The Web Practice of Mathematicians on the Web: An Insight into Significant but Neglected Web Groups

Mandy Lo, Hugh Davis, Julie-Ann Edwards, Christian Bokhove
University of Southampton
England, UK
{cmml100, hcd, J.S.Edwards, C.Bokhove}@soton.ac.uk

ABSTRACT
In this paper, we describe the findings from a three-year multi-phased investigation into the Web practice of online mathematics communities. Our results indicate that the equivalent technologies that enable text-input or image-uploads without the need to understand programming languages have not been made available for the mathematics/ scientific communities to enable fluid communications. Given the global importance of mathematical and scientific collaborations, we argue that the mathematical and scientific communities are significant but neglected groups, and that more attention should be given to the user-interface designs to support fluid online mathematics communications.

Categories and Subject Descriptors
H.5.3 [**Information Systems**]: Information Interfaces and Presentation – *Web-based interaction.*

Keywords
Mathematics Communication, Web Practice, Mathematical and Scientific Communities, User Interface, Handwriting Recognition.

1. INTRODUCTION
The Web is hailed as the universal communication platform, and an ideal platform for supportive/ collaborative communication. However, "the lion's share of online interaction is still in the form of written text" [4], and in terms of "support for mathematics expression… a practical and intuitive mathematics input for users is still under investigation" [8]. While the difficulty with mathematics input is widely acknowledged, little is known about the impact this is having on Web communities that are heavily dependent on mathematics communications.

2. ETHNOGRAPHIC OBSERVATIONS
After examining 500 posts on a popular mathematics forum typically used by young mathematicians, a total of 4819 mathematical statements were found to be posted over a 25-day period. The amount of mathematical statements posted by young mathematicians within the short period of time, and during the summer holiday period, clearly demonstrates the vibrant activities within the forum, and it highlights the potential for the Web as a medium for collaborative mathematics communication.

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Most of the mathematical expressions were entered using Latex (50.11%) or ASCII (44.24%). The use of ASCII plain text is at times sufficiently effective for communication purposes. However, when algebraic fractions are involved, ASCII plain text is evidently inadequate. In order to engage with the mathematics, $(\sin(n+1)A-\sin(n-1)A)/(\cos(n+1)A+2\cos(nA)+\cos(n-1)A$ must first be converted into a format as shown in Figure 1 before one can begin to interpret/ comprehend the mathematics communicated. One major issue with ASCII plain text is that mathematics communication can become unwieldy, and sometimes confusing. Therefore, when complex mathematics is involved, the use of ASCII plain text can distract the user from the mathematics and render its use unsuitable for spontaneous communication. As Bos explains, in order for a piece of technology to be useful for mathematicians, the technological representation of mathematics must be faithful to a) the mathematics represented and b) the cognitive process of mathematics [1].

$$\frac{\sin(n+1)A-\sin(n-1)A}{\cos(n+1)A+2\cos(nA)+\cos(n-1)A}$$

Fig 1. A mathematical formatting which enables interpretation and comprehension.

Although Latex can be helpful, an expert helper with more than 10,000 posts wrote, "*I wasn't about to Latex it all*", and provided a scanned-copy of his/ her handwritten work instead. These Latex-replacement-uses of scanned-pictures show that, unlike text-based communications where users are often able to think and communicate simultaneously, mathematicians are having to rely on pen and paper methods for mathematical thinking, before communicating through the Web. This Web practice, peculiar to online mathematics communication, indicates a heavy cognitive cost associated with online mathematical communication.

3. PARTICIPATORY RESEARCH FINDINGS
Of the 80 online questionnaire participants, 72% believe handwriting recognition technologies will be useful. Regarding MathPen, our handwriting recognition user-interface designed to address the challenge of online mathematics communication, experts with extensive online mathematics communication experiences commented:

> *"I have used the free Microsoft Mathematics 4 on a tablet PC and on an interactive whiteboard, although it is not very accurate and it is only one line at a time. The ability to convert multiple lines is particularly attractive" --- Head of Department, Comprehensive Secondary School, UK*

"Scanning to jpeg goes partway; Using MathType can be slow but is easily edited. If editable markup is available, MathPen would be a superior choice" --- Emeritus Professor of Mathematics Education, USA.

"I do have experience with web sites that offer Latex symbol recognition by drawing the corresponding math symbol using the mouse. If MathPen works as shown in the video, then MathPen is a vast improvement over what I described above" --- Experienced Mathematics Teacher, Community College, USA.

"MathPen would let me concentrate on substance rather than formatting." --- Expert Helper of a Free Math Site

"MathPen streamlines computer-mediated math communications; Learning Latex is tedious and will no longer be necessary." --- Professor in Mathematics Education, a university in Finland.

"Yes. A robust, reliable, scalable mathematical character recognition package compatible with the industry standard of Latex is long overdue and something that we have been saying should be developed for the past decade." --- Senior Lecturer in Mathematics, UK

Finally, our real life trial with young mathematicians aged 15-16 revealed that, compared with the control group using only keyboard and mouse entry methods, the intervention groups using MathPen had better mathematical engagement, spent more time in progressive discussion and had sustained interest throughout the group discussion. By contrast, the control group became disengaged with the mathematics, spent more time in summarising ideas rather than progressing the discussion and eventually abandoned the mathematical discussion completely.

4. DISCUSSION AND CONCLUSIONS

From a Web Science point of view, the online mathematics communities (and by extension, the scientific communities) function in much the same way as any other online communities. The frequent and in-depth mathematical discussions on these forums highlight the eagerness to communicate mathematically. This, therefore, poses a challenge to those who, on basis of the common belief that mathematics is "difficult, challenging and boring" [2], believe that interactive mathematical discussions online are relatively scarce because of a lack of interest in mathematics.

Instead, we argue that where text-based communications enjoy a wide range of tools which enable faster and more accurate text-input as well as easy means for image-uploads, the equivalent attention and/or development has not been extended to the mathematics and scientific communities. This, in turn, hampers the fluency of online mathematics communication, which in turn has the effect of unintentionally marginalising the mathematics and scientific online communities.

The mathematics and scientific communities are sizable communities with both scientific and economic significance. Researchers such as Harasim and Wegerif have written extensively on the Web's significant role in accelerating scientific and academic knowledge progress through better collaborative communications within the scholarly communities [3, 9]. The mathematics and scientific communities are also recognised by politicians and ministers as economically significant [5, 6]. As researchers such as Reeves argued, research which only concerns itself with theoretical advancements, with little consideration of how this may be implemented for the general public, and assuming that the research finding will somehow turn into public good, is "*socially irresponsible and a job incomplete*" [7]. While we do not believe any researchers are intentionally irresponsible, we do argue, from a socio-technical Web Science standpoint, that the mathematics and scientific communities are significant but often neglected groups, and that the Web needs to be more inclusive for these unintentionally marginalised communities. Therefore, on the basis of these findings, we suggest that technological advancements in Web protocols, such as MathML, alone is insufficient (a job incomplete), and that more research into suitable user-interface/ interaction designs for online mathematical communications should accompany these.

5. ACKNOWLEDGMENTS

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