What’s the concentration of water?” is always a good one because they go “Well, it’s 1 moldm-3” and then you go “Well why is it that?” “Because it’s water, its 1” “Well that's probably why” and then they suddenly realise that there’s a bit more of a trick to it, but, all those little ones that like giving them a mechanism they haven't seen before or if you’re doing electrophilic substitution show the OMP directing effects which is very accessible to them it also helps them to understand why you draw your horseshoe structure and what that actually means because it’s not touched on in our AQA, I don’t know whether other exam boards do.

I: Uhh, very briefly.

G: They just teach them it’s a horseshoe, it only extends over 4 sides, but actually pointing out that the resonance structures of those is why we draw that. And actually normally with the top set I would do OMP directing although it’s not on the syllabus, but normally I wait for them to ask a question, and as I said give them, start with the proviso of “You don’t need to know this for your exam” which means that half them will just switch off, the other half who are interested will listen, but interestingly I think a week after I’d done the OMP directing and one kid said “Uhh do I really need to listen to this” “well you are applying to Chemistry at University” went to [REDACTED] and during his interview he got asked a question and he weren't “Oh that was really useful doing that, because it made me sound really knowledgeable” Ok, yeah that's the idea, but I wouldn’t go, I don’t go completely off syllabus but all those extension things, they ask the question I give them as much as I think they could know, which is clearly far beyond the A level and just see if they’re interested in it.

I: Yeah, that's great, and how do you approach it if you don’t know the answer to the question they’ve asked you?

G: I say that is a very good question, this is my initial thought and I say I might be completely wrong, but from what I think this is possibly the way you need to be thinking about it, and then I say, but then I’ll come back to you on that. And then we have a weekly staff meeting and I’ll normally ask colleagues and we sort of share ideas, there was, we had a good one about naming organic molecules, and a colleague of mine was adamant, what was it...It was naming something I think, and I was adamant I was right, he was adamant he was right and then obviously we talked about it in the department and it was basically him and I talking why we thought we were both right and then obviously I went to Wikipedia, whatever, looked up IUPAC naming found some article from 1980, this is when it was decided how to name it, but I think that if a good asks a really good question you try your best at answering it, if you’re not 100% sure just be happy to say that’s my initial guess but I’ll come back to you, talk to other people and it’s quite nice actually with colleagues discussing things which are outside of the curriculum because then you realise that linear colleagues normally have an expertise in organic or physical or (......) I quite like myself, in inorganic not many people seem to like that branch [laughs], but we talk through the ideas and then I would get back to the kid and say “Oh you know mentioned that, this is what we’ve come up with” by that time they’ve completely forgotten it, but it's quite good to come back to them and say actually that was a good question and I’ve had to research it, I’ve gone away and thought about it a bit more, this is now my answer”.

I: Yeah, okay that's great. And so how often do you find yourself teaching content within a lesson that lies outside the specification, you say not very often? You have extra sessions to do that?

G: Not very often, but there are some things, yeah there are somethings that lend themselves more to that, mostly organic, possibly a few physical things if you...But mostly it’s organic because we find that a lot of our pupils study chemistry and biology and especially when it comes to something like synthesis, just giving them a starting molecule and an end molecule and asking them to think about it and what might happen, they are more likely to ask you stuff on organic I’ve found. Inorganic, never really asked, they take that more as a “this is what I need to know, I don’t want to know anything more” because it's a bit more rote fashion learning I think for them in terms of the A level syllabus, I think mechanisms if you teach it in the way that I do which is teach them what the curly arrows mean, what could happen, and then throw the mechanisms out after that, they have some idea of actually how could this work.

I: That’s good, and what do you believe the scope of a teacher’s subject matter knowledge should be? Do you believe that it’s an issue if a teacher’s subject knowledge is limited to the A level spec?

G: It can be if you’re teaching bright kids. You don't want to be in a situation where pupils feel that you’re redundant and you don’t know as much as them, or that there’s someone in the class that seemingly knows more than the teacher, I think you have to stuff really well I think. I think it would be bizarre if you didn’t know it perfectly, but that's because I’m lucky enough to have gone through it I think. I think if I was to teach physics, I think I could get away with it for a few weeks and then they’ll see through my knowledge, biology I might be able to do 20 minutes of a lesson before they realise I can’t, I don’t really know what I’m doing [laughs], but I think because as I said Chemistry although it is topic based, it does have things from, every has topic has something that you’ve built upon from previous information, if you get to a point where you’re coming to an end of your knowledge and you’re having to go further at the same time with pupils it’s just going to get messy, and they will see very quickly through it, and then they lose trust.

I: Okay, excellent, so this final section now is about common misconceptions, so specific topics in the A level and the potential issues that are involved in both teaching and understanding those ideas.

G: Yup.

I: So, in one of the pre-interview surveys you did you indicated, you rated 10 topics within A level chemistry and said these are the ones I’m most confident in, and these are the ones i’m least confident in.

G: Yeah [Laughs] If you asked me today they’d probably be very different [Laughs].

I: [Laughs] so the ones that you are, that you said you are most confident in your ability to teach were atomic structure, molar calculations and kinetics, so what is it about those particular topics that make you feel most confident in your ability to teach them?

G: I think because there is an expected right answer, there is, in those sorts of ideas there is a distinct methodology of doing it, there is a way that works there are many ways that don’t work. I think I have a mathematical mind, I think I’m really quite confident that even mental arithmetic those sorts of things I can very quickly see the problem, see the issues of those. I think just because there is a right answer and if you gave me problems I would be pretty confident I would get them right or if you then said “no that's wrong this is the right answer” I’d be able to work out where my error is, I think when I’ve always done Olympiad questions etc I’m much more confident doing those than some organic mechanisms where you’re not sure of it. If you’re sometimes not sure of an organic mechanism, if you don't quite see that step, that middle step, you can’t teach someone, you can’t help someone through it if you don’t see it yourself, I think with a mathematical thing I’m quite happy that I know there is a logical progression from 1 to another to another, this has got this therefore therefore, it therefore works for me much better than other things.

I: And how do you find yourself approaching teaching those topics, so when you know you’ve got those lessons coming up?

G: Its really, yeah, that’s really difficult because you have such different mathematical strengths of the pupils in front of you, it’s, you have to give them a clear very clear framework of this is how you should be thinking of it, this is how you should set it out and as much as possible have it, i used to just do it moles of this equals moles of this, now i try to do it a little bit more diagrammatically, so have the chemical equation and put the numbers below and therefore they can see what’s happening to things so, I think beforehand the way I was taught and probably the way I did it I would not refer to the equation as much, I think you realise after time that pupils have a preferred way of doing it, and I would always set it out, I would do every single step and say to kids when kids, bright kids, will see you could go straight from one to another I say “Yes, you can do that” but I’m still not going to recommend that because if you make a silly mistake you’re not going to be able to see it, but I don’t know, I think sometimes if you, the topics which you are aware the pupils find most difficult, you have to be much more careful when you are teaching it and therefore you have to have the strategies that you know in the past pupils have made these mistakes so if you set it out like this it’s not going to happen.

I: Okay

G: And a lot of the time I will say “That is not how I taught you how to do it, do it this way” and you have to do that from the start, if you’re doing teaching moles if you teach them a method, don’t allow the bright mathematicians to try and do the jumps and shortcuts straight away because they then miss out when you put the extra detail in to it. I demand that at least for the first 5 or 6 questions they set it out fully, and then next time when you bring in another concept that they can see where that’s come from. I think just with maths it’s my most confident subject.

I: Okay, that’s great. So now we’ll move on to the topics that you’re less confident.

G: Yeah, what did I say?

I: So the two that you put were chemical equilibrium and transition metals.

G: I think the chemical equilibrium is because you made me feel uncomfortable a year ago so.

I: [Laughs]

G: That’s completely your fault, so that’s why, I blame you entirely for that [laughs]

I: Yeah blame me [laughs], but you rated the transition metal chemistry below that, so what is it about transition metal chemistry that you’re less confident with your ability to teach that?

G: I think it’s just that it’s, it’s one of the bits that is more rote fashion learning than others, I think I, all my teaching is based upon chemistry is beautifully easy subject, because if you know this you can apply it to so many different things, and that's how i say to them, i say “you don’t want to study biology because biology you need to learn this, and then this and then this” although they call it a science, the ideas are subtly linked, there isn't much of a link between them you just have to keep learning more and more facts, which is fine if you like that but it doesn’t help you, the beauty about chemistry is if you can see it, and you can do a few of them, you can do any question that they ask you. If you can’t see it, you’re always going to struggle, but if you have that brain, you have that way of thinking and it makes it so much easier. But when you come to transition metal chemistry, especially when the (......) you’re just making up silly rhymes for them. So why vanadium the colours go yellow blue green mauve or violet or things like that and you say “You bloody great morons” or “Yogi bear guzzles vodka” it’s like, it just gets a bit (….) so add how many ammonias get attached to a ligand, we had like “6 cool crones” because cobalt and chromium have 6 ammonias on it, “4 cousins” because copper is 4, and “2 hags” because silver, there’s no, and then kids go “why?” “because that's what we observe” and that's a really, it’s true you can’t argue against it, but it’s such a weak argument without going into a lot of very complicated university level stuff.

I: Yeah, crystal field theory, yeah.

G: Unfortunately, if we could do chemistry without the inorganic, well what most people consider chemistry, it's a bizarre thing to to say but the more the more if you’re a chemist you realise that the inorganic, the real bit that's only true to the chemistry is the most tough to learn because it’s a bit weird, and you just have to learn stuff. If we decided to rebrand chemistry as a little bit of physics and biology without the really boring rote fashion learning, kids would enjoy it more. I think the transition, i hate it because you say “you just have to learn it” I can’t really help you learning the colours and the formula, obviously the shapes you’ve done before because you use VSEPR theory or whatever, but at the end of the day I feel that I can’t I can’t do much to improve their knowledge, I need them to go away and learn it. In every other subject, in every other topic I can say to them “right, this is how you need to think about it, so, if this is the way you’re thinking then the next time a question comes up, if you think the same thing you’ll get the answer right or nearly right”, with transition, i’m going “that does that, it just does it” there’s no, they don’t have much knowledge, previous knowledge they can use to help them out, I just don't like it.

I: [laughs] That’s fair, that’s fair.

G: It’s not necessarily my understanding, I know what the exam board requires, but to me being a teacher, you need to do much more than that, you can’t, you have to give them a way that they can remember it in an exam, and you’ll have the kids who are weaker who will panic in an exam and go “was it? Was it 4 NH3 was it 6 NH3?” and then because you have to give them, and then they rely on something which is entirely non-chemistry based to get the right answer, which I find, I don’t like that idea.

I: And with chemical equilibrium, so you said that the session that we [laughs]

G: [laughs]

I: Wasn’t ideal, so did you find yourself more confident in that topic before that session last year?

G: I know exactly what the exam board require, I also know that it’s a simplification, but the way I always approach equilibria is with a very mathematical viewpoint and if you were to show me people’s responses I’d probably be able to pick out mine, because I think I would do it in a very different way to other people, I try to use the numbers and say “look at the extremes of that and that” but that’s because I’ve done a degree in it, you realise that the numbers will tell you, you can have some idea but teaching that idea to A level kids just get a little bit lost. Trying to convince them that Kc and Kp don’t change unless a temperature change, I can do that, I can pretty much put up a little proof and show that, I can do that bit but it’s, I can teach it but again if you were to ask me “do the pupils know what’s going on?” “No.” “Do they know how to put numbers in an equation which they can rearrange?” “Yes”. Does that mean they have any understanding of what it means? No. So you spend a lot of time on Kc even if you say like “If Kc is much greater than 1, equilibrium lays on that side” and then they get a value and they go “Well I don’t know what that means” well “It’s much less than 1 so it’s going to be on that side” they can do the maths because most of them are doing maths A level, but they’ve no idea what it means.

I: I see.

G: And at the end of the day, the exam board require them to calculate Kc, calculate Kc for the reaction in the opposite way so they know it’s one over, does that mean much to them? No because you just told them that, and then that. It’s one of those topics where you feel that the kids are just jumping through the hoops of getting the exam question right rather than having a more in depth understanding of why it’s important. So on a simplistic level at GCSE you’ve taught them Le Chatelier’s principle, if this happens then equilibrium moves to do the opposite and therefore it will do that, you’ve given them such a generic thing to follow because you know that’s what they’re going to be asked in the exam. A level they have to know that plus how to put some numbers in, if you ask any of our kids any of the questions that you asked a year ago, they would just look at you like going “Okay” even with our bright kids who are going to get A\*s they would just look at you and go “Well, I don’t know, I know how to work out Kc, I know how to explain but I’ve got no idea what you are chatting about”.

I: Ok, well that's it’ I would’ve been the same, even at the first couple of years of my degree.

G: Yeah, so they were, yeah I can teach what the exam board want but then I’m fully aware that’s not the same as teaching them what equilibria is.

I: Yes of course, that’s fine. And two of the other topics, so you put 7 and 8 out of 10, so you put electrochemistry and analytical techniques, so how do you feel about electrochemistry? Because what we’ve found from electrochemistry is that on average it’s the one that people rate the lowest, I think the highest anyone rated it out of 10 is 6th, and most people have put it at 10. What is it do you think about electrochemistry that teachers don’t feel confident in teaching?

