UNIVERSITY OF MINNESOTA ROCHESTER

# The Organization of Learning: Measuring How Students Connect the Visual Literacy Skill of Vertically Translating the Oxygen Binding Concept

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## Abstract

Biochemistry is an upper-division course that teaches topics using visual representations of systems of data, which can be a very challenging way for students to learn. To lessen their cognitive load, students may find that improving visual literacy skills aids their understanding of biochemistry. There is little existing research that assesses how students interpret and store biochemical information and representations in their memory. Previous studies performed with undergraduate chemistry students measured structural knowledge, or neural networks, of topics by asking students to categorize the relatedness of diverse chemistry-related words/phrases. Our study intends to analyze neural networks of a biochemistry visual literacy skill by requesting university students to rank the relatedness of biochemical representations as an alternative to words/phrases. Specifically, this study assesses students' structural knowledge of the vertical translation visual literacy skill, relating to the oxygen binding concept. Preliminary analyses compare the University of Minnesota Rochester's (UMR) students enrolled in chemistry and biochemistry courses to assess if students are becoming more expert-like in correlation with their exposure to chemistry. The data from student responses is analyzed in Pathfinder against an expert reference network to generate average degree and eccentricity values, as well as average neural network images. Degree values indicate the most branched nodes, while eccentricity values indicate the most central node in the neural network. We intend to discover if pedagogical strategies and course instructional modalities impact students' neural networks related to the oxygen binding concept, which may aid the improvement of curricular materials for optimal learning and retention of information.

## Research Questions

How do the neural networks for the vertically translated oxygen binding concept compare for students at the University of Minnesota Rochester's (UMR) by years (freshman-senior)? Across the UMR freshman-senior year timeline, are students becoming more expert-like?

## Study Timeline

**Data Organization (Spring 2022)**
- Background research and wrote UROP grant
- Organized Oxygen Binding survey data
- Processed data through Pathfinder
- Obtained quantitative data values for experts and student participants

**Data Processing (Summer 2022)**
- Collected average neural networks from students according to course using Pathfinder
- Used Pathfinder to generate Degree and Eccentricity values

**Data Analysis (Summer 2022)**
- Data were analyzed against the experts to provide evidence for our research question

*Figure 1:* **Study timeline.** Timeline of this research project is during Spring 2022-Summer 2022. We are currently in the data analysis phase of this project.

