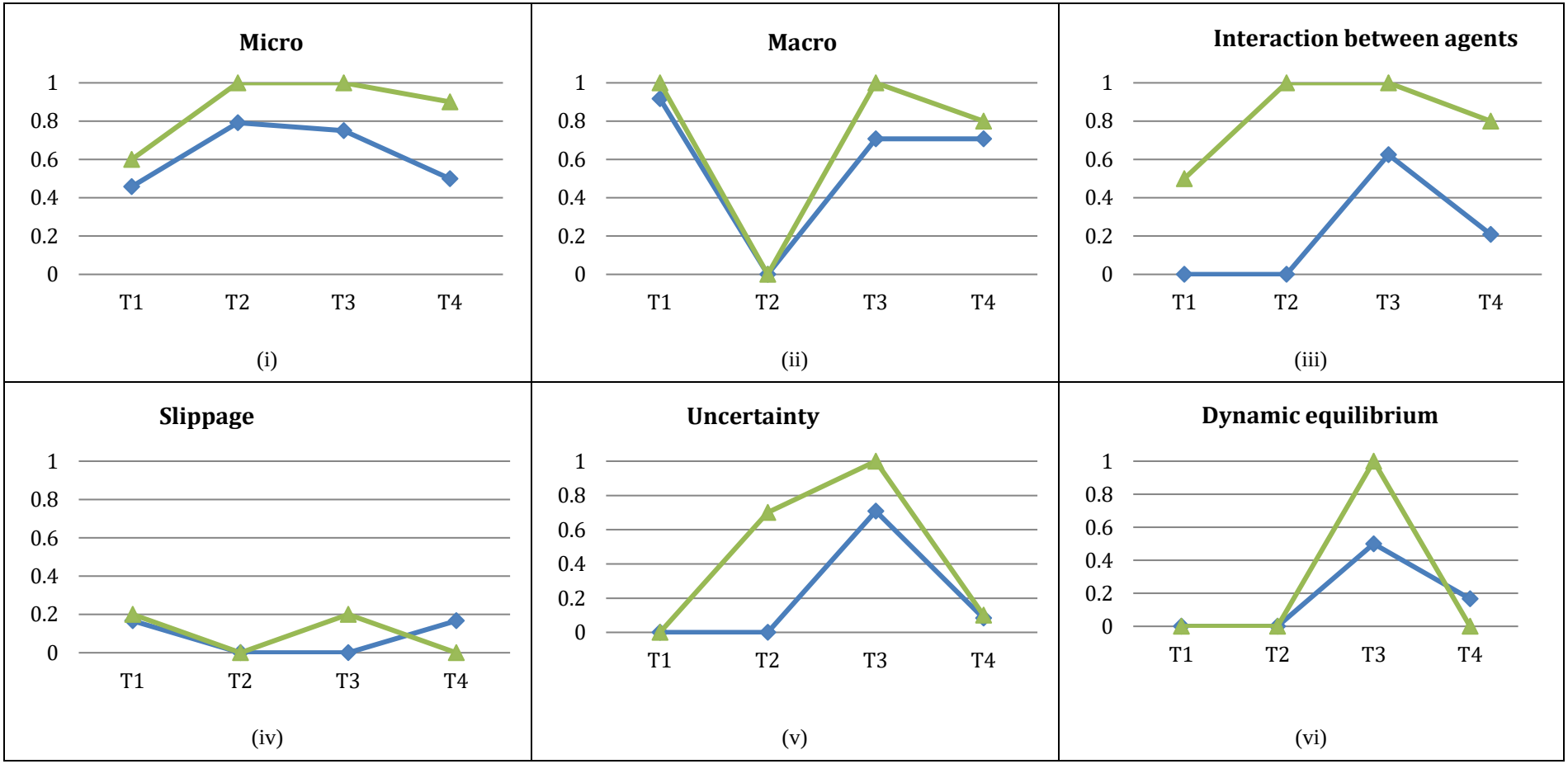
Supplementary Material

Learning progression graphs not included in the main text


Micro
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(i)
Macro
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(ii)
Interaction between agents
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(iii)
Slippage
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(iv)
Uncertainty
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(v)
Dynamic equilibrium
1
0.8
0.6
0.4
0.2
0
T1
T2
T3
T4
(vi)