G: It’s a difficult, it’s really difficult for the pupils to understand. We’ve done electrolysis they can get electrolysis, but then electrochemistry is sort of just weird, the battery bit of that. So there are so many confusions, there are so many yes or no, true or false, plus or minus, reduction/oxidation it’s a...And because unless you’re precise, if you’re talking them about even what’s a reducing agent, you say “itself is oxidised” they can just make a mistake, even on the stuff that they should really be confident on because it is so polar opposite, it’s either they will say to you “Oh no that's what I meant”, when they talk to you about so and so is the best reducing agent you go “well you didn’t even pick a reducing agent, you picked an oxidising agent” and then they go “oh but what I meant is….”. It’s too easy for them to kid themselves that, like an electro-potential they get Ecell to be -7.3 and its +7.3 and they go “Oh no, I see where I’ve gone wrong I meant to do that” but they don’t understand. I think it’s the one topic that, I don’t think I did it at A level, I think that might be...It’s the only topic which I had to, which I couldn't remember being taught well at A level, I think it might be a historical thing, if it’s been in previous courses, and it was, I did when I did A levels there was a transition metal complex, an extra section on it and my teacher was rubbish, I didn't understand what was going on, and I think it might be an historical thing that because teachers have always been taught by people who don’t find that area a strength, that it’s a thing which will keep on appearing throughout.

I: Yeah, okay.

G: I think that it is, you are having to, you are going to have understand, they have to understand redox very well, they have to understand...It’s just a bit different, I now try to introduce it as just “look at that, it’s just a reactivity series”, if I ask you which one is more reactive you’d be able to do it but there are so many, there’s so many chances for them to make a mistake and get 0, it’s not like, if there’s a 3 mark question on explaining the ionisation energy or whatever, they might have some concept of it and you can tweak little bits of what they’re saying. I just don’t find it that exciting, I think the practicals are a little bit dull because you just basically put, make your little half cells, read it off, boom, excellent. “Okay, what does that mean?” You stick metals into a potato and they produce a voltage, that’s quite exciting because they go “Oh look, the potato has produced a current” “well no it's not actually but never mind we’ll ignore that.” I blame physics, it’s a very physics things and if you haven’t, from a very early age, I don’t know when they start teaching electrical circuits and things in physics, but it's one of those things if you ask a physicist or pupils of physics, they don’t like it, they struggle with it because physics, as soon as you start to do that you have the idea of parallel and series and kids get confused and then they go “You’re making a battery, that’s physics” and they immediately switch off.

I: Yeah, they compartmentalise the subject rather than see…

G: Yeah, but even those who do physics find it not that exciting, I don’t know how, I don’t know...If I was going to take any topic out I’d take that out, I don’t...But again as a purist it’s a chemistry thing, we need to understand how batteries work etc. It’s really important, and you can see why in the new spec, they’ve put more ideas of fuel cells, hydrogen cells etc because it’s really important for people to know how batteries work and what you can do, but it’s not an easy topic.

I: No.

G: It has limited prior knowledge required for it, but your prior knowledge has to be perfect to understand it properly, and it’s too easy as I say to, It’s too polar, the kids can say that they know it, and even teaching it there are times it’s the only topic I go when I’m teaching it “I really have to get this right, because If i get this wrong, It’s just going to confuse the life out of them” It is the only time when I’m teaching I’m really stressed, that if someone asks a question, that I have to get this right, there is no excuse for me getting it wrong, because If I get it wrong you’ll just confuse them and the pressure then on the teacher to deliver something that they’re not confident themselves in, and knowing that any slight mistake will confuse everyone else, it’s just not easy.

I: Okay, that’s really good, no that’s really insightful, thank you so..Just briefly, if you could reflect on the approaches that you take on teaching the concepts you feel more confident with those -that you feel less confident with, do you think there’s any difference in your approach to those?

G: I review much more what I'm about to teach and the topics I’m not confident on, I can walk in to, I could walk in to any room at any point and start doing mole questions with them or anything like that I could explain it to them, anything else if even now after teaching for 15, 17 years, as soon as I get to electro-potentials or anything like that I will almost write out my notes again. I don’t use PowerPoint, I don’t have formal notes for any topic I do, I know it. That’s a bit arrogant I suppose to say that.

I: It’s not.

G: But it, the one thing...The only few topics that I will think about very carefully about how I’m going to deliver this, and what sort of structure, what I’m going to start off with, what I’m going to try to get to in each lesson, the ones that I do will be equilibria because you have to build up that one in a very specific way, and electro-potentials. I experiment each year sometimes, I do it slightly differently but I know some people use the diagrams with 0 in the middle and things like that, I don’t like them. I have my own unique way of doing it, I don’t think it’s very, I know it works, again as we were talking about, I know it works to get them the right answer, I do, everyone sort of talks about right minus left but for electro-potentials I deliberately turn an equation around to make it an oxidation, change the sign and then go “we know we had a reduction to an oxidation, so just add up the numbers” and therefore if you’ve got a kid who likes right minus left and you’ve done that one that's another confusing point about it. But it’s the only topic where my, the way I approach it is I will very carefully plan a series of lessons for those topics. There aren’t many other topics where I will go back almost to the drawing board sort of saying, putting myself in their shoes and going “Okay, in this first lesson this is what I need to get through. Lesson 2 this is what I need to get through” with the other ones it just happens, I sort of know how those lessons will be delivered and even if I forget something, if you forget something in most other topics you can put it in once you realised you’ve forgotten it, if you forget to do something suddenly you go “Oh no, they can’t do that because they haven’t done that bit.” It’s the ones where you have to plan out much more carefully.

I: Yeah, okay. So finally in this part, I was just interested, you mentioned the use of analogies earlier, how often do you find yourself using analogies in your teaching of A level chemistry?

G: For A level?

I: Yeah

G: I don’t know, most lessons [Laughs]

I: Yeah. Do you find that you tend to use them more with topics you’re more confident with than those that you’re less confident with in your knowledge?

G: No, equally I suppose. I think sometimes, no because of the way I thought about things, I always think “okay, if i’m not getting it how can I make that a little bit more understandable”. I think now I’ve been teaching so long that you know where kids are going to fall down, and most of my analogies are based upon, or ways of doing things are based upon as I said 50/50 of it, if it’s this or that just a way they can help them to remember them.

I: Yep.

G: But, yeah most of them are memory aids. Some of them are analogies, but that is a memory aid. No, I’d say equally, I wouldn’t say every lesson obviously, for something like moles, no, never. But if you’re asking to work out the solubilities of your group 2 hydroxides and sulphates and say big and big clump together so you’re going to make a precipitate, little and little clump together, so little people always date little people, big people always date big people, it’s just a bit of fun, and then you go, yeah they clump together so they move, they get themselves out of the dating pool of all the other ions etc. It’s really really poor science, it has an element of truth about it, but in an exam you know a kids going to go “I can’t remember, it’s magnesium hydroxide and magnesium sulphate, which ones the soluble one, which ones the insoluble one” It’s one of those 50-50’s and then they think “Oh right, [REDACTED] taught me the little ions like the little ions and come together and form a precipitate, so that will be the insoluble. It’s little and little so it must be the hydroxide which is insoluble.” Those little things, they’ve no chemistry value but the kids get the answer right.

I: Yeah, okay.

G: Although, that one does a little bit, but most of other analogies, no, no real [laughs] it’s just that it helps them to do it. But, yeah if you just, all analogies are just to help them to remember which way to think of it. If you’re trying to think of anything that you need to remember over a long period of time, whatever way of doing it, you think of a way of remembering it, analogies work quite well if you talk about people who want to learn all your cards and all these sort of mind palaces etc that they try to get people to think of stories etc. It’s sort of what we humans have done for millennia to remember things, to have a story behind it.

I: So what support do you get for subject specific CPD?

G: Umm, so we obviously every year we get the big people who do courses in London etc. If i’ve got someone who’s new to the department, that would be like teaching A level for the first time, go up to London and do that course or whatever. In terms of my...It’s easier for somebody who hasn’t, who’s subject knowledge or way of teaching the topics needs to be improved, that’s quite easy to do. I go to the [REDACTED] conference every year, I think that’s really useful, not only in terms of a bit of subject knowledge but listening to colleagues this is what I do, it’s, living in [REDACTED], it’s regarded, as you’ve found today it’s sometimes not the easiest place to get to, you find that most of the things are [REDACTED], there's those sort of big hubs around here, there’s not much around. You have to be fairly selective and search out ideas, I would love to be nearer to a city, where you can say to kids, “right we can all go to whatever”. [REDACTED] in London and they can go to the Royal Geographical Society and listen to a lecture, down here it’s really difficult to do. So in terms of increasing my own knowledge of stuff, I read Education in Chemistry, I’m a bit old, I don’t like Twitter and things like that, I’m not on Twitter I probably should be there seems to be...I don’t know, it’s an interesting one. So as I said so I go to [REDACTED], I tried to go to another one, the school are very good at if you want to go to something you’ll go to it.

I: That's great.

G: I’ve learnt over time that quite a lot of them are quite expensive for what you get, you get one or two good ideas. I think some of the best practice is, as I said to you earlier before the interview started there's a group of us heads of departments of schools in the [REDACTED] and we meet up once a year and we share our ideas in that group, that’s often a good way of sharing sort of best practice but in terms of keeping up with current ideas, just a few little journals from the RSC, that's about it.

I: Okay, great. So next couple of questions are going to centre on the A level topic of kinetics, that’s one you said you were quite confident with.

G: Okay

I: So, as part of the A level reforms that happened in 2015 they reintroduced the Arrhenius equation back into the specification, were you okay adapting to the reintroduction of that onto the syllabus? Did it cause you any particular issues?

G: It’s a nightmare for people who don’t do maths. It’s just...For the first time for many years I’ve got kids who are just panicking about their maths ability, if you do physics you’ve seen Ln before, how do you teach kids who haven't done any A level maths what Ln is? How do you spend a lesson on going through irrational number e, no? It’s just that funny button on your calculator, where does it come from? I wish they hadn’t put it in. I can see why it’s better, it’s better for kids who want to go on and do Chemistry, fine, but you don’t...You can do that in a week at university, I’d have preferred them not to have done it. The only thing it does is it discriminates those who can do maths and those who can’t do maths. Which is fine because the idea is to have your now 20% maths content, was that the driving factor? Someone said “there needs to be more maths in A level so let’s put in this idea”, that's the only reason I can think of it.

I: Essentially, yeah. That’s what it was.

G: Yeah, and therefore I think, great, it just means that I’m going to advise kids who don’t do A level maths not to do A level chemistry. It’s just going to be, those kids who quite enjoy chemistry because it’s quite a fun subject, you do practicals and things like that are finding it, don’t know what's going on here. Personally in terms of the teaching, I still had a few resources from previous years, it’s, if you’ve got a mixed ability class it’s a nightmare because the kids who’ve done physics and maths are absolutely fine, easy, just rearrange it fine, can get an answer out. It’s a little bit similar to when they did time at flight mass spectrometry, i’ve had brilliant answers for the length of a mass spectrometer ranging from 10-12m to to quite a few kilometres, or the time taken for it to go through I had a very bright guy who does maths and physics, is likely to get A\*s in each told me that the time for a particle to go through a mass spectrometer was something like 1012 seconds, and i'm going “So how many billion years is that? Should we just work it out on the board?” [laughs] The problem with a concept which is heavily maths is they can try and put it into a calculator but they don’t know what the answer is. I don’t like it but.

I: Okay, but do you feel confident teaching the topic?

G: I feel very confident teaching the subject, I feel very confident teaching it. If you ask the pupils how confident they were on their understanding it, it would be low.

I: Right, okay.

G: In terms of, if you ask them to list topics which they were confident on they would put that down the bottom.

I: Okay, alright. So we’ll move on now to structure and bonding, so I’m going to show you a question or a statement, you may have seen this before. So we gave this to a bunch of teachers and a bunch of students, this statement. So we told them “The sodium ion is more stable than the sodium atom, is that true or false?” So students responded, right, so those 70% said true, 30% said false, and teachers that were asked the same question, you found 53% false and 47% said true. So what I’m asking you, I’m not asking you for the correct answer…

G: Oh good, thank you [Laughs]

I: I just am interested in, so why do you think those are the typical responses of students and why those are the typical responses of teachers?

G: Because the teachers will read more into it than the pupils is the obvious answer. The pupils will go “we’re taught that obviously atoms are always lose electrons to become more stable and therefore sodium has one electron on its outer shell therefore to be more stable” or some people use the word ‘happy’, I hate it, but I have heard that before.

I: Yeah, we have had a lot of discussion before.

G: Happy atoms? No that’s really not what they are. Because there understanding is sodium will lose an electron and therefore...Teachers look at that and go, “Okay, why have they asked me this question? There must be more to it than that, okay what i'm going to do is I’m going to think of something else that I know” and then look at something like ionisation energies and, they’ll be the ones who will...The problem is teachers know that there’s a trick, teachers are older and wiser and have a reason “Why are they asking me this question?” your first idea is it’s this, and then you go “but there’s a trick” so you think of something else.

I: Right, okay.

G: And that’s pretty much how I exactly worked, I have seen the question before that’s what I went for, “why are they asking me?” So being a teacher, you’re asking the question, your first question is “why are they asking me this question? And then you try to answer it.” As a pupil, you just try to answer the question.

I: Yeah, okay that’s great, cool. Umm, that’s fantastic, and now we’ll look the topic of chemical equilibrium, so you've seen this question before.

G: Oh good [Laughs]

I: Just the responses, this is the responses we had okay? So the question is down the bottom, so it’s related to the PCL5 PCL3 equilibrium…

G: Yeah.

