Patterns of student reasoning in solving structures from organic spectra

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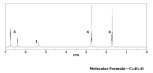
Problem solving in the context of organic spectroscopy is highly dependent on students' abilities to accurately interpret expert-like external representations (ER). Building on Schönborn and Anderson's[1] model of interpreting biochemistry ERs, we revised their 3-Phase Single Interview Technique (3P-SIT) to examine the nature of student reasoning while solving structures of organic compounds. In efforts to examine patterns of student reasoning, we utilized Carlson and Bloom's[2] framework in the phases of problem solving.

Methods

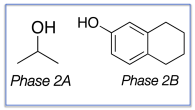
Selected spectra



Adapted 3P-SIT

Interviewed students upon spectroscopy instruction → Analyzed student-generated structures → Examining the phases of problem solving

- Students were enrolled in the second semester sequence of organic chemistry at two different universities (N=20)
- Students were prompted to solve the structures of two compounds from ^{1}H NMR spectra, with our primary focus on Phase 2B



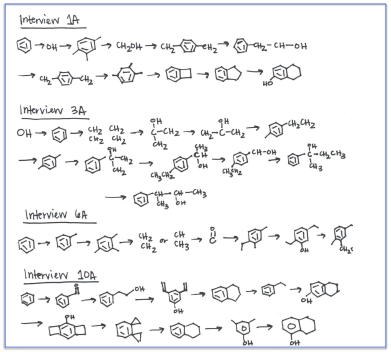
- Transcribed interviews were coded in Nvivo for:
  - Resources
  - Reasoning
  - Monitoring
- Videos were coded for instances when participants:
  - Sketched parts of structure
  - Sketched complete structures
  - Consulted the provided chemical shift table

Problem Solving Phase	Behaviors	Spectroscopy Examples
Orienting	Sense making	Asks questions about the given spectrum or reiterates parts of the problem.
	Organizing	Makes a table, or label parts of the problem like the chemical shift ranges for functional groups.
Planning	Conjectures on viable approach	Interprets what the structural pieces might be from individual peaks.
	Imagining of how the approach would play out	Considers how the pieces might fit together in the whole structure.
	Evaluation of the viability of the conjecture	Looks at the chemical shift ranges or the molecular formula to confirm their idea.
	Decision to carry out strategy	Continues on to draw the whole structure together (executing) or will make a new conjecture.
Executing	Decoding	Deciphers neighbors from splitting, or hydrogens from integration.
	Accesses resources	Looks at given chemical shift table.
	Executing strategies and procedures	Draws whole structure from the parts planned out. Calculates elements of unsaturation.
Checking	Verification	Checks the correctness of their whole structure, by counting atoms or bonds and considering the spectrum.
	Reflections about the reasonableness of the solution and computations	Makes comments on their results about how their structure looks overall.
	Decision to accept/reject results	Cycles back to make new conjectures of the same part of the problem or cycles forwards to make plans about a new part.

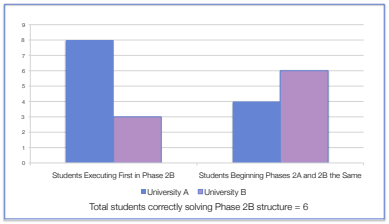
Preliminary Results

Phase 2B, University A

Interview 1A*	Interview 3A	Interview 6A	Interview 10A*
Executing	Executing	Executing	Executing
Planning	Planning	Planning	Planning
Executing	Executing	Executing	Orienting
Planning	Planning	Planning	Planning
Executing	Executing	Executing	Executing
Checking	Checking	Checking	Planning
Executing	Planning	Executing	Executing
Checking	Executing	Planning	Checking
Planning	Checking	Executing	Executing
Executing		Checking	Checking
Checking		Planning	Planning



Students in the class with procedural based instruction (University A), exhibit similar monitoring styles, yet their structural pathways are different (shown below left).



Phase 2B, University B

Interview 1B	Interview 2B	Interview 9B	Interview 10B
Orienting	Planning	Executing	Orienting
Executing	Orienting	Checking	Planning
Orienting	Executing	Planning	Executing
Planning	Planning	Orienting	Checking
Executing	Checking	Planning	Planning
Checking	Planning	Executing	Executing
Executing	Executing	Checking	Checking
Checking	Checking	Executing	Executing

Students in the class with emphasis on theory and no procedural instruction (University B), exhibit less similarity in monitoring styles, yet 60% of those students began both Phases 2A and 2B with the same steps.

Discussion and Future Directions

- Students receiving procedural problem solving instruction utilize the methods they are taught.
- Students not receiving procedural problem solving instruction still develop their own problem-solving processes.
- Although monitoring progressions can be similar, their generated structural pathways typically differ.

- Further examination of monitoring patterns may provide evidence of other reasoning strategies, e.g. trial and error.
- Connecting monitoring to the specific language used in the transcripts may elucidate what steps in monitoring lead from one structure to the next and the reasoning behind these actions.

References

1. Schönborn, K. J. & Anderson, T. R. A model of factors determining students' ability to interpret external representations in biochemistry. *Int. J. Sci. Ed.* **31**, 193–232 (2009).

2. Carlson, M. P. & Bloom, I. The Cyclic Nature of Problem Solving: An Emergent Multidimensional Problem-Solving Framework. *Educ Stud Math* **58**, 45–75 (2005).

For more information

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