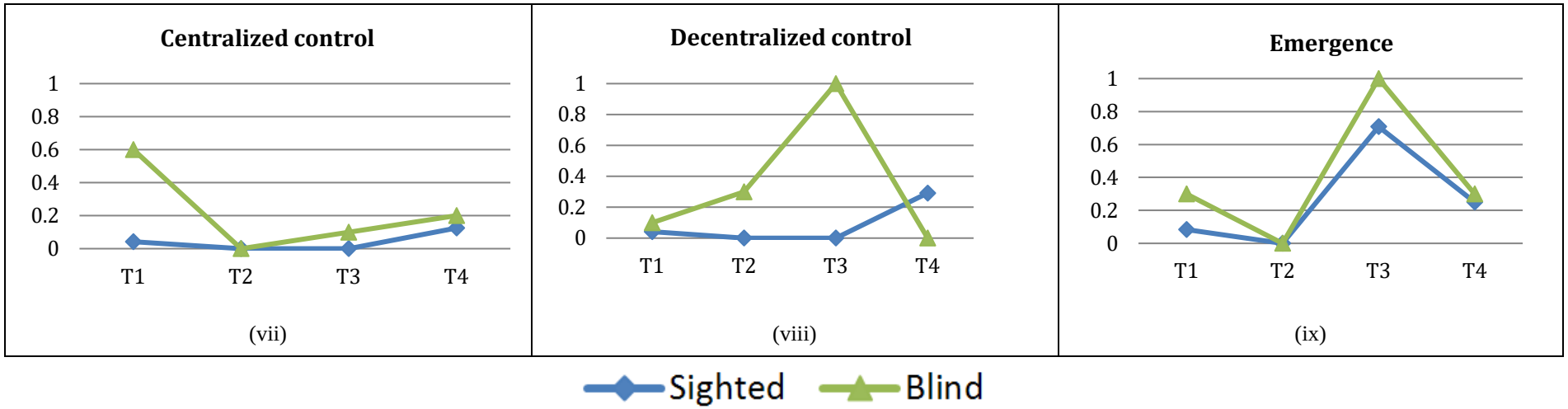
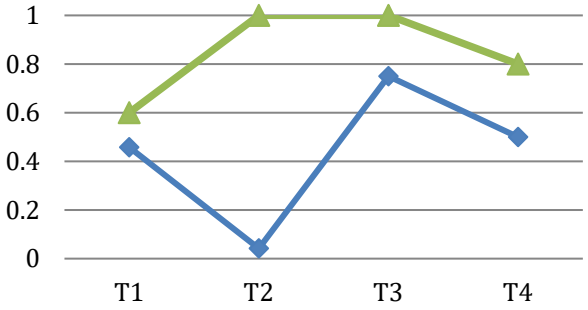
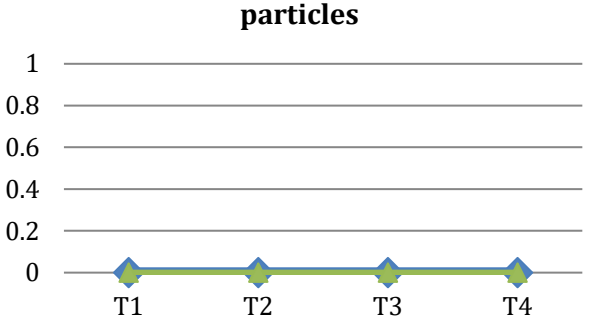


Figure S1. Learning progression of systems thinking.

The graphs depict the expression of nine components of systems thinking in items chosen in four progression analysis windows (T1, T2, T3, T4). The y-axis show the rate of expression of the component in the items. If the component was expressed in all items in the window, the score shown on the graph would be 1.