I: And, we asked teachers what would the effect of adding an inert gas so Neon and keeping the system at a constant temperature and pressure even after the Neon’s been added, what that would do to the equilibrium position? So the blue bars indicated what teachers thought initially, then we asked them to talk to one another, and then after they’d spoke to each other the red indicates what they then changed their answer to or kept it the same as. So before the discussion teachers initial reaction was that there was no shift.

G: Yes.

I: And afterwards the answers, more answers were towards thinking the right shift is what occurs with the equilibrium position. So, again i’m not going to ask you what the correct answer is, I’m just asking why do you think that that was the initial response and why do you think it changed following discussion with other teachers?

G: So, this question obviously this was asked to A level teachers wasn’t it?

I: Yes it was, yep.

G: So, what would..So you’re asking me why do I think it shifted?

I: Yes, so why do you think the answer went from no shift to right shift in terms of most popular answer.

G: Umm, because in terms of this the more confident chemist would have been the ones who would have been more confident in giving their idea, and therefore swinging that around. And, it’s, so the first thing is if you’re not a confident, you would rely upon the A level answer of the only thing which effects position of equilibrium is temperature, so you would look at constant temperature and then you would go “okay, it’s constant temperature i’m probably going to go more likely for no shift”, and then obviously you’ve got almost, not too much difference between left and right, people guessing I don’t know, and then I would presume after a little chat someone would have said “yeah that might be true that the constant temperature might not…” But then someone would have probably mentioned “Right well KP” write out Kp expression, how will Kp change, how will the partial pressures change if you put in an inert gas in it, so I’m presuming that someone has maybe rightly gone in and said “that’s too simple” they’ve probably said “why have they asked us this question? Clearly there is, it’s probably not going to be no shift, so is it left or right?” and then someone has come up with an idea and talked it through, and people have agreed more with them. I think once you’ve got that, if you’ve got some people around and they give their view point you’ve got the anchoring effect that once someone tells you that “I think it's gone right” and they sound knowledgeable, people will do that, there's a psychology in terms of if you listen to a group and someone you perceive to be the brightest will give an answer, if you’re not sure you’re more likely to go with that. Obviously therefore that person might be completely wrong but if they’re believable and what they say is logical, you might go for that way. I don’t know whether that is the answer you wanted, but that’s…

I: Yeah, the correct answer in this case is that the equilibrium shifts to the right because adding the Neon at constant pressure it reduces the partial pressures of all of the species, and because there’s more species then.

G: Oh I might have got that right [laughs]

I: Yeah [laughs], because there’s more species on the right then the equilibrium will shift to the right to counteract that change because it’s been reduced. So that’s the answer we were looking for….

G: Yeah, I think also…

I: This was taken from a paper from 1995 I think, testing…

G: This is like when I said earlier on about if a pupil asked me something that I don’t know going talking to colleagues, if you talk to colleagues, if you have your own ideas that’s fine, but as soon as someone brings in another idea, I think as chemists we’re quite happy to evaluate what we’ve just heard.

I: Yeah

G: Is it a better answer than the one I previously gave, and then we, if you’ve done a chemistry degree then that’s entirely what you’ve basically been told to do, you think of an answer, you're given information, does it agree with it, if not, you’ve got to think of it. If you can’t think of it and someone else gives you a viewpoint which sounds like it could be meaningful, plausible, correct you’re going to go for that one. I think, yeah I would say the ability to discuss ideas in chemistry is really important

I: That’s great, okay. So one final question then, so having considered those 2 problems that I’ve said to you, do you believe that the limitations of chemical models and analogies that we use in the A level specification and GCSE specification should be taught to the students at those levels?

G: Teach them the limitations of them?

I: Yeah, teaching the limitations of the model. At GCSE and or A level.

G: They become aware, they always say to you “What you taught us at GCSE, you lied to us” I hear that every single year from my AS lot, my lower sixth, year 12s. They say “so what you said was a lie” “No, no, no. I didn’t tell you a lie, it was the information that you required at that time to help them explain” So when you're starting talking about ionic with covalent character they go “woah woah, it's either ionic or it’s covalent. If it’s a metal with a non-metal you’ve told us it’s ionic” well that’s what you needed to know at that time but...And then I say “but if you want the whole thing, we could spend months just looking at bonding and going into it, I have to give you some idea of what the answer is and then we’re going to refine our model all the way through.” But with everything, in everything, in every subject at GCSE and A level you are giving them a limited model of certainly of your understanding. Do they, I’d be very interested to say do History teachers get told “Oh, you didn’t tell us that!” If you were to study the period again in much more detail, would they say “Oh, so you lied to us?” I don’t know whether that happens in Biology or with Physics, it does happen a lot in chemistry because they don’t have, it’s such a spiral idea, and as I said before all the ideas build in from different places to your model, you have to start with a simple model, and then you have to keep refining it. But should you teach, should you tell them there’s limitations, should they be inherently aware that everything they learn is [laughs] often a simplification, you can go into it in a lot more detail? I don’t know I wouldn’t, I think it becomes apparent during the A level, I wouldn’t say you need to tell them at GCSE because it becomes very apparent at A level that actually what we taught at GCSE is very simplistic, and that’s why I sometimes call it A\*-C and a kid who can get an A\* at GCSE can very quickly get a C at A level because they can understand the simplistic thing and they can learn the rote fashion answer but they don’t have the knowledge when it comes to the required, they might not be able to adapt the model that they have in their head about it sufficiently enough, they so have a fixed mindset on “this is the answer” and then when it comes to a question where, often even the brightest A level ones if it asks them a question which vaguely annoys what they’ve been told about, even if you’ve gone through intermolecular forces and you give them 3 things and say “these are the boiling points” they will ignore the data, they will just look at the molecules and go “that’s got that, that’s got that and that's got that and therefore….” And then you go “well that’s not what it shows in the trend” I think especially in A level, you start to throw in that “this is what we taught you, but if the evidence doesn’t support it you’re going to have to think differently.” They suddenly, they become more aware of it. Should we say it at the beginning of the A level? “What we’ve taught you before is a very limited model, we’re just going to extend that model” I don’t know...It’s sort of inherent and then everything that is taught to them, that they are taught what we perceive they should be able to understand at that point in time, if they carry on they’ll realise that if they go on to university the A level is much more simplified than they’ve realised [Laughs].

I: Okay, excellent, well that's everything.

G: Okay.

I: Thank you very much for taking part.

**KENNETH INTERVIEW TRANSCRIPT**

I: Okay, so if you could just please state your name for the recording?

K: Uh, [REDACTED]

I: And can i confirm that you've signed the consent form, and you fully consent to this interview being recorded and used for our research project?

K: Yes.

I: Okay, excellent. So this first section of this interview is regarding teacher training. So focus on your teacher training, and your degree beforehand and its influence on your own subject matter knowledge. So which aspects of your undergraduate degree, if any, helped you to develop your subject matter knowledge for teaching?

K: Um, okay so I did a degree in biochemistry at the [REDACTED], and the subject knowledge that I gained in my first year and partly my second year, were directly relevant to my A level chemistry teaching.

I: Right.

K: I had a very good experience at [REDACTED], where I did my first degree in terms of the quality of teaching. I believe, that [REDACTED] a long time ago, they had an emphasis on teaching. This is anecdotal, I don’t know of course but I’ve been led to believe, and I certainly had a very good experience. I was a very curious student, I wanted to become a professional scientist, and I was encouraged in this so...So the subject knowledge for the first two years were directly related to what I do now, the final year and what I subsequently specialized in less so directly, because it was molecular biology, which the course that we teach, the OCR salters, we do a little bit of that. But certainly in my attitudes towards how science works, ??? science, and in my approach to teaching, all of these experiences are very important.

I: Yep, okay. And to what extent would you say that your teacher training addressed subject matter knowledge development during the training period?

K: Again, I think it was very good. So I did my PGCE at the [REDACTED], and I had an excellent tutor, who had a strong background herself, being head of department, had written a textbook, this kind of stuff. Actually we had a very large tutor group, about 19 of us, and I knew from the outset that my knowledge was very patchy, that I was very strong in some areas, things that I’d worked on as a researcher, but other areas, for example I remember clearly when it came to some year 9 stuff to do with metals + acid, I could remember some bubbles, but that was it!

I: [Laughs]

K: So I knew that I was going to have to do a lot of jetting up, and the course is actually good at getting me to realise where I was particularly weak, and that was at university, but also at my other school where I did most of my teacher training, which was at [REDACTED], a comprehensive, the teachers there were very good my mentors, my head of department would give me exposure to different kinds of lessons, and it became, it was very clear areas I was stronger in and then areas I was weaker in, and it was a very positive atmosphere, it was accepted that that was going to be the case, and we all had to teach Biology and Physics as well as Chemistry up to GCSE, everybody in the department despite the fact they had enough specialists.

I: Oh right, okay.

K: That was just the way they felt about things, and I think it was a very good idea, and we all knew that there were areas of weakness, and that was just part of the culture.

I: Yeah, excellent, that's really good. So, did you personally engage in any self-directed activities to develop your subject matter knowledge while you were training?

K: Um, yes. Basically I would do my own reading around, sometimes we would have directed activities, so my mentor for example gave the whole department an inset on teaching electricity, because he said “you know look, this is a difficult subject for visitors to teach, never mind everybody else.” But yeah, i’ve got a little book shelf up here, and a number of those are books I acquired once I’d become a teacher, essentially because I was curious about questions would come up from students, and sometimes it would be an area, so for example aspects of electrochemistry. There’d be part of it that I’d done a lot of work on as an undergraduate, but other parts not so..I decided to jet up on that kind of stuff.

I: Okay, excellent. And what do you remember about the impact of the subject matter knowledge activities that you engaged in, what do you remember about the impact on your confidence in your subject matter knowledge? So not necessarily the level of knowledge you had, but your confidence in it. So how confident did you feel?

K: Umm, it's a long time ago now, It’s now...It’s [REDACTED] I did my training, but essentially my recollections are very positive. I think the key thing was to realise what my limitations were and then, as I said I had very supportive colleagues, I had a lot of material I could look at, so I basically felt confident. I mean a key thing that I do remember from that time is asking my mentor who was later the head of department, and who was the head of physics, I said “Look, how long was it before you felt that you were really comfortable with all of the questions you’re likely to get? Likely to get, the routine questions at A level?” Now this came from a guy who did a straight physics degree at [REDACTED] and had been a teacher for about 13 years at this stage. He said “about 6 years.” And he was teaching, he’d taught A level from the outset, so I knew it was going to be quite a while before I felt fully comfortable. And the thing is that, I mean I now have been teaching Chemistry for 17 years and there are still questions that come up and I say “look, I’m going to have to look that up”. Now most of these are beyond the scope of the course, but there are still ones that come up within the scope of the course which I’d forgotten, or I haven’t really thought about. It doesn’t happen very often these days, but it still happens.

I: Yeah, of course, yeah. And you say you undertook a degree in Biochemistry, do you feel that compared to colleagues, who say have got a straight up Chemistry degree, your subject matter knowledge as at a deficit compared to them?

K: Yes, I mean I definitely think that. Now interestingly we have 9 Chemistry teachers here, but only 2 of them have straight chemistry degrees.

I: Right, okay.

K: So the former head of department, who’s know the assistant head academic, he’s got a chemistry degree from [REDACTED], and he did a PhD in organic chemistry. But he himself, you know there are areas where he is not so strong. I’ve got a colleague who’s a house master, a very experienced teacher, he’s got a straight chemistry degree from [REDACTED], but again there are areas where he feels that he’s not so strong. So I again I think its, and the rest of us are all people who’ve got biochemistry backgrounds, the current head of department has got a Biochemistry degree from [REDACTED], there are people who’ve done conversion courses, so three of them did courses at [REDACTED], so extended PGCE’s with extra chemistry, one of them had been a physio before, and one of them a marine Biologist. But I would say yeah, most of us are deficient in comparison to those who did straight chemistry degrees, but we’ve taken varying steps to try and remedy some of those deficiencies.

I: Right, okay excellent. Thank you. So this next section is primarily focusing on what you think makes a good teacher, and how a teacher’s subject matter knowledge can influence that, okay? So first question, very broadly speaking, what do you believe makes an effective teacher of any subject?

K: Ok, well its basically to do with communication, so communication, I would also say you're trying to create a safe environment. Now with chemistry, a practical subject, of course you're talking about the safety in terms of you have enough..Adequate subject knowledge to prepare students to do practicals, carry them out safely, and actually get something out of it, in terms of some sort of learning outcome. But also that they feel, and I feel that this is totally key, that you have to make students feel comfortable to ask questions, that they can admit to weakness, and that's vital. Because also, as a teacher, unless I can find out what student’s weaknesses are, I can’t really help them. Of course I can get a certain amount of information from people writing things down, but ever since i’ve been a student teacher where I was lucky enough to do some observations of people in the school I mainly taught in [REDACTED], but also in a school in [REDACTED], where they’d taken part with the wool inside the black box research, and there was a teacher who was very good at questioning, our head of department had come to give a talk as part of our PGCE course. And on the basis of that I decided can I go do part of my teacher training there. So I think for effective questioning, you’ve got to have people feel that it's safe for people to give an honest answer. I’ve also, so it's basically you’re trying to get as much information out of students about where they are, and having an effective, I mean I guess this is where subject knowledge becomes really important and also the structure of the syllabus, this kind of stuff, and I feel that for many of the things we teach, the IB Chemistry, A Level Salters and now IGCSE Chemistry, that i’ve been teaching it for long enough that I can anticipate where people are likely to have problems, that I’ve got a good enough knowledge of the structure of the course that I can, I try to structure lessons so that people can get key information, and also where the pitfalls are likely to be, and try and get people to make links between areas.