## Data

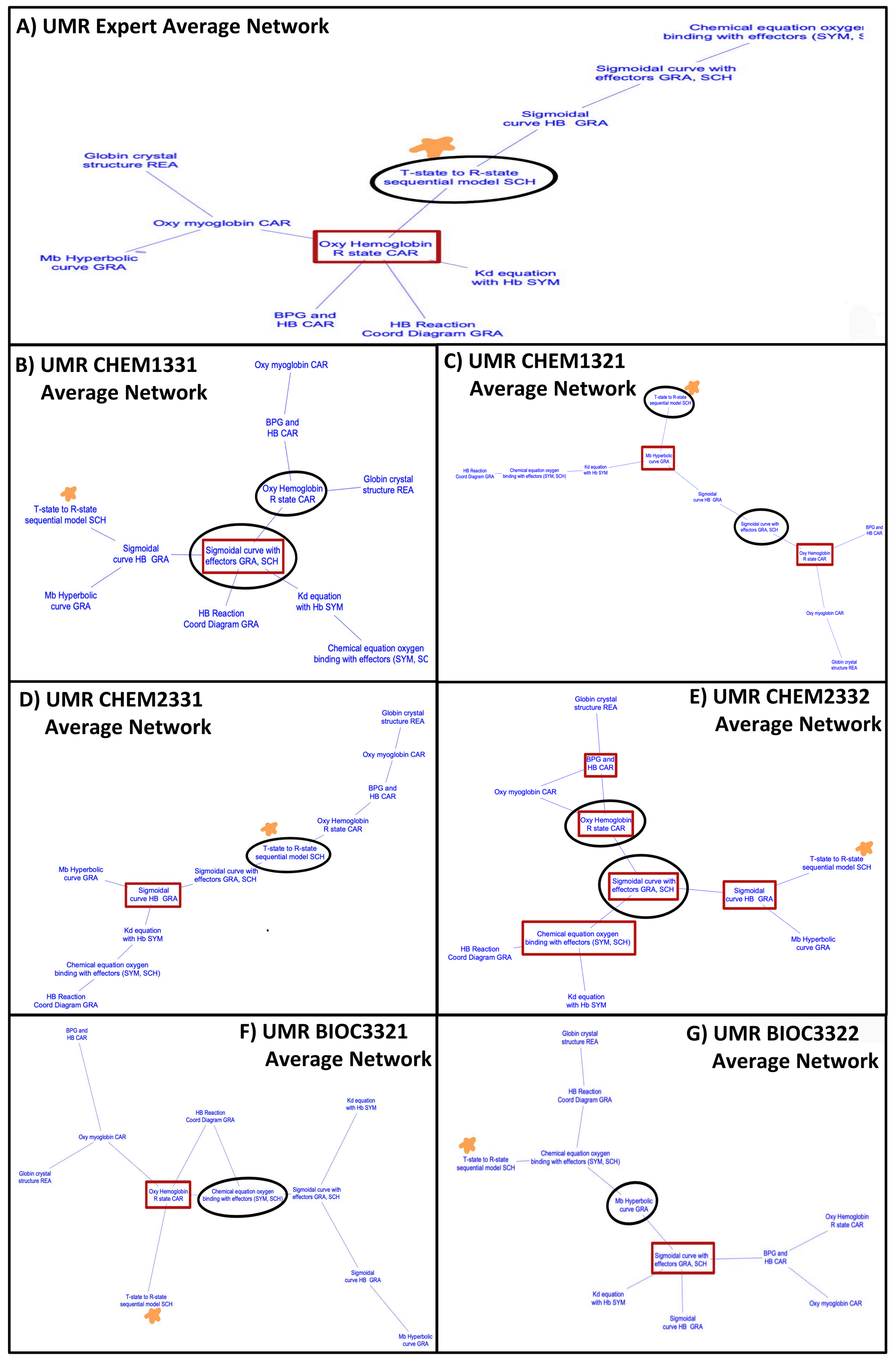


*Figure 2:* **Expert (A), CHEM1331 (B), CHEM1321 (C), CHEM2331 (D), CHEM2332 (E), BIOC3321 (F), BIOC3322 (G) UMR average networks.** In the images above, the orange star represents which node is the central node based on the expert network, the red rectangles are the most branched node, and the black circles represent the most central nodes. The UMR Expert Network (A) was used to compare against each average student network. By assessing the images alone, BIOC3321 (F) appears to be the most expert-like due to similar node placement, contrasting BIOC3322 (G) which appears to be the least expert-like.

## Results

| Degree Table | BPG and HB CAR | Chemical equation oxygen binding with effectors (SYM, SCH) | Sigmoidal curve with effectors GRA, SCH | HB Reaction Coord Diagram GRA | Oxy Hemoglobin R state CAR | Oxy myoglobin CAR | T-state to R-state sequential model SCH | Globin crystal structure REA | Mb Hyperbolic curve GRA | Kd equation with Hb SYM | Sigmoidal curve HB GRA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OB Expert | 1 | 1 | 2 | 1 | 5* | 3 | 2 | 1 | 1 | 1 | 2 |
| CHEM1331 | 2 | 1 | 4* | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 3 |
| CHEM1321 | 1 | 2 | 2 | 1 | 3* | 2 | 1 | 1 | 3* | 2 | 2 |
| CHEM2331 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 3* |
| CHEM2332 | 3* | 3* | 3* | 1 | 3* | 2 | 1 | 1 | 1 | 1 | 3* |
| BIOC3321 | 1 | 2 | 3 | 1 | 4* | 3 | 1 | 1 | 1 | 1 | 2 |
| BIOC3322 | 3 | 3 | 4* | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |

