Analyzing the Visual Literacy Skills of Enzyme-Substrate Representations of Undergraduate Students in Science-Related Courses Across the Chemistry and Biochemistry Curriculum

Juquila I. Contreras Vital[1], Chloé S. Morin[1], Vanessa Andrade[1], Xavier Prat-Resina[1], Cassidy R. Terrell[1]

1. University of Minnesota– Rochester, 111 S. Broadway #300, Rochester, MN 55904.

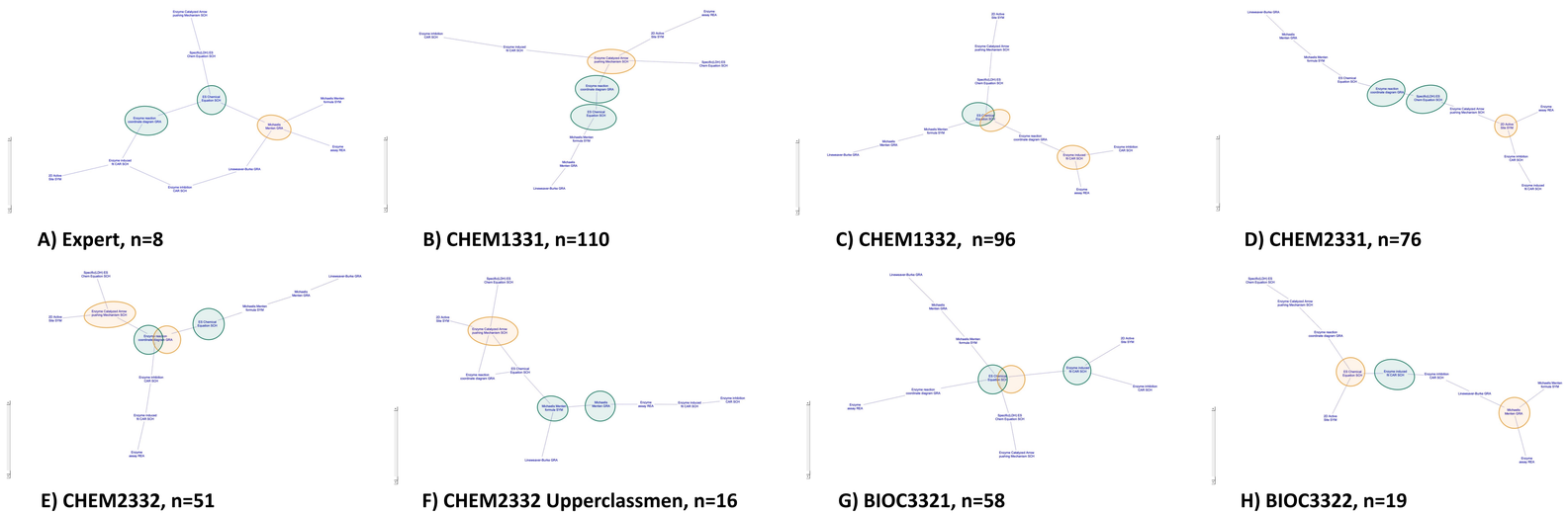
Abstract

The development of visual literacy skills in undergraduate students has both the potential to increase the interpretation of external representations and aid in the development of conceptual understanding. To date, there is very little visual literacy research addressing the capabilities of students in interpreting and storing information, and how students organize this information in their neural networks. This study aims to provide both visual and quantitative data on expert and student visual literacy skills with respect to enzyme-substrate representations. To do this, the data was taken specifically from chemistry and biochemistry courses across the curriculum. Rather than looking at individual data, the data was categorized based on course and was averaged via the Pathfinder program. This allows for the observation of progress, or changes, depending on the course in which the students are enrolled across the curriculum, which can then be used to compare against other findings. Through this, the Pathfinder program was used to obtain the neural networks of these averages and the network properties such as degree values and eccentricity values. The degree values look at the nodes that are the most branched, or who appear to be the most connected to other concepts. The eccentricity values look at the most central node, or what is deemed to be most closely connected to other concepts, and this is indicated by a lower value. The average student neural networks and quantitative values were analyzed in reference to the average expert neural network and quantitative values. These findings may provide insight into how student organization of knowledge and visual literacy skills are acquired and maintained, which can be helpful in aiding educators adapt their curricula to further support student learning in relation to scientific topics.

Data and Results

Research Questions

How do the neural networks of students evolve with respect to horizontal translation when compared to experts?
Do the neural networks of students differ depending on the amount of exposure to science-related courses?



A) Expert, n=8 **B) CHEM1331, n=110** **C) CHEM1332, n=96** **D) CHEM2331, n=76**

E) CHEM2332, n=51 **F) CHEM2332 Upperclassmen, n=16** **G) BIOC3321, n=58** **H) BIOC3322, n=19**

Figure 1: Average Neural Networks for A) Expert, B) CHEM1331, C) CHEM1332, D) CHEM2331, E) CHEM2332, F) CHEM2332 Upperclassmen, G) BIOC3321, & H) BIOC3322. The average network was obtained for each category for comparison. Each student network was generated from the expert reference network. While the student networks appeared to have a more linear shape and less branching, the expert network was more connected and has more branching from the center. Note that **F and H** consists of 3rd and 4th years. The central node/s are circled in green, while the max degree is circled in orange.