I: Right, okay.

K: So yeah, those are the things that I feel are really important.

I: So as an aside, do you those pitfalls, those are things that you will only be able to pick up with experience of teaching, or do you think there are any ways we could..

K: Okay, so I would say of course with experience of teaching, you’re going to.. That will allow you to pick these things up, you’ll see where the mistakes are made by the teaching itself and also by the mistakes that students make. But, again, now that you’re questioning, my memory is starting to come back, we had some fantastic stuff done on misconceptions in science and I remember that on the basis I did some, I took some students aside, they would have been GCSE students I think, and I took them into a resources room while they main lesson was going on, and it was questioning about what's happening when I’m putting this sugar in a cup of tea.

I: Yeah.

K: Or hot water, and getting them to write down their ideas, telling me their ideas, draw diagrams and that kind of stuff. So that was specifically, I’ve got it still here now, a big photocopied document on misconceptions in Science. So yes I do feel that yes you can flag these things up and you can address them, And I think that was a really important part of my PGCE. So the questions you asked us, experienced teachers, last year on equilibrium, I think that would be fantastic, that’s the kind of stuff that should be included in teacher training. Actually I think it should be part of continuing professional development, so people are constantly being challenged, in a way that's supportive. You know, you’re not going to lose your job because of this, although ultimately if you don’t perform from scratch then you know, It could be...But much more you know we realise people are going to have areas of strength and weakness, and that areas come up from, you know the kind of research you’re doing, or identify them nationally as areas of weakness. One of the things that I like telling my students is that when we come across an area like mechanisms or something, when we use some of your material, is to try and reassure them before we start “Look, there is a good likelihood that you’re going to find some areas tricky here. Nationally this is found to be the case..” So it’s trying to achieve this balance between making people feel safe and secure, but also letting people know that they’re going to be challenged, and that’s what I’m intending to do as a teacher. I will challenge you, but I’m going to do it in a way that I hope is as comfortable...Well, it’s going to be uncomfortable but it’s not going to be nasty. It’s basically going to be hard, and that is something which I, I guess it’s part of my philosophy of life, that it’s going to be hard, but that doesn’t mean, if we break it down in to fine sized bits, then its achievable. And I guess that’s another thing, my expectation of students are, “Look, for many of you guys i'm sorry you are having to do much of this” You know the school has this policy of making you do an international GCSE in Chemistry, which is, you know there are good aspects to it, there are aspects that are perhaps not so good, however that’s there expectation, and my job is basically to try and allow you to get the most out of it that you can. And once people have reached sixth form, well then the expectations are even higher.

I: Yeah, of course.

K: Because you guys have chosen to do it.

I: Yeah, okay, no excellent, that's really great. So in addition to everything you’ve just said, broadly speaking, do you think there’s anything that additionally makes an effective teacher of Chemistry, specifically?

K: Yeah, okay. I think we’re really lucky in Chemistry and it’s one of the reasons actually why I decided to teach A level Chemistry, to be a chemistry specialist at secondary level rather than Biology, is that the kind of demonstration and practicals we can do. I feel, well they can be really exciting, and I know there’s a lot of debate about, and we dealt with this quite a lot in my initial teacher training about the role of practicals and in fact perhaps practicals are sometimes not done for a very good reason, but I think that there are enough practicals that are done for good learning reasons, and also for capturing people’s attention, so yes, I feel that that side of things is really important, and in order to actually do practicals well and safely, you’ve got to have a pretty good understanding, you’ve got to have a very good understanding of what's going on.

I: Yeah

K: And I can understand why people might shy away from that, those kind of activities, if they felt deficient in their subject knowledge. Another thing that I’d add incidentally here is that we’re very fortunate with set sizes because we have, well the biggest group I have is 26 and my GCSE group in year 11 is 17. And also we have equipment, we have enough gas syringes for a group of GCSE students, they use gas syringes, they can do titrations. And once we go to the sixth form, I have groups probably about 10 or 12 and we have enough equipment that the students can do this. It’s also very good for me because it means I’m doing a lot of practicals the whole time, so I keep current, we’re good about sharing good practice. Something that I felt was really great, which unfortunately has now gone from A level was the coursework.

I: Right.

K: The Salters coursework.

I: So the extended project kind of thing?

K: Right, the extended project. That was really great. We actually did, it did a service I think, we actually told student’s what to do, we mainly did kinetics experiments, the ex-head of department did start to introduce a bit of organic synthesis because that was his interest. Interestingly the IB course they now also do an extended project, and in fact, there rules and regulations mean we can't just feed the students the topic, which I feel is excellent, and that I feel is very good, and it's good for us as teachers as well, because basically what it means is that often they are doing things that we are ourselves are not very familiar with. We have to familiarise ourselves with the safety aspects, but for what the results will be, we don’t really know, and I think that's really good.

I: Yeah that is, excellent. So how important do you believe that a Chemistry teacher’s level of subject matter knowledge is in their teaching?

K: I think it’s extremely important, so I wouldn't be happy if you had somebody who’s background is just A level chemistry, there’s got to be further study, and I feel that I’ve probably got, I would say close to the minimum in some areas, and in other areas much more. I think I’m very strong in my understanding of how science works, because I worked as a scientist for about 12 years in total.

I: Of course, yeah.

K: As a research scientist at a number of different universities, different countries, different projects. But in terms of the core knowledge, I’d have thought my 2 years of chemistry, that was basically, that was a minimum.

I: Yeah, and do you think that a teacher of Chemistry should be an expert in their field? Or to what extent do you agree with that statement?

K: Okay, I feel that they should be an expert to the extent that once they've...You can’t expect new teachers to be total experts, I think that’s unrealistic. And I think the comment I made earlier about my mentor, the head of physics, he said it was about 6 years before he felt totally comfortable.

I: Yeah.

K: I think that once that kind of period has gone, has elapsed, then people really should be expert, they should have a mastery of the subject matter content for whatever courses they are teaching, be that GCSE or sixth form studies. I think that that’s a reasonable statement, but I wouldn't expect everybody to be completely up to speed with all of their undergraduate studies, for example. It’s ideal if they are…

I: Yeah.

K: But I would say a minimum is anything you encounter at secondary level is no problem.

I: Okay, excellent. So do you feel that your teaching of Chemistry is limited by any external factors? So things that you personally don’t have any control over?

K: Okay, let's see now. I think, what I can say, I can talk about the things that I feel don’t limit me so much here, I think I mentioned set size is something I’m very fortunate with. And yes, there are things I can’t do with some groups, say 26, as this room is relatively small so it means some practicals I’d be limited in with my larger groups.

I: Right.

K: But I’m lucky with most of the groups I can pretty much do all the practicals I’d like to. I feel that we have, we are adequately resourced, we have the chemicals we need, and there’s sufficient expertise to do appropriate risk assessments. We’re encouraged to do appropriate CPD, that kind of stuff. Under a previous headmaster, unfortunately, there was a limitation there. He had a, well, I’m just trying to think how to put it diplomatically…[laughs]

I: [Laughs]

K: But basically, he actually put a special reporting regime in for chemistry, for accidents. It meant that we had to report to him directly any incident. And, I know from talking to, what's called the SHE, the person responsible for health and safety, essentially they felt this was pretty unreasonable, and it reflected a misunderstanding of risk, and of course if you're involved in riskier activities, you tend to have more accidents. And of course I may be biased, but I think that the accidents that we had, and as the SHE said it weren’t things that came up on his radar…

I: Right.

K: And I think the headteacher’s previous background meant that he was very risk averse…

I: Right, I see…

K: But that’s not happened under the current head, that kind of, that was a constraint. It didn't actually stop me doing any of the practicals I’d normally do, but it did lead to, it lead to difficulties. For example, our head of department had an accident, it’s an interesting one, he was talking to a class and cleaning out a beaker at the same time, and it broke, and he ended up with an extremely bad cut.

I: I see, I see…

K: Which could have actually, he was very lucky not to have nerve damage and tendon damage. But this is the kind of thing which can happen. It was partly, as a result of that the reason we were put on this special reporting scheme, so there was that, that’s one thing. But it didn't actually, it didn't lead to any changes in our practice really, but it wasn’t a good atmosphere. What other kinds of things... As I said, we’re properly resourced, we’ve got enough specialist teachers, our students by and large are well behaved, there are occasional you know stupid behaviours, but they are pretty unusual, so I can't really think of, I can't think of much that constrains us. The thing I would really like to see, and this isn’t a criticism of [REDACTED], even though we are an independent school so we do have more control of what we teach, but I think this is more of a general comment about science education certainly in England and Wales, that’s what I understand of it, is that we just don’t do enough project work.

I: Right, okay.

K: That we spend far too much time actually looking at content, I was very much influenced by a book on the syllabus when I was a PGCE student, I think it was called “Educating the inquiring mind” It was basically some ideas of his for an alternative way of teaching science at a secondary level 11-16, and essentially it boiled down to 20-25% of the time, doing what we do at present content, 25% of the time doing long term projects, 25% he talked about doing science of the critical consumer, so for example looking at shampoos, why they’re making these claims, let’s do some experiments to see if there’s actually any grounds to these claims, and then 25% basically how things work, taking stuff apart like a bicycle and putting it back together. And I particularly, all those things were good, but I particularly liked the one about the long-term project, and he gave us an example, it wasn’t rocket science. It was three schools in the north of England collaborating with three Norwegian schools, they were looking at acid rain for about a year, and doing pretty mundane stuff, but it would have given these students a very good idea of how scientists work. So that would be my main, that’s what I would like to see happen. I would like to see, essentially, quite radically change what we teach.

I: Okay yeah, that's basically asked my next question. I was saying, in an ideal world how would you personally like to teach Chemistry, is there anything you would like to add to that?

K: Well, actually it's interesting you know, I did find what this guy said, I can’t..I've not actually thought about any better way of going about it. That’s what I would like to see. Also, I do quite like, now this is reflecting my personal background, I don’t really like splitting things up into Physics, Chemistry, Biology...Geology.

I: No

K: Having the background I have, it’s science, and of course people have areas of expertise, some of them fall neatly into the areas of physics, other’s not, or Chemistry. And what I feel is really important, yes there are some key ideas that you’re not going to be able to get around, you know things like cells and energy and this kind of stuff, but it’s how scientists gather information, and I think that that's something lacking in science education in England and in Wales, that people don’t come away with a very good idea actually I think that a lot of science teachers don't actually have a very good appreciation of how science works either.

I: No, there’s been some studies to show that is the case, yeah.

K: And I think that that’s really doing a massive disservice to, well to our country. Because I do, as I mentioned before when we were at lunch, I have very broad interests, but I really like science, and I do feel that it’s people in a civilised society it’s really important that people have a good understanding of how we get information and that science is a fantastic way of getting information, it has its limitations, and it’s got to be done in certain ways. So I’m very keen on, I’m almost evangelical about getting people to read bad science, you know you’ve got to look at this stuff. That's something I would say in initial teacher training, I would be saying “you’ve got to read bad science”.

I: Yeah.

K: For example, and I think that one of the things that was very good about the PGCE we did was that we were challenged. I remember there was an excellent guy came in, a KS3 advisor for [REDACTED], and I’m sure he deliberately came in to wind us up, and he did it very well. The two things that I distinctly remember, one of them is do you… “So how many of you guys get students to take notes?” we all put our hands up. “Well, waste of time isn’t it? Look at this revision guide, that’s got all the notes these guys need.” A very good point, and I’m trying to remember the other thing he got us to think about but there was a lot of that, there was a lot of challenging ideas, getting to think about things in different ways.

I: Cool, that's really excellent. So just finally in this part of the interview, so you’ve said you’ve had quite a lot of experience working outside of teaching before you started teaching, do you feel that your experiences in work outside of teaching have helped you with your teaching?

K: Definitely, and again something that I...There are plenty of exceptions, there are lots of teachers who have gone from school, to university and then straight into education and again my physics teacher who I was lucky enough to observe the first week of my PGCE and he taught me actually 16 years before that, a fantastic teacher, he’d gone straight from doing a metallurgy degree to teaching at the school I was in and he remained a regular teacher until he retired, but most of the people I’ve come across I would say, who are a teachers, have benefitted from doing something else. And I think that’s really important, and it’s something I also feel sometimes it's possible for some teachers perhaps to have not a very good sense of perspective as to what they’re doing. I think in this school actually increasingly, the senior team there’s an emphasis on everything we’re doing in this school is really important for people’s future outcomes. And I do feel it’s important that if you’re going to be teaching a subject like chemistry you have a certain level of expertise, but all the other stuff around it is very important. So I was lucky enough to work as a scientist for a long time, but I feel my experiences working in a hotel kitchen were also very important.

I: Oh, okay yeah.

K: And as I said my time in Spain was very important, I think people having lots of diverse experiences, so travelling abroad, working in different kinds of school, doing different kinds of work in addition to teaching, I think that's really important.

I: Cool, excellent, okay. So this next section will primarily focus on your opinions on the Chemistry A Level syllabus and the spec. But briefly before that, do you personally engage in any activities outside of schools, such as wider reading or watching television or listening to the radio to expand your knowledge of Chemistry?