(i)



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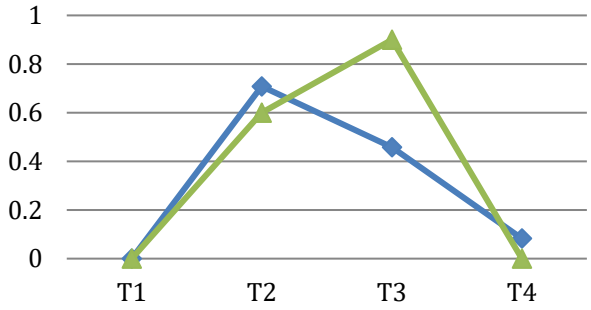
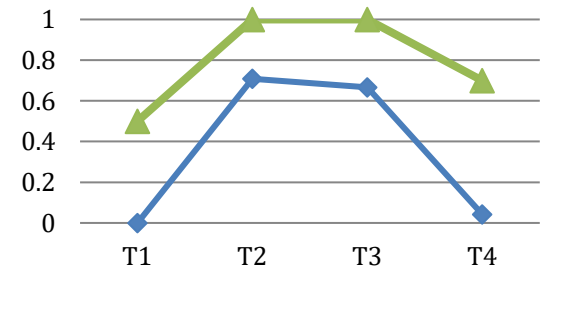


(iii)



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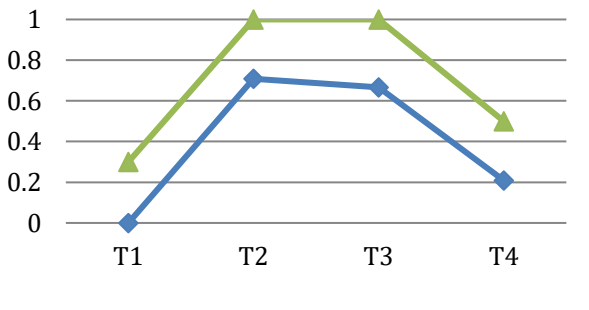
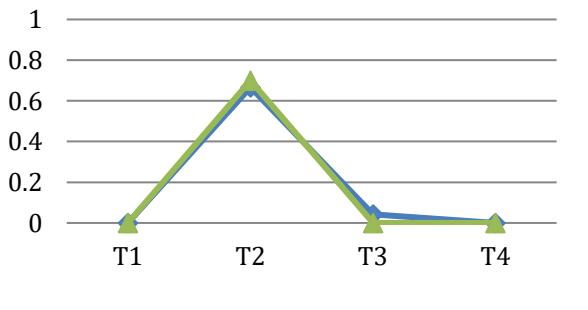


(v)



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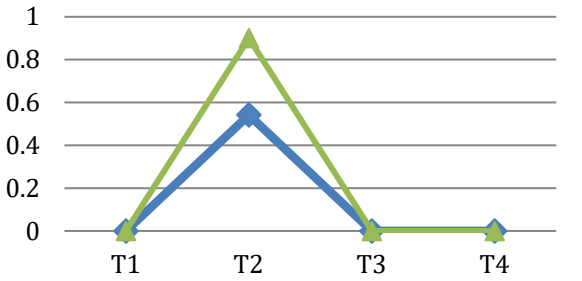

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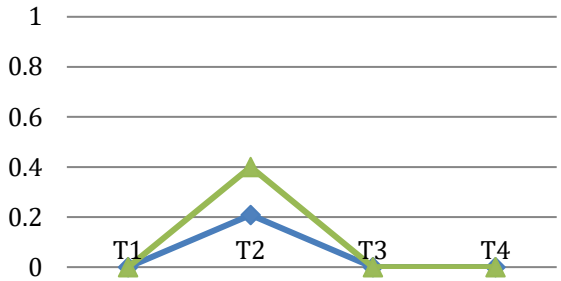

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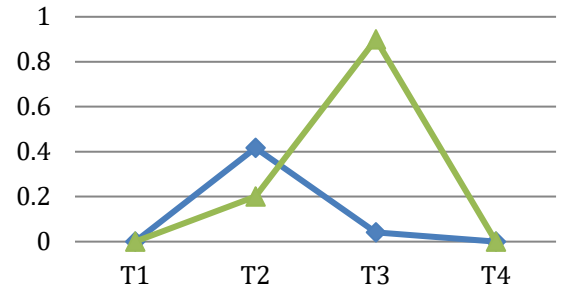