Data and Results

Eccentricity	2D Active Site SYM	ES Chemical Equation SCH	Specific(LDH) ES Chem Equation SCH	Enzyme inhibition CAR SCH	Enzyme reaction coordinate diagram GRA	Enzyme induced fit CAR SCH	Lineweaver-Burke GRA	Michaelis Menten formula SYM	Michaelis Menten GRA	Enzyme assay REA	Enzyme Catalyzed Arrow pushing Mechanism SCH
ES Gluc Expert	5	**3***	4	5	**3***	4	4	5	4	5	6
CHEM1331 (CHEM1)	**6**	**4***	6	7	**4***	6	7	5	6	7	5
CHEM1321 (CHEM2//Ochem1)	6	**3***	4	6	4	5	6	4	5	6	5
CHEM2331 (CHEM3//Ochem2)	7	6	**5***	**8**	**5***	9	9	7	8	8	6
CHEM2332 (CHEM4//GenChem2	6	**4***	6	5	**4***	6	7	5	6	7	5
CHEM2332 (CHEM4//GenChem2	7	5	7	7	6	6	5	**4***	**4***	5	6
UMRBIOC3321	5	**3***	4	5	4	4	5	3*	4	5	5
UMRBIOC3322	6	5	8	5	6	**4***	6	8	7	8	7

Table 1: Eccentricity values for each node and the corresponding course. Lower values of eccentricity are deemed to be more central or more closely connected to other concepts. Most of the groups share a common central node with the experts, regardless of their more linear shape of the neural map. These values, however, were either the same or even a bit higher than that of the experts. While they may group concepts together similarly, their connection with concepts are not as central with each other. The central node is bolded.

Degree	2D Active Site SYM	ES Chemical Equation SCH	Specific(LDH) ES Chem Equation SCH	Enzyme inhibition CAR SCH	Enzyme reaction coordinate diagram GRA	Enzyme induced fit CAR SCH	Lineweaver-Burke GRA	Michaelis Menten formula SYM	Michaelis Menten GRA	Enzyme assay REA	Enzyme Catalyzed Arrow pushing Mechanism SCH
ES Gluc Expert	1	3	2	2	2	3	2	1	**4***	1	1
CHEM1331 (CHEM1)	2	2	1	1	2	2	1	2	2	1	**4***
CHEM1321 (CHEM2//Ochem1)	1	**3***	2	1	2	**3***	1	2	2	1	2
CHEM2331 (CHEM3//Ochem2)	**3***	2	2	2	2	1	1	2	2	1	2
CHEM2332 (CHEM4//GenChem2	1	2	1	2	**3***	2	1	2	2	1	**3***
CHEM2332 (CHEM4//GenChem2 3rd/4th yrs	1	3	1	1	2	2	1	3	2	2	**4***
UMRBIOC3321	1	**4***	2	1	2	3	1	2	2	1	1
UMRBIOC3322	1	**3***	1	2	2	2	2	1	**3***	1	2

Table 2: Degree values for each node and the corresponding course. The higher the number of degree, the more connected it is to other nodes, meaning it is more branched. Each group had a max degree of either 3 or 4, however, this varied for each node. Each node had on average either 1 or 2 branches. The max degree is bolded.

Conclusions and Future Directions

Conclusions

- In comparison to expert neural networks, student networks appear to remain relatively linear across the curriculum.
- Based on the quantitative data, the eccentricity values for students were either the same or a bit higher compared to experts, however, this varied for each node, meaning the connection for the concepts and what was deemed to be central differed in comparison to the experts.
- Student neural networks do not become more expert-like
- While the curriculum can be assumed to get more complex, student knowledge organization and visual literacy skills, such as horizontal translation, change very little.

Next Steps

Move onto generating heat maps for data visualization as well as to determine further meaning of data.

Funding, References & Acknowledgements

We would like to thank the chemistry and biochemistry students at the University of Minnesota Rochester who participated in our study. This project was supported by the University of Minnesota's Undergraduate Research Opportunities Program. The project was approved by the UMN IRB under STUDY00012054.

Neiles, K. Y., Todd, I., & Bunce, D. M. (2016). Establishing the Validity of Using Network Analysis Software for Measuring Students' Mental Storage of Chemistry Concepts. *Journal of Chemical Education, 93*(5), 821-831.

Neiles, K. Y. (2014). Measuring Knowledge: Tools to Measure Students' Mental Organization of Chemistry Information. *American Chemical Society,* Washington, DC.

Offerdahl, E. G., Arneson, J. B., & Byrne, N. (2017). Lighten the Load: Scaffolding Visual Literacy in Biochemistry and Molecular Biology. *CBE—Life Sciences Education*, *16*(1), 1-11.

Schönborn, Konrad J, & Anderson, T. R. (2010). Bridging the Educational Research-Teaching Practice Gap: Foundations for Assessing and Developing Biochemistry Students' Visual Literacy. *Biochemistry and Molecular Biology Education*, *38*(5), 347–354.