K: Yeah, I really enjoy listening to the radio a lot, so i’m very keen on Professor Jim Al-Khalili.

I: Ah yes.

K: So anything he produces I think is fantastic. So my brother directed me towards the series, “The atom” and then his programmes on Islam and Science. He did a special on chaos, the life scientific I like listening to the podcasts for that. I like reading popular science, and so for example another book up there I’ve got for the student’s to borrow, Bill Bryson “The History of nearly everything”, this kind of stuff. I don’t keep up with science journals like I really should do, and that's actually something I would really like to do more, but we do take New Scientist here, and I often read that. So, I do feel it's important, I like doing it. Should I do more? I would say probably yes, but I like doing it.

I: Okay, that's excellent. So going back then to the A level curriculum, if a student asks you a question relating to content outside of the A level specification, how do you approach that situation, and if it has happened can you provide an example?

K: Okay, now what I would say is unfortunately it doesn’t happen as often as I would like it to. But, now let me try and think of some examples. Now generally what I would do is, if it’s something that I do know about then I can give them some pointers, it may be that I even have a book or I can direct them towards a website or something like that. Usually, depending on who the student is and that kind of stuff, I’d ask them to go off and see maybe if they can do something themselves. Now something I can do, if we just go over here…

I: Yeah, yup, sure.

K: Is that I had a very interesting student who came here from [REDACTED], a year 9 student, and he was asking some questions about fundamental particles.

I: Right, okay.

K: And I asked him to actually go away and do some research, and this is what he produced. Now this guy was a year 9 at that stage and now..My head’s gone, I think he’s gone to [REDACTED] now, now he was a fantastic student, but that’s what, in that case it was a simple case of you have these questions “Look, can you actually go off and have a little research and reach his own answers”

I: Do you mind me photographing that? Is that okay?

K: No, no go ahead.

I: Yeah, just so I’ve got a bit of context for the recording. Thank you.

K: So for me, that's the best kind of..

I: Yeah of course. Yeah, that’s fantastic.

K: And I remember another student I had a long time ago, this was an IB student. They were an unusual student in that they had already identified an area not only as they wanted to do as a degree subject but as a research area.

I: Wow.

K: So they were very interesting in drought resistance in crops.

I: Oh, okay.

K: So something that I thought would be useful for them was have a read of “Guns, Germs and Steel”, which they did. So this is something again that comes from, that book case was already there but when I was in NQT in [REDACTED], we had some CPD for all NQT students in the area. And there were, it was very simple, there were 3 teachers who came in, 3 practicing teachers, and they had a particular thing that they’d done which they felt was very helpful. Now one of them, they’d built up a little library, now that influenced me, so they’d actually used part of the science budget to buy some books. So I thought when I moved here and I had this book shelf, well I might as well put some of the science books I’ve got at home, I’ll just put them here. And the main aim is that actually people see them, and they can borrow them if they want to.

I: Yeah.

K: And one thing I do, I’ve put my thesis up there, and occasionally I get questions about that. And I can use that as an example “Look well, you see people around the school who’ve got the title doctor, we can talk about what it means” and then sometimes people have a look at it, so it means that they’re starting to get an understanding of well, where all this education might lead to. Because I distinctly remember when I was an undergraduate, I really didn’t understand what was involved in a PhD. I was doing an undergraduate project, my final year project, I was really enjoying it, and then my supervisor talked about the possibility of, you know would you think about doing a PhD, and I was quite interested, but I just didn’t know. And I remember thinking “Wow, this sounds great, there’s no exams and I’ll get the same holidays”

I: [Laughter]

K: It’s for those reasons you know I like putting things up so people can, well they see them, and then you can sort of pick it up.

I: Yeah, okay that’s really good. And how often do you find yourself teaching content that lies outside the A level specification? Say, to your whole class.

K: Okay, it comes, I find it very difficult to say how often it happens, but it does come up, and it’ll tend to come up more with people who I think are more interested, and of course it will happen more with the older students. And it'll depend upon the group, but if there are enough people in it who I feel will be interested in it, then we will talk more about these things. So, I mean one example is something I had no knowledge of at all, so I started doing some reading when I was a relatively new teacher, was on supercritical fluids, and I read them in this book, that is very good, with a very unpromising title [Laughs] “Descriptive Inorganic Chemistry”, which I happened to be in Blackalls bookshop looking for a yoga book.

I: [laughs]

K: And I found myself going to the chemistry section, and I found this book, and it’s fantastic. I mean It's now I don’t know, 20 years old or something like that, but it had something at the time that I think was quite novel was that these boxes with...So, it talks about all the different groups and so on, pretty regular stuff halogens and that kind of thing, but then it’ll talk about, say for example the use of carbon dioxide as a supercritical fluid. Now this was completely new to me, and it's not in the scope of the course, at least not the A level, but sometimes that kind of thing will come up. It tends to be prompted by questions.

I: Yeah of course.

K: That kind of thing I will chuck in, just because I think, well actually this is really cool.

I: Yeah, that's really interesting, and so finally in this section, what should the scope of the, in your opinion, what should the scope of the Chemistry teacher’s subject matter knowledge be? So do you personally believe it to be an issue if a teachers subject matter knowledge is limited to the A level specification?

K: Yeah, I think it is an issue, because, another example, something I don’t know much about myself but I’m very aware of is when we talk about allotropes of carbon, which we do quite a lot…

I: Yeah.

K: When I’m questioning students and we’re going back to the nuts and bolts, okay so, a lot of the problems come in when people are writing a formulae for compounds, or working out structures and bonding. And the basic rules that we use at this level are very handy, okay so we look at carbon, we look at the group number, how many bonds, okay its 4. But when you look at this kind of model, well there are problems because most of the carbons aren’t making 4 bonds, and then we can talk a little bit about that on the surface. But then occasionally I do get questions, and sometimes I just anticipate them and I don’t wait for the question like “what about this one here? There’s a problem, what's actually happening here?” And it comes up occasionally when we’re talking about polymers, “what happens at the end of the chains?” And I know from my knowledge of molecular biology that's very interesting. In chromosomes for example you have telomeres, very interesting structures. Now I don’t know very much about what happens at the surface here, but I had a colleague in my first school, we were NQTs together, he had a fantastic background in chemistry, he had a first degree in Chemistry from [REDACTED], a PhD in surface chemistry, and he worked in industry before becoming a teacher. Now I know so I said “Look, this is an area that is very important when we come to talk about catalysts because of course surfaces are very important.” An area I did work on for a while is transport across cell membranes, these boundaries, these surfaces they’re really interesting, so what I can do there is, I don’t know very much about this area, but I know enough from beyond the A level syllabus that it’s very interesting. And hopefully what I can do, I’m trying to get people to really think about this. “Okay, I can’t tell you everything that’s happening at the surface here, but I can tell you there are people that do know quite a lot more. The stuff won’t be known but it’s very interesting and important.” And that’s why I feel it’s important, that you can sort of highlight things and maybe plant a little seed of “Okay, this might be interesting”.

I: Yeah, okay. That’s great. So, this final section, these questions primarily focus on specific topics in the A level and the potential issues involved in both teaching and understanding them. So I’m going to just draw back quickly to your survey responses. So, you were asked about your confidence in topics of chemistry and you stated that atomic structure, molar calculations, bonding and intermolecular forces were the topics you felt the most confident in your subject matter knowledge for. What is it in particular about those topics that make you feel more confident in them than other topics?

K: I think it’s because the amount of time I had to spend teaching them, that's the main reason. I think that interestingly with intermolecular forces, I did an O level course, I can’t remember what the board was but we had 2 special topics, and one of them was on hydrogen bonding in water and the other was in food chemistry, and I really really liked that. I just felt very comfortable with the hydrogen bonding, I did a little, first part of my degree course I had to do quite a bit more on bonding that we teach. A lot of it I’ve forgotten, but I remember feeling very comfortable about it at the time, so we have to teach a certain amount of co-ordination chemistry, so with metal-ion complexes, that kind of stuff, I did a lot more of that as a part of the bioinorganic course so we did things like the crystal field theory, which we don’t deal with at all. I’ve forgotten most of the details, but I think, I know that I could go back to it and I’d be happy with it again, so I think it’s a combination of having to teach it a lot in different contexts, I feel like doing the IB as well as the A level is really lucky here, because they are, there are different emphasis, the core material is the same, but often approached in a different way, we use different nomenclature, and then you have the GCSE as well. So, it’s a combination of having to teach it quite a lot and then also my previous background.

I: Right, okay. Do you approach teaching those topics in particular, so when you’re planning a lesson do you go right, I’ve got a lesson coming up on bonding, how do you approach those topics?

K: Okay, now of course it does depend on people’s background. So if it’s GCSE, A level or the IB, but most of it, I’ll be, essentially I’ll be trying to find out, and I’m always trying to do this, what people already know. In some cases, say for example you’ve got IB students, these guys some of them will come from different countries, people will have done a different board, some of them won’t have done IGCSE. So I have to start asking questions, find out what do you know already. That’s extremely important, in fact that's the case for everything, well what do you know already? And then, so with bonding let’s say for example we’re talking about covalent bonding, these guys are going to have to have a some sort of understanding about electronic structure, so I have to find out what’s going on there, and then based on those responses, I’ll take it from there. But, of course it’s a group, let's say for example I’m dealing with a year 10 group, almost all of these students will have been in the school from at least year 9, and so I know from the way we teach the course they will have dealt with electronic structure and in fact they will have dealt with some aspects of bonding. So, I will ask them the questions but I’ll be fairly confident that most of them will be okay. But as I said with an IB group it could be a very very diverse understanding of what’s going on, very poor to pretty good.

I: Yeah, okay. So going back to that pre interview survey, looking at the other end of the spectrum, you stated that acids, bases, buffers and electrochemistry were the topics where you felt the least confident in your subject matter knowledge, so what is it in particular about those topics?

K: Yeah, it’s interesting because actually as I said, so with electrochemistry for example, I did quite a lot as an undergraduate, but more theoretically, because I was interesting in membranes, cell membranes, and I did a lot of reading around the subject. But, I think that I don’t, I don’t think that I grasped a lot of this, and when I came to teach electrochemistry at A level, when I was a student teacher, I found it quite tricky. And I think my understanding is good enough, but I think it’s something which probably I should actually spend some more time doing.

I: Yeah.

K: Now acids and bases, again as a molecular biologists I had to make up buffers the whole time, but there were aspects of that area which, so for example pH curves, I’m having to do pH curves again because of a change in the specification but I hadn’t done them for a while, so I think it’s mainly that my understanding of it was just fine but I haven't used it for a long while.

I: I see, okay.

K: I think that’s the main problem, I think that it's not, I understood it at one stage, but I think if it isn’t being used then it falls away a little bit.

I: Okay, I see. So with respect to the electrochemistry, most of the teachers that have been surveyed and already interviewed, most put it right at the bottom at 9 or 10. Why do you think, what is it about electrochemistry that you think is...Is it the fact that, you know, it’s only covered in brief in the A level? I mean it’s only normally a small part of the end the second year I believe, or at least it was when I studied it.

K: Yeah, I think it is a combination of, so for example I think when I was, the stuff I was looking at when I was an undergraduate, a final year undergraduate, I was really interested in organelles, sub-cyclic organelles. And I think It was quite complicated, and maybe I realised that, I think it’s partly that I realised it’s a lot more complicated than what we look at. It’s partly that and also I feel like it's one of those areas which I think mainly by chance I haven’t taught as much. I think it’s a combination of those things. I think if i were to look at just the nuts and bolts, just as simple two half cells connected by a salt bridge or something like that, that would be okay. I think that it’s, maybe I realised, and also to say for example I realised that my understanding of the nature of electricity, you know it's very much an A level understanding, that's it. And I realised there’s a lot more to it, which I don’t know. I think that’s probably it. And I think actually that’s an interesting question because my knowledge, I mean I did A level physics maths and Chemistry, I’ve got a fairly solid background, but I realise it’s A level, I can’t go beyond that. I think that probably, I think that underlies my unease with it, that i’ve got enough but no more.

I: Right, okay. And so going back to, so yeah with respect to the electrochemistry and with acids and bases, how do you approach teaching those topics?

K: Right, okay, so with something like the electrochemistry, I wouldn’t be attempting to do anything beyond the syllabus, I would be sticking pretty religiously to what I have to do..

I: Would, sorry to interrupt you, is that, so with other areas you feel more comfortable with, will you go beyond the syllabus a little bit if…?

K: Certainly when it comes to questioning, yes. It’s unlikely that I would do, I might do some demonstrations that are beyond the syllabus, I’m just trying to think with electrochemistry do I do anything that’s beyond the syllabus, I don’t think I do.

I: And in terms of asking questions of students as well?

K: Ah, okay, I do some demonstrations, but I don’t go much into the electrochemistry behind it. There’s one, you must have seen it, the turning copper and silver into gold, electroplating.

I: Yes I have, yes, I know that one.

K: So I use these demonstrations, so there I’ll freely admit “Look, the details of this, I can give you some more details, but I can’t go any further than that”. It’s interesting because one of my favourite demonstrations, that, one of the few that i’ve actually started using in recent years because I’ve become a bit lazy about coming up with new demonstrations, that a colleague of mine pointed out at the excellent classic chemistry demonstrations, the RSC one…

I: Yep, ah yes I know that.

K: Is the oscillating reaction…

I: Ah yeah! That’s a good one!