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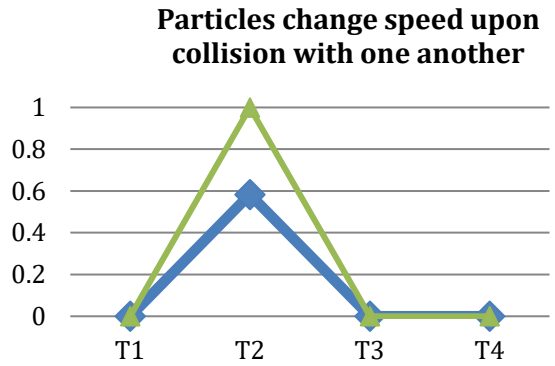
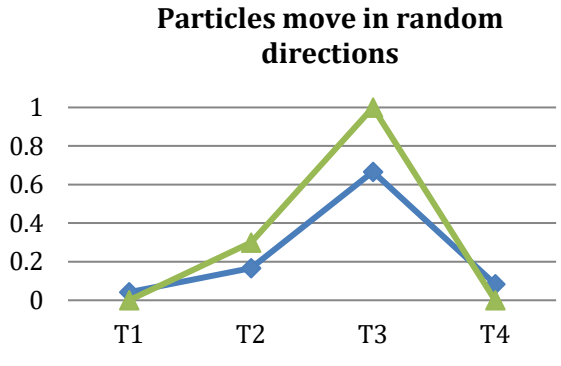
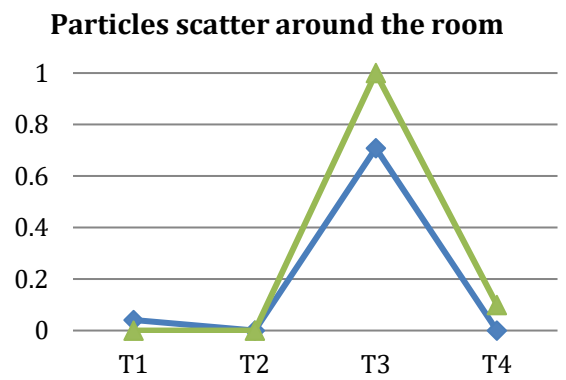


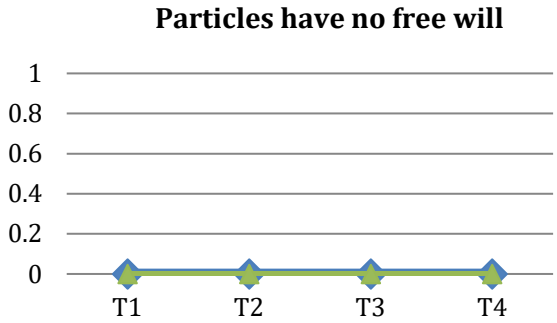
(x)



(xi)



(xii)



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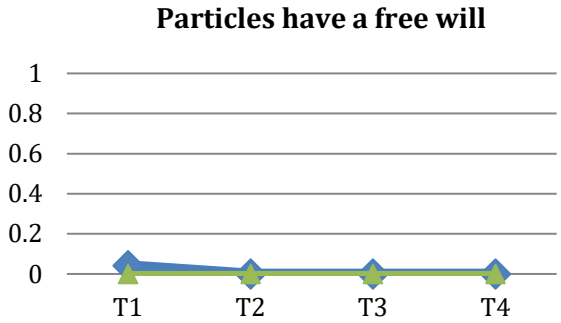