*Table 3:* **Table of student degree values from all chemistry/biochemistry courses at the university of Minnesota Rochester.** In the table, the black boxes and bolded numbers with * represent the highest degree value at which a single node connects with another node. When comparing the student values to the expert values, CHEM1321, CHEM2332, and BIOC3321 are closest to expert-like knowledge, with BIOC3321 the most expert-like. BIOC3322 is the least expert-like since the degree for OXY Hemoglobin R state CAR is the lowest. CHEM2332 categorizes five of the eleven nodes as equally related, while all the other nodes except CHEM1321, which indicates two nodes, only have one node with the highest connections.

| Eccentricity Table | BPG and HB CAR | Chemical equation oxygen binding with effectors (SYM, SCH) | Sigmoidal curve with effectors GRA, SCH | HB Reaction Coord Diagram GRA | Oxy Hemoglobin R state CAR | Oxy myoglobin CAR | T-state to R-state sequential model SCH | Globin crystal structure REA | Mb Hyperbolic curve GRA | Kd equation with Hb SYM | Sigmoidal curve HB GRA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OB Expert | 5 | 6 | 5 | 5 | 4 | 5 | 3* | 6 | 6 | 5 | 4 |
| CHEM1331 | 4 | 5 | 3* | 4 | 3* | 5 | 5 | 4 | 5 | 4 | 4 |
| CHEM1321 | 7 | 8 | 5* | 9 | 6 | 8 | 5* | 9 | 7 | 7 | 6 |
| CHEM2331 | 7 | 7 | 5 | 8 | 6 | 7 | 6 | 8 | 5 | 6 | 4* |
| CHEM2332 | 4 | 4 | 3* | 5 | 3* | 4 | 5 | 5 | 5 | 5 | 4 |
| BIOC3321 | 6 | 3* | 4 | 5 | 4 | 5 | 5 | 6 | 6 | 5 | 5 |
| BIOC3322 | 5 | 4 | 4 | 5 | 6 | 6 | 5 | 6 | 3* | 5 | 5 |

*Table 4:* **Table of student eccentricity values from all chemistry/biochemistry courses at the university of Minnesota Rochester.** In the table, the black boxes and bolded numbers with * represent the lowest eccentricity value, referring to the most central node in the network. When comparing the student values to expert values, only CHEM1321 has a similar central node to the experts, however it had the highest eccentricity numbers of all the courses. When looking at the numbers for the T-state to R-state sequential model SCH node, CHEM2331 appears to be the least expert-like as it has the highest number for eccentricity.

## Conclusion and Future Directions

In terms of degree values, most of the UMR courses have a similar node with the highest degree. This means that most of these courses are leading to students becoming more expert-like, with the exceptions of CHEM1331, CHEM2331, and BIOC3322. A loss of the retention of biochemistry knowledge is evident, as students in BIOC3321 have a high degree value of four, while the students of BIOC3321 have a degree value of one for that node.

In terms of eccentricity values, none of the students in all UMR courses appear to be expert-like, as only one course shares the same central node. For almost all the courses, the eccentricity values are much higher than the experts, which indicates a lack of expert-like knowledge. Looking at the networks,, BIOC3321 has a similar pattern, where T-State to R-State sequential model SCH, Oxy Hemoglobin R State CAR, and Chemical equation oxygen binding in effectors (SYM, SCH) are all connected in a similar way, indicating expert-like behavior.

→ Across the freshman-senior year curriculum, students become most expert-like in BIOC3321, as they have the most biochemistry knowledge, however, in BIOC3322 they lose that biochemistry knowledge due to a loss of retention.

→ Report on findings in an academic journal article to help encourage further research

## References and Acknowledgements

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