K: And I really like that, I think that’s fantastic, mainly because, partly I think that it's just a really cool demonstration.

I: It is, yeah [Laughs]

K: But that, look, this is really complicated, and there are plenty of examples of oscillating reactions where nobody really knows what’s going on just yet. And that’s interesting because that doesn’t bother me so much, that actually, I don’t really know what's going on. And yet with electrochemistry, I think it’s partly, I’m trying to work out what it is I feel uneasy about. Tell you what, when I was an NQT, I was observed, I had 3 observations as part of an OFSTED inspection…

I: Ah, right.

K: And I think one of my lessons was on electrochemistry, which was okay, but it wasn’t that great. And it was a very good guy who was actually doing the observation, he had a very strong background in Chemistry, in fact he observed me in another lesson for year 9s demonstrating simple distillation, which I felt went pretty well. He’d actually written a masters thesis on demonstrating simple distillation, so he had lots of feedback to give to me.

I: Oh wow!

K: So that’s partly it, it’s partly kind of an uncomfortable experience I think.

I: Yeah I see, and reflecting on the approaches you take between teaching the concepts you feel less confident with the ones you feel more confident with, what would you say is the biggest differences between those two approaches? In your own practice.

K: Right, well I guess it’s coming down to, basically perhaps it’s a bit more guarded, not opening up too much to questioning, which is what I tend to do, I tend to basically tend to let people ask me anything they want. Now, I’m pretty good about judging how good my understanding is, and it can be I’ll give you answer now, I can direct you to something, I’m going to have to come back to that, or it may be that I don’t think anybody knows this. As I’ve become more experienced, I’ve been able to do with the questions on the hoof better, with those areas, perhaps you know not so much.

I: Okay, cool. So, final few questions relate to specific topics. So the first ones relate to the A level topic of kinetics. As part of the A level reforms in 2015 the Arrhenius equation was reintroduced to all of the A level specifications. How have you adapted to the reintroduction of the Arrhenius equation?

K: Okay, that’s an interesting one that, because that’s no problem for us. Because of the way we did coursework in salters, all of our students…

I: Yeah, you would’ve…

K: All of our student’s used the Arrhenius equation.

I: Right, okay.

K: So it meant that it was no problem for us.

I: Okay, okay that’s great. So you evidently feel confident teaching that concept. And do you feel that you and your students understand the mathematical processes involved in the Arrhenius equation?

K: Now again, I’m lucky because, in a nutshell, maths was a subject I found very difficult from my primary school days until about year 10, with a combination of I think, basically just calming down and accepting I wasn’t in the topset like I was for everything else, I was in the 3rd set. I had a very, extremely kind and competent teacher, I was at a comprehensive and she was just a regular teacher, a very humble person but she had this fantastic background in maths, but basically anyway things started to click, and actually I ended up getting an A at A level, I had to work very hard, but I really liked it. So my, so in fact I did very well in maths course my first year as an undergraduate, so my knowledge of, the maths we have to use is very sound, it’s pretty limited, but things like logs and so on, I can help these guys out no problem.

I: That’s really good, okay. And do you feel that you and your students understand the application of the Arrhenius equation to further understand chemical kinetics, what it's actually for?

K: This is a good question, I think I give them, I think they go away with some understanding yes, how deep it is, I don't actually know. I think that they, what I would say is actually, I would be very surprised if the understanding of my students now, now that the coursework has gone, is as good as those who did the coursework. Because those doing the coursework, they had to find this out for themselves, and then actually apply it. I mean yeah, because that was a thing, we deliberately didn't touch the Arrhenius equation, we left them to find it out for themselves, and I think that that was actually really good, they would often, guys would often come in and ask for help, especially with manipulating it, but that was fine. I would actually, I mean again I don't actually have any evidence to back this up, but I would venture to say that understanding is probably not as good now.

I: Yeah, okay. So next few questions centre on structure and bonding, atomic structure and bonding. So I’ve got a question that’s been asked to students and teachers before so this is the question at the top there, so a sodium ion, one sodium ion is more stable than the sodium atom, true or false? That’s how a group of teachers responded, and that's how a group of students responded, so the student’s, 70% of them said it was true, but with teachers 53% of them, more of them said it was false. So, this is how the teachers and students responded to the question, why do you think that these are the typical responses?

K: Okay, I think with the student’s it’s this idea, this fundamental stuff to do with teaching of electronic structure and the periodic table and that as teacher’s we’re always banging on about noble gas configurations and I think that that is at the heart of this.

I: Yeah?

K: This is where it’s coming from. Of course also, what does this word stability mean? It’s a very good point.

I: Yeah, exactly.

K: And as I would say that, I’m going to have to think about how I would go talking about stability, means that the students, actually they’re not really sure what it means.

I: Yeah, okay. Excellent. Do you have any other comments regarding, so how the teachers answered, why have the teachers...So you know it's pretty split, 53% 47%, pretty even split, why do you think that might be?

K: Okay, I think one thing is I would be very interested in what these guys interpret by the world stable. I think that for me that would be the heart of it, what is meant by the word stable?

I: Okay, excellent. Just out of interest, how would you go about answering that question? Would you say it’s true or false?

K: Umm, okay.

I: Sorry to put you on the spot, but…

K: No, no It’s okay, i’m trying to think so, there’s things like so...Does it mean reactive? Does it mean that it’s energetically stable?

I: So we’re talking about energy here, yes, and this is a single sodium ion and a single sodium atom in the gaseous state.

K: Okay well the thing is that the..

I: So it’s a completely hypothetical situation, you would never have this in nature [laughs]

K: No, well the thing is in order to actually ionise the sodium atom, you had to put energy in to remove the electron and so if were to draw an enthalpy diagram then the sodium ion would be at a higher level.

I: Exactly, yeah. And that’s the answer that’s basically expected, so yeah, the answer there is it’s false, because yeah the sodium ion, you have to put energy in to get there. But as you say there is ambiguity around the world stable, a lot of people seem to, they see the noble gas configuration.

K: And they concentrate on that!

I: That’s it, exactly. So next couple of questions, well next question, is on chemical equilibrium now, so going back to you know, that session.

K: Yes! [Laughs]

I: This is actually from that session you attended, so the question is at the bottom, you don’t need to worry about this emblem here that's just the number of people who responded. That’s the question and these are the responses, so the blue bars indicate what the teachers initially thought was the answer and the red bars indicate what the teachers thought after they discussed with one another. So beforehand they thought there was no shift, the majority did rather, and afterwards the majority thought the equilibrium shift would shift to the right, so why do you think this is the typical response? Again I’m not looking for your take on what the question is, I’m looking for why you think did they….

K: Yeah! Let me have a look at it again.

I: Yeah, that’s fine, I’ll let you have a bit of time to have a read of it.

K: Okay. So we’ve got this PCl5 and it’s going to PCl3 and Cl2 and you add an inert gas at constant temperature and pressure.

I: So that’s, the whole system remains and constant temperature and pressure. So you’ve added some neon.

K: Okay, so the pressure is unchanged? The temperature is unchanged?

I: Yes.

K: So my initial thought would be, well if you haven’t changed the pressure and you haven’t changed the temperature, you wouldn’t shift the equilibrium position. That would be my initial thought.

I: Of course, yeah.

K: But then I’m seeing these guys have put the right shift so...What made them do this [Laughs] What made them do this…

I: So when we say the pressure of the system remains constant…

K: The partial pressures! Are the partial pressures changed?

I: I can tell you, yes, they do. Because once you’ve added neon, the pressure’s the same, so that includes the partial pressure of neon.

K: Of course, yeah okay. Of course, okay, so you’ve increased the...The number of particles has increased, there was no neon before, that’s got an increased partial pressure, so the partial pressure of the rest of them has gone down.

I: Yes, that’s exactly right. Which is why it leads to the right shift, so the right shift is the correct answer in this instance, but you can see why a lot of teachers would consider there to be, or a lot of people anyway, any change. It wouldn’t have to be teachers necessarily who would say there’s no shift. Do you think that the responses given here could be anything to do with the reliance on Le Chatelier’s principle?

K: Umm, yep, I do think that! I do think that, in fact of course whilst I may not be so useful as other teachers as because I was present at the session, although it’s a year ago and I’ve forgotten stuff.

I: Of course, it’s fine.

K: But I would definitely think that's the case. And I do remember from your session and talking to, it was one of your professors…

I: Yeah It would have been.

K: Now something I do, I came away I felt heartened by, because there were some things I felt a bit disheartened by my understanding, that I stress to my student’s that Le Chatelier’s principle is not an explanation at all, it’s a summation of observations. And I think that the problem is, and from your session it made it clear to me, it works under certain limited circumstances, and that's it. So I can see why it is that, Le Chatelier's principle has got to be handled very carefully.

I: Yeah, exactly, because it’s not an explanation saying what will happen. It’s using the, you know say if you this then...It's the same as saying if you drop a pen on the floor it's going to fall down because of gravity, you know gravity is the explanation, the rule would be saying the pen is going to fall on the floor, but I could just say if you drop the pen it’s going to fall. So, having considered those problems, so this one, and the one related to atomic structure do you believe that the limitations of chemical models and analogies should be taught at GCSE and/or at A level?

K: Absolutely! No, I definitely feel that. I think, as I talked to you about earlier, as I think the nature of science, it’s really critical, absolutely.

I: And do you think it should be at both A level and GCSE? Or do you think…

K: Yeah, I think it should be, I mean I think it should be before GCSE, we should be looking at, I mean modelling is just totally key. And if...All the models are going to be totally floored, it may be we don’t know where the floors are yet, but they’re going to be floored, that’s it.

I: Yeah. Of course, yeah. And um..Oh, one more other thing I was going to ask...I need to get it back in my head now [laughs]...Oh it's gone, that's really frustrating, hang on.

K: That’s alright

I: Oh that’s it, so do you find yourself, so when you’re discussing any models in your teaching, do you ever find yourself discussing the limitations of certain models?

K: Yes, and I’m trying to think of examples. I mean the classic one is to do with, well actually perhaps this is one of the reasons I feel more confident about talking about things like bonding because all the time going from GCSE to sixth form study, we’re looking at, and also looking at the different treatments of IB and A level, we’ve got different models here. Or we’ve got, basically we’ve got models that are more refined, and one of the things I like about the IB actually are they’ve got lots of exceptions to the octet rule, and..So that’s a classic here, I’m just trying to, off the top of my head I’m trying to think of other ones. So something I talk a little bit about with groups is to do with electroscience, looking at models of gravitation, so that is an area, that’s where i’m going outside of chemistry. Because you know there’s fantastic examples, you know there’s Newton's laws working very well, but when people started looking at things moving near the speed of light then it starts to fall, it falls down. This doesn’t mean it’s not useful, I mean you can get people to the moon using Newton’s laws, but if you start moving at the speed of light, then i'm afraid you're going to have to start using a new model, but again, that doesn’t even always work. What happens when you try and combine quantum mechanics with relativity? Well people are trying to do that but they haven’t near succeeded. But no, I can’t think of any more off the top of my head, but yeah I do think that’s really important, and I would like to do more of it. And If i see an opportunity, I’ll deal with it, and one of the things I like very much about the IB is actually, especially with the recent syllabus change to the IB (which came in a few years ago), we have to deal with it.

I: Right, excellent.

K: And it’s actually highlighted in the textbook,

I: Oh really?

K: So Nature of Science, you have theory of knowledge. Theory of knowledge ties in with, so IB students have got to do the theory of knowledge essay, so that’s I think a strong point of that course.

I: I definitely need to look into that, as obviously we’ve been primarily focused on A levels, we haven’t really looked into the IB. But knowing that, that would provide a of insight so thank you. Well excellent, that’s all of the questions I have.

K: Great!

I: Thank you ever so much!

**ROLAND INTERVIEW TRANSCRIPT**

I: Okay so if you could just please state your name for the recording?

R: [REDACTED]

I: And can I confirm that you’ve signed the consent form and that you fully consent to this interview being recorded and used for our research project?

R: Yes

I: Okay, so these first few questions will primarily focus on your teacher training and its influence on your subject matter knowledge. So before we get on to that, which aspects of your undergraduate degree, if any, would you say helped to develop your subject matter knowledge specifically for teaching?

R: I’m not really sure that any of it did specifically. In the sense that, I suppose apart from some very early work in the first year when a lot of it seemed to be like making sure that everybody was at the same stage after A level, I would say most of it is not desperately relevant for my teaching, except in those circumstances when you get asked a question from a very able student who’s sort of thinking a bit beyond.

I: Yeah, okay. And to what extent did your teacher training address subject matter knowledge development during your training period?

R: It didn’t

I: Didn’t at all?

R: No, because basically what I did, I did a generic PGCE and that generic PGCE was done by sort of...It was assessed by continuous assessment of doing certain, improving competence in certain things, by producing something, it was a bit like a GVNQ thing used to be where you had to do something to prove you’ve matched that competence. And so the training was all about teaching, nothing about subject matter and there were lots of people doing the same course on all sorts of different subjects.

I: Right, okay, and did you engage in any self-directed activities to develop your subject matter knowledge whilst you were training? That weren’t formerly part of it.

R: No not really other than frequently I had to refresh my knowledge of some of the informational aspects of the A level at that time, which have now actually mostly gone from the specifications anyway. I’m talking about things like students had to learn a whole series of reactions in group 4 and group 5 and group 6 and period 3 and all that stuff most of which is now gone from the spec, so yes I had to sort of look a lot of that up in books and so on in order to make sure I was familiar with it before I taught it.