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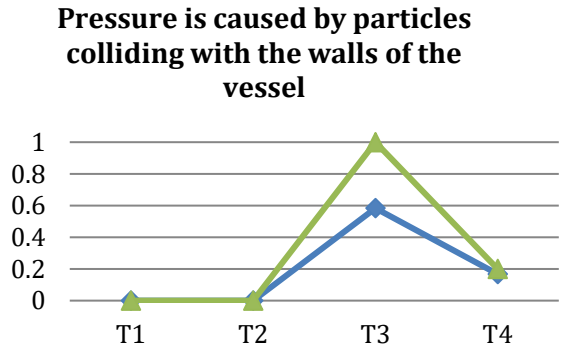
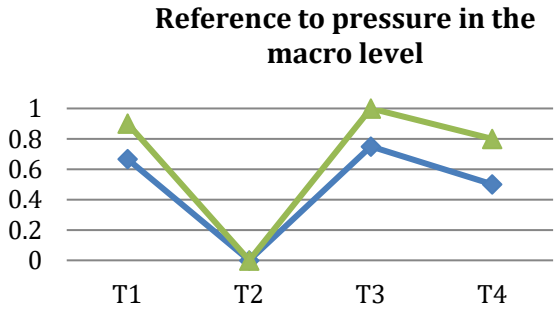


(xv)



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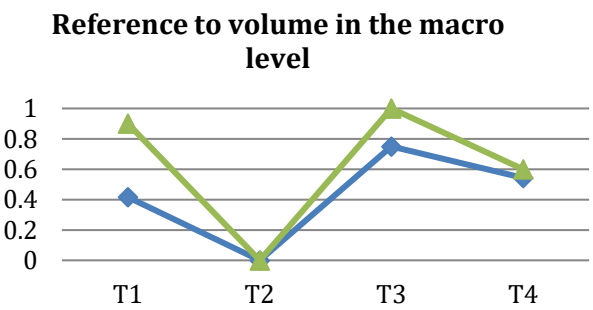

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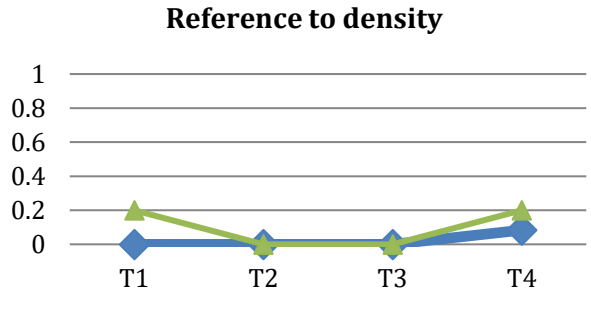

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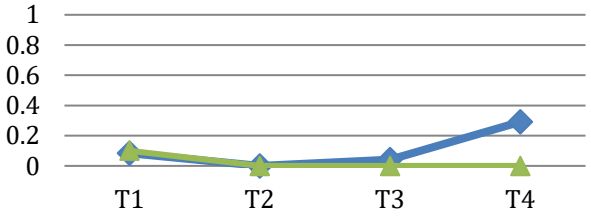

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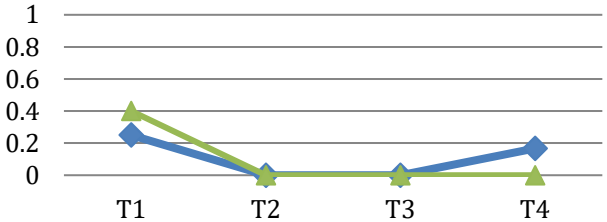

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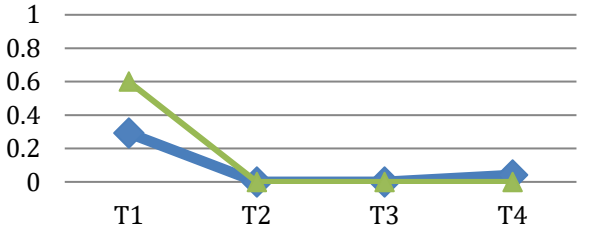

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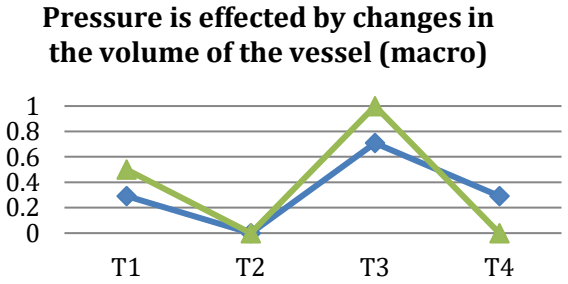