I: Okay, and what do you remember the impact of the subject matter knowledge activities, so those things that you engaged in on your confidence in your subject matter knowledge of chemistry? So you said in your pre interview survey that you were already rather confident in your knowledge of chemistry when you went into teaching. Do you think those had any more impact on your confidence or?

R: I don’t really know that they did, they were very informational, there was very little understanding involved as far as I was sort of aware. Therefore we ended up in a situation where students were having to know something so that they could regurgitate it for the purposes of doing the exam.

I: Right, okay.

R: There was no understanding or real knowledge in it, and they probably forgot it as soon as they had done it because I certainly did [laughs]

I: Right, okay [laughs] So moving on from there we’ll talk about what do you believe makes a good teacher and how a teachers subject matter knowledge can influence that. But before we get on to that, very broadly speaking what do you believe makes an effective teacher of any subject? So very broadly speaking, it's a very broad question.

R: I think it’s the ability to understand or work out where students are coming from. Trying to be able to put yourself in their head to work out what it is they’re actually thinking, and what links they are making. And frequently bringing subject knowledge down to a level of actually being able to explain it to somebody who doesn't understand the subject necessarily to level that you do. My experience in actually in some cases, that actually sometimes unfortunately very high-level subject knowledge can often get in the way of that.

I: Yeah, okay. And broadly speaking what do you believe makes an effective teacher of chemistry specifically? Do you think there’s anything else that is more important for chemistry as a specific subject?

R: Logical thought, a logical step by step thought process.

I: Okay. And how important, so you touched on this briefly just a second ago, so how important do you believe a chemistry teacher’s level of subject matter knowledge is in their teaching? So should we expect teachers of chemistry to be an expert in their field?

R: I think they need to have an understanding beyond the level at which they are teaching so that a) if they get questions from students they can do something with it. b) so that if it’s clear students have got misconceptions and so on they might be able to bring some additional knowledge and understanding to try and deal with the misconception, whereas actually if their knowledge just stops at the spec then where do you go if there’s an issue? I’m not necessarily so sure that very high-level subject knowledge, I would say that that’s a relatively neutral thing, it’s not vitally necessary for teaching, as I said earlier sometimes in some cases it can get in the way but it’s not necessarily a problem if the person is able to bring themselves down to the level of the student.

I: Okay.

R: I mean interestingly I’ve done very little teaching below A level but I think now I would find it quite difficult because trying to bring things down to that level I think I’d probably find quite difficult.

I: Yeah, okay. So do you feel that your teaching of chemistry is limited by any external factors? So things that you don’t have any control over.

R:Time. Time because in my role as head of department I have so many things that I’m expected to do to keep the department running, that if I don’t do those things then other people will not be able to do their teaching. So and therefore I have to try and balance that and that inevitably limits the amount of time I have available to actually think about my teaching per se. Fortunately to a large extent I’ve been doing it for so long that I’ve been through specs so many specs and here, the base resources are all there that generally speaking it works.

I: And in an ideal world, how would you like to teach chemistry? Would you change anything about the way you teach at the moment or what is limiting your teaching at the moment?

R: I think as with anything, there are things that I when I’m teaching I think “why is that there?, why is that in the specification? Why isn’t this in the specification that might be a bit more of an opportunity to explore things in more depth?” And sort of get more of an understanding rather than just a knowledge. Unfortunately there’s a tendency in A level for things to be governed sometimes by what's testable, because it’s driven by a test.

I: Yeah. Do you believe that to be an inherent problem or?

R: That’s a difficult one because if there is no assessment then how do we judge what’s going on? And obviously individuals need something that says yes they can do this this and this, or whatever it is. And I don’t know what the answer to that is but inevitably sometimes, I mean a classic example is the 2-4 DNPH derivative melting point, I mean and in fact when I’m teaching it I have a sort of [ ] story that I tell them about sad chemists because I cannot for the life of me imagine why anybody would ever do that. In the days when we’ve been using NMR for several decades, which gives you an answer like that, why on earth would you both recrystallising something several times in order to do a melting point, but it’s still in the A level specification.

I: So do you think that they need to have a rethink about some of the things that are on there?

R: I think some things that are in the A level specification are no longer relevant, they’ve got rid of a lot of them, to be fair to them they’ve got rid of a lot of them, but I think there are still some things in there that are not really relevant anymore, and they’re in there for whatever reason that I don’t really understand, maybe it's to tick a box, maybe it's because somebody in particular who’s on the committee that drew up the specification and it’s their thing, and so on and so forth. So I think there are a few, there are some things still left. I think another thing that is anachronistic really is needing to know colours of transition metal hydroxide precipitates or whether they do or don’t dissolve in excess alkali or ammonia and what colour the solutions are. That to me is anachronistic as well, I don’t understand why on earth you need to know that, bearing in mind if you wanted to know it, you can google it, so why is it necessary? And I think the only reason that’s necessary is because it allows questions to be asked.

I: Yeah, I think you’re probably right.

R: So things like that. Having said that, the new specification has a lot going for it relative to the old one because for example we’ve now got activation and deactivation and directing effects of benzene rings, although that is odd because it’s presented in the specification as a piece of learning, generally speaking most of us probably hear “try and do some level of explanation on it” using Kekule structures and moving the charges round and the tautomeric structures and so on and so forth. But my suspicion is in a lot of cases that doesn’t happen, we have the luxury of doing that because we have a lot of highly able students but I suspect in a lot of cases that doesn’t happen so it just ends up being a piece of dry learning and “right, okay OH group activates that means this, and NO2 deactivates and that means this” end of story. I mean fortunately with a lot of students if we didn’t tell, we’d get the question. Now how you then react to that question, and I suppose this then does relate to a little bit of where you sort of started which is about academic knowledge and having a certain amount of academic knowledge which is actually a bit beyond the spec because otherwise you can’t extend it to actually get the understanding. I mean I suppose the boundary line and the specification have to be drawn at a particular point and so if you’re not careful you end up with a biology spec which is just too full so yes, I think in content terms it's better than the old one used to be, structure wise I’m not so convinced but they didn't have much choice over that, but as I say I think there are still some things in there that I don’t know why they’re there.

I: Okay.

R: And I can think of more understanding-based things that could be there instead, like if you do understand directing effects and activation and deactivation then it doesn’t matter the group is, the principle is still the same so you know a lot more than just learning “oh right NO2 is deactivating, OH is activating, end of story.”

I: So you said in your pre interview survey, so you worked for [REDACTED] for a few years?

R: I did.

I: And you undertook a PhD as well?

R: Yes.

I: Do you find yourself drawing on your experiences in your teaching ever? From those 2 parts of your life?

R: I suppose early on I did. Now it’s reached the stage where it was probably so long ago that it’s no longer quite so interesting or relevant. Certainly when I first went into it, although what I was doing at [REDACTED] was not desperately relevant to the A level spec, I think I probably did think more of sort of industrial processes and how things were done, I probably don’t so much know, probably because it’s a long time ago.

I: And what about your PhD, do you ever find yourself discussing that?

R: Not really, no. I mean that again is sort of beyond undergraduate stuff so trying to make that accessible to students would be quite awkward I think.

I: Yeah, sure. And do you personally engage in any activities outside of schools, so that could be wider reading, watching television, listening to the radio that expand your knowledge of chemistry?

R: Not chemistry directly, although I do like watching scientific programmes, I will flick through the odd scientific magazine if I come across it and, I don’t subscribe to anything like New Scientist largely because I wouldn’t have the time to read it all the time. But if I’m sort of somewhere and there’s a copy there I’ll have a flick through it and I’ll have a look. And there are things that come up periodically from the Royal Society of Chemistry that I might have a flick through, but as I say the issue is time and work-life balance.

I: Yeah, of course. Okay cool. So these questions now will primarily focus on your opinions of the A level chemistry curriculum, we’ve already touched on this, so if a student asks you a question relating to content that lies outside the A level spec how do you approach that situation?

R: I think it depends on the student, it depends on my knowledge of the student, it depends on the context on which its asked. I mean sometimes students will ask a question in a lesson and it’s then a question of well “am I going to take this question now, or am I going to hold it and go and talk to the student individually later?” Maybe when they’re doing some work, or am I going to go through it with the whole class. What would be the effect of me going through it with the whole class, am I going to cause more confusion amongst the rest of the students than, so it almost certainly depends on the student, it depends on the class because some of our classes, we have something called supported sets that are sets largely populated by on the basis of our intake, less able students on the basis of GCSE. So in any normal setting they probably wouldn’t be any lower ability, but from our perspective because we’ve got such high ability students, I mean we actually have six students in our chemistry cohort that we have just taken in who have got straight 9s in their GCSEs, they’ve got 10, 11, 12 9’s.

I: Wow, that’s amazing.

R: Exactly, now there won't be many of those nationally, and we’ve got six of them in chemistry. So yes we have a lot of very very very able students but some of our sets are largely populated by the slightly less able ones and we tend to tweak a little bit the way we do things, maybe we cut out some of the more esoteric work and stuff that we might talk about. So probably it depends on the student, it depends on the set, depends on the context as to whether they’ve come up to you in the corridor or whether they’ve asked a question in a lesson, it depends how far out of where I’m intending to go with the lesson it would take me to delve into that question.

I: Right, okay.

R: If that makes sense?

I: It does, yeah yeah. And how often do you find yourself teaching content that lies outside the A level spec? So say in a lesson, or do you find that you’re too limited by time to veer away too much?

R: It probably happens for bits of lessons relatively regularly. I mean one of the things that I try and do, although they’re not going to get asked questions on it, I tend to delve a little bit into the theory of NMR, we delve a little bit into sort of the structure of a mass spectrometer, we delve a little bit into bits in pieces of this, not that they are going to get asked questions it but just so that they understand something about what's going on, and then because they’re more likely than to be able to put what they do have to be able to put in the exam into context.

I: Yeah, okay, so yeah we’ve gone through that already. So these next questions will primarily focus on specific topics in the A level and the potential issues in both teaching and understanding them. So in the pre interview survey I asked you to rate 10 topics in order of your confidence in your knowledge of them.

R: Yeah I know, I did find that quite a difficult exercise to be able to say “well am I confident or otherwise” because having been teaching A level for sort of other 20 years it was a bit…

I: Of course, yeah [laughs]

R: It was bit like actually yeah I’m sort of reasonably okay on most of them I suppose.

I: Yeah, yeah.

R: And If I did it again I’d probably put them in a different order.

I: Yeah, yeah.

R: So I apologise for that, sorry.

I: That’s okay, no we’ll discuss those the ones you’ve put in there, and also the ones that have proven to be the most commonly picked and why you think those might be the most commonly picked. So the ones you put at the top were atomic structure, molar calculations and energy calculations. So what is it about those particular topics that made you feel like those were your most confident?

R: I mean in terms of atomic structure I actually really quite enjoy teaching it because it’s, I think it’s, in many ways it’s the first things that A level students do that isn’t just GCSE +, Because when you start delving in to s,p,d,f and so on and you can sort of point out that's why the GCSE electronic configuration finishes at calcium, if they’ve ever wondered why they only go up to calcium, that’s why we only go up to calcium because the rules don’t work after that [laughs]

I: Yeah [laughs]

R: And so on and it’s at that point that I think the students start to realise that they’re A level students. Now for some of them that’s frightening and it sort of shakes them up, but equally there’s a relatively straight forward set of rules that they can follow to sort themselves out. So I think I quite enjoyed doing that. As regards mole calculations I think it’s just they crop up so often, wherever in spec you are they turn up.

I: Yeah, you can just do them in your sleep [laughs]

R: And so you end up “oh right okay it’s mole calculations” see you’re doing so often, it’s not something you do just once a year, I mean I do s,p,d,f once a year, mole calculations well every week [laughs]

I: Yeah [laughs] and what about energy calculations? I guess that’s similar isn’t it?

R: Well it does come up several times, I think, I find often I find calculations quite satisfying because you get a definite answer, and it’s not a question of “have I explained it as adequately as the examiner wants” and so on, I’ve got the answer that's it.

I: That’s great and so the ones you put near the bottom, I mean as you say you’re pretty happy with everything, were analytical techniques and transition metal chemistry?

R: Well I mean the reason I put transition metal chemistry there is not because I have any problem with transition metal chemistry, it’s because that particular topic ends up being more about learning facts frequently than it is about understanding the sort of thing going on. I mean transition metal chemistry is unbelievably interesting, I mean I did my PhD do on it, yes it’s incredibly interesting, there’s a lot to it, but unfortunately it gets mangled up a bit in the A level spec and again you end up “oh right okay, the chromium hydroxide precipitate is grey-green, it’s not grey-blue, its grey-green because the examiner decided that you’ve got to have the word green in it” and you’re like “what?” Why is that a demonstration of how good you are as a chemist? Whether you choose to use the description grey-blue or grey-green, because actually it’s a fairly orange colour [laughs] green is green as far as I’m concerned, and so I said, yeah that's why I particularly, it’s not so much that I don’t feel confident at it it's that “I don’t want to look at transition metals again”. Some aspects of it are nice! I like doing stereoisomerism of complexes but again I think, and unfortunately you will probably find that my least or most confident about teaching is often probably related more to whether I like it or not.

I: Right [laughs]

R: Unfortunately, rather than, because as I say it’s difficult for me to say I’m not confident about something I’ve been doing for 20 years. I think analytical techniques, I think probably the reason I put that there is because I think sometimes students particularly weaker students do find it sometimes quite difficult to get hold of, putting all the information together, and again it’s not, its frequently not about whether they can actually do it, in other words can you take an infrared, an NMR and a something else and work out what the structure is? Because very frequently they can do that, and do that very very well. The issue becomes do they actually explain it and put down the points of explanation that the examiner is wanting them to write? Because otherwise they get no marks or very few marks. So have they put down, because they can put down its a triplet so there are 2 hydrogens are on the next carbon or a quartet because there are 3 hydrogens on the next carbon or whatever but have they have written down therefore that it’s CH3CH2, they know its CH3CH2 and they’ve put the CH3CH2 in the diagram of the structure, but have they actually written down “therefore it is CH3CH2” which the examiner wants to see, and therefore they have not explained it adequately in the mind of the examiner. That’s what my less confidence is about, is not so much the subject matter, it’s what is going to be required in the exam.

I: So do you think there are fundamental issues there with the examination process? In terms of how questions are written and how stringent the mark schemes are?

R: I think there are, and I think they are becoming more of an issue over time. I mean I remember [REDACTED] asked me a question about this several years ago because I think there always used to be a rule that if an answer was correct and answered the question it would get the marks, and that actually used to be written into mark schemes. It’s gone, and so you end up with a mark scheme that I am not totally convinced isn’t just a prescription “this is the answer that’s required”. The other issue I think that has happened, I think because most standardisation meetings now are not face to face, they don’t even take place they are done online. Now when I marked, I don’t mark anymore because I don’t have the capacity, I don’t have the time. Now when I marked I used to go to the standardisation meeting and there was a discussion and well “how about this?” and “well what about?” “well no you can’t do that.” “well why not? What about this, this and this?” and there was a discussion, there was an interaction. Now it’s the principal examiner says that, nope that’s wrong, that’s the answer, that’s wrong. And the other anecdotal thing I’ve got, I’ve got no particular direct evidence of this but anecdotally I think therefore in the end the quality of the marking, I don’t think it’s as good as it used to be. Not that that would ever be picked by the exam boards because when the exam boards describe quality of marking, basically what they’re saying is “whether a particular person has adequately applied the mark scheme that they were given?” That’s all the question the exam board asks. Because it’s so prescriptive and so on, people do follow that mark scheme and therefore as far is the exam board is concerned it is correct marking. Whether in reality it’s actually penalising students who might have put something in a slightly different way that’s certainly actually from what they’ve written they definitely understand what’s going on. And I think that given that my understanding is that there are fewer and fewer markers who are actually practicing teachers, a greater and greater proportion of them either aren't teachers at all or never were, or have long since retired, in which case they’re out of the understanding of what students mean when they write certain words.

I: Yeah, of course.

R: And therefore I think that the quality of the assessment is less good than it was. But it’s not something that would ever be picked up by exam boards because what they’re interested in is whether their particular prescribed mark scheme has been followed.

I: Yeah, of course. Okay. So we discussed those topics that you felt less and more confident with, the topic that we’ve seen come up the most as one that teachers have the least confidence in their subject matter knowledge of is electrochemistry. So what is it about electrochemistry that you think might be causing trouble for teachers?

R: By which presumably you’re talking about redox potentials and so on?

I: Yes, yeah.

R: I don’t know really. I think maybe what causes a certain amount of confusion is that some numbers are negative and some numbers are positive. And so you end up having to talk about “more negative” or “less negative”. It’s one of those things where, and personally I don’t like telling students to apply what seem like arbitrary rules. And I know some teachers I can imagine probably teach it as you write one above the other and then you get the anti-clockwise rule or something, or something like that, and that’s fine but I would probably say that doesn’t necessarily really get to the understanding of really what's going on. I don’t like teaching it that way, and I wonder whether some teachers get themselves in to a bit of a mess over that one because basically they are telling a student to apply a rule which there may be the information to apply it, there may not, and I wonder whether therefore they’re not actually teaching the understanding, they’re teaching the application of the rule.

I: Yeah.

R: Now, that maybe a luxury we have here of having students who can cope with the understanding, although actually I’m not convinced that the understanding is actually that difficult. If its got a more negative potential it's more likely to produce electrons, and as long as you remember that you can pretty much well answer any question. And it’s the same sort of thing that happens with buffers and the Henderson-Hasselbalch equation. I never teach the Henderson-Hasselbalch equation and I tell the students the reason I never teach it is “I can never remember which way round it is, which way up it is and what the sign in the middle is”. Because of course it depends which way up it is depends which sign in the middle is, and I’m always going to get it wrong. So I said “okay, KA equation, and that's how you do it.” Now if people attempt to teach by “Oh well the is the Henderson-Hasselbalch equation, this is the equation you use, plug in the data” then they’re going to get it the wrong way up, they’re going to get it the wrong way round, they’re going to get the sign wrong in the middle, and then if the question is slightly different and you’ve got to work out something else, instead of working out the pH you’ve got to work out the pKA, you’ve got to work out the concentration of something, then you’ve got to rearrange the thing, and it’s another equation to learn if that makes sense?

I: It does, yeah.

R: And I said to my students, I said “yeah you’ll find that equation in the textbook, you can use it if you want as long as you understand it and you know what it is, but frankly I think you’re better off using this.” Because you’ve got to learn the KA equation anyway. So I do wonder whether those sorts of things are because people are, perhaps because they are less confident in the subject matter knowledge is therefore they attempt to teach something as following a set of rules.

I: Right, okay thats good.

R: And then you potentially get yourself into difficulty because some of the questions might not fit the rules and then you’ve got to manipulate the rules and “oh my goodness, how do I do this one, because I can’t do that” and so on and so forth. Whereas if you actually teach the understanding which is always what we try and do here I think you’re far less likely to come unstuck.

I: Yeah, that's really good, that's really interesting. So the next couple of questions are going to centre on the topic of kinetics. As part of the A level reforms of 2015 the Arrhenius…

R: Can I just break off just a second there to go upstairs and turn the coffee machine on?

I: Yeah, that’s fine, no problem.

I: So yes, the next couple of questions are going to regard kinetics. So as part of the A level reforms of 2015 the Arrhenius equation was reintroduced to all of the A level specifications again. How did you adapt to the reintroduction of the Arrhenius equation to the A level syllabus?

R: Well we rewrote or re-jigged most of our study packs in relation to the new specification and we had to either sort of find or invent some exercises and questions to ask students about it. I mean a lot of staff sort of use PowerPoint for teaching so there was a lot of sort of rewriting of PowerPoints and so on. Some people had to refresh their understanding of it. I mean I’d not done it for a long time, I knew of it obviously, but I’d not done anything with it for a long time, I mean it’s, yeah I think it’s nice to do it I’m not quite sure about the questions that get asked about it where the issue as to whether you get the marks or not seems to be determined to a large extent to whether you draw the graph as the exam board wants you to draw the graph and so on, and whether you draw the line of best fit in the place the examiner wants you to draw the line of best fit and so on. But I mean it was really a question of trying to think what question might come up and inventing ones to look like them.

I: Right, okay, and do you feel confident in teaching the concept?

R: Yes I mean it’s a, I mean I did actually I don’t think it was last year, I think it was the previous year I ended up having an interesting discussion as to exactly what shape the graph was. And one of the students actually pointed out to me it wasn’t the shape that I thought it was, which was an interesting one [laughs]

I: Right.

R: So we ended up having quite an interesting discussion about it and then somebody sort of plotted it out on something or found a plot of it and so on and so forth. So yes that sort of thing can happen here and I think in situations like that it’s a question of how much credibility do you have with the students. I mean fortunately I’ve known these students for 18 months so therefore they knew I pretty well knew what I was on about and so on and so forth, but it’s interesting that some of them will go to those lengths in order to try and test what's going on.

I: Yeah, and to what extent do you feel that your students understand the mathematical processes involved with rearranging the Arrhenius equation?

R: I think it depends crucially on whether they do maths or not.

I: Yeah?

R: But I mean those who do maths or particularly double maths will have no problem with it at all. Those who don’t do maths have probably not come across exponentials before. In reality they don’t actually need to do the re-arrangement because they’re given the linear form in the datasheet in the exam.

I: Okay.

R: So we don’t actually go through the rearrangement and the derivation, I say “if you’re mathematical you can probably work this out. If you’re not mathematical don’t worry about it because it’s on the datasheet” [laughs]

I: Of course. Okay, so the next couple of questions focus on the topic of atomic structure and bonding. So I’ve got a question here, you may have seen a question similar before it’s a true or false question. A sodium ion in the gaseous state is more stable than a sodium in the gaseous state, hypothetical question of course. This is how the students responded 70% said it was true, 30% said it was false. Now if you turn that off now you see how some teachers responded to it, so ignore the sizes of the bars relative, it is still 47%/53% so more, slightly more it's about even but slightly more teachers went with false than true. So I’m not asking you for a correct answer, but I’m just asking why do you think that these were the typical responses of students and then of teachers?

R: Students I think it’s because they are always taught all the way through school that a full outer shell is more stable than not having a full outer shell, and that's why they would answer it like that.

I: Okay.

R: Teachers, I suppose the question then is, quite a number of teachers I suspect have been so drilled into them what they end up teaching in GCSE or lower school that sometimes they probably lose the concept of it themselves. And of course the other question is, these teachers are they all chemists? Or are they biologists masquerading as chemists or not I don’t know. But I would suspect it’s probably because you get so in to I can imagine teaching that sort of thing at GCSE and below that you almost start to believe it [laughs]

I: Yeah, of course, okay. And so the next question I’ve got for you centres on chemical equilibrium, so it’s a similar one. This one's more pitched at first, second year undergraduate level and it is designed to catch people out, just so you’re aware. So we asked a question that is given there; so there is an equilibrium system and we asked teachers of A level chemistry what they thought the effect on the position of equilibrium would be if you added neon with the system remaining at constant temperature at pressure, so same temperature and pressure before and after the neon has been added to the system. So the blue bars signify what the teachers initially thought. We then invited the teachers to discuss the answer with one another and then the red bars indicate what they then answered after they discussed it. So you can see that more teachers said that there was no shift to begin with, and then their opinion changed after discussion and more of them thought there was a right shift. So again I’m not asking for the correct answer, but why do you think that those were the typical responses of the teachers? It is a tough question, and we’re not trying to catch you out.

R: No, I mean it’s uhh…..I mean I would suspect that it’s something to do with a misconception of exactly what information is being given and what the likely effect on a position of equilibrium is. I mean I know given constant temperature and pressure so the total pressure is the same?

I: Yeah

R: The total overall pressure is the same.

I: Yeah

R: I think it’s about whether people, whether there’s a real understanding of partial pressure is, and therefore what the effect of doing that on the expression that gives you Kp if its at equilibrium is going to be. And I think that I’m reluctant to answer it without a piece of paper to try and go through and work it out.

I: Well that's it, I know that if you do have a piece of paper with you and you were going to answer it, you would find the same that it would be a right shift. Because you’re on the right lines it’s all to do with KP and the partial pressures, yeah so when you add the neon the partial pressures of all the species decrease because the total pressure is the same, and therefore when you look at the Kp equation you see there are more values on the bottom.

R: And I suspect that the reason that a lot of people say no shift to start with is because well if the pressure and the temperature are constant then there’s going to be no change in the position of the equilibrium, because if the pressure is constant it won’t move either way, if the temperature is constant it won’t move either way, and I suspect that's why it’s going on, it's all to do with what goes on with KP which interestingly the new A level specification does try to get in to in some sense.

I: Yeah it does.

R: I think it gets in to it probably too superficially to be worth something and then, because I end up trying to explain it to my students and they sort of get the equations and so on and so forth and then when you look at exam mark schemes they’re very sort of, they’re very blasé about it “oh well, the top decreases more than the bottom” and you sort of think, well I know what they’re trying to do, they’re almost trying to do something to put it on the A level spec which is a good thing, but then they’re not really quite sure how they’re going to assess it.

I: Yeah, yeah, okay that’s great. So having considered those problems that have just been presented to you, so this one regarding equilibrium and this one regarding structure and bonding, they rely on, you know if you rely on the octet rule and you rely on Le Chatelier’s principle it's going to cause some problems. What we want to know is do you believe personally that the limitations of chemical models and analogies should be taught at A level or at GCSE? At both, or at neither? So what’s your opinion on that?

R: I would say that limitations of models should be taught all the way through otherwise they’re presented as gospel and then suddenly you shoot at them. I mean suppose then there’s a within reason argument because I’m not suggesting we go and we sort of delve into quantum mechanics at A level and so on but I think that the fact that there are limits to the models students should appreciate sooner than they do.

I: Okay.

R: I wonder sometimes whether part of that issue comes from the fact that very very rarely is lower secondary school chemistry taught by a chemist. A lot of schools yes by the time they get to GCSE they might be taught by a chemist, but they haven’t got enough chemists to be able to teach it lower down so they’re all being taught by biologists, who probably, who don’t necessarily have the level of understanding. They know enough to be able to teach the spec and what's tested but they don’t necessarily have the full level of understanding.

I: And do you think that’s an issue?

R: Yes.

I: Do you think we need to do, do you think there’s anything we could do to get more chemists to go into teaching?

R: [Laughs] You mean other than pay them more?

I: [laughs]

R: I think we need to look at salaries, I think we need to look at status and I think we need to look at the demands that are put on teachers.

I: I would wholeheartedly agree with all three of those points. Yeah, okay, well that's all the questions I have.

R: Oh right.

I: Thank you very much.