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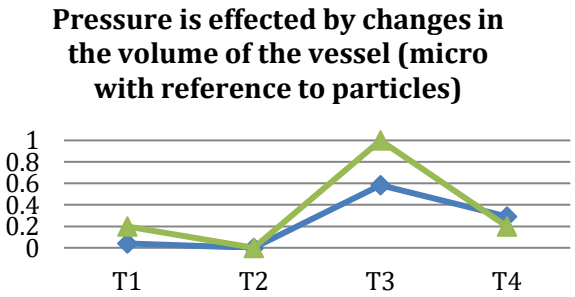

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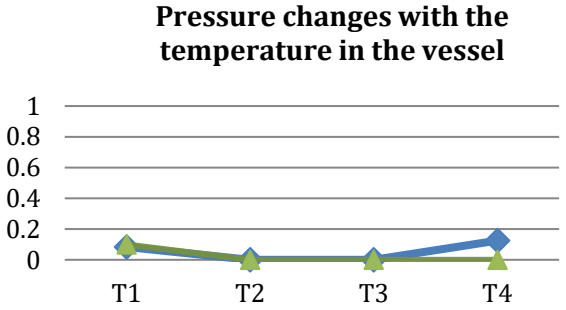

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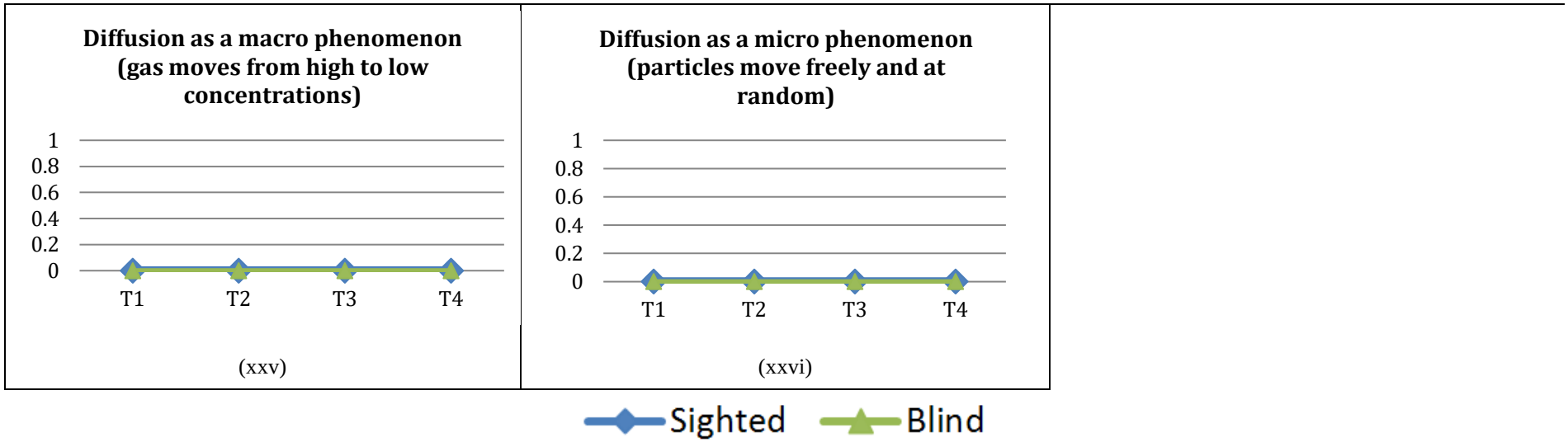

Figure S2. Appearance of 26 specific scientific explanations in the four time windows (T1, T2, T3, T4) in the workbook.

The graphs show expression of specific scientific explanations in four progression analysis windows (T1, T2, T3, T4). The y-axis show the rate of expression of the scientific explanation in the items. If the concept was expressed in all items in the window, the score shown on the graph would be 1.