Preliminary Findings Regarding Student Learning from Lecture and Homework

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Lectures and homework both provide opportunities for students to learn mathematics. Researchers have focused on learning from lectures (e.g.,Krupnik et al., 2018; Lew et al., 2016; Lew & Zazkis, 2019) and learning from homework (e.g., Dorko, 2021; 2020a, 2020b; 2019; Ellis et al., 2015; Glass & Sue, 2008; Kanwal, 2020; Krause & Putnam, 2016; Lithner, 2003; Rupnow et al., 2021). Dorko and Cook (under review; 2022) propose attending to learning across the two settings is crucial to improving student learning in both settings. To that end, our study addresses the questions (1) *What did two developmental mathematics students learn in lecture and what did they learn from homework?* and (2) *How can we explain why they learn particular things in a particular context?*

The data collected spanned eight 75-minute lectures, three written homework assignments, six online homework assignments, and one exam from a developmental math class at a large US university. This constituted the material from the class period following the first exam to the class period directly prior to the second exam, and the exam itself. The content included creating graphs on a graphing calculator, using the graphs to solve inequality and optimization problems, solving linear equations by hand, and using slope to find horizontal or vertical changes in right triangle problems. The data corpus includes videos of the lectures, videos of each student doing the homework, and an interview with each student about their graded exam. In the homework sessions, the interviewer asked students to "think aloud", asked where they had learned particular ideas, and showed students clips from the lecture video and asked what sense they had made of that portion of the lecture. In the post-exam interview, the interviewer and student discussed where the student felt they had learned the material tested in each question.

Because the course is a developmental math class, our theoretical perspective is that of *relearning*, which Amman and Mejia Ramos (2022) define as "learning about content that one has tried to learn before in a previous math course" (p. 752). Relearning is a suitable perspective for our work because it allows us to look at student learning in the context of homework and lecture in terms of the outcomes that are occurring and how the circumstances of the contexts support or limit those outcomes (Amman & Mejia Ramos, 2022). Data analysis is ongoing, following a thematic analysis method (Braun & Clark, 2020). Preliminary findings indicate students learned (a) how to identify independent and dependent quantities; how to use the calculator to make graphs, (b) how to interpret graphs, (c) how solving an inequality is different from solving an equation and how to do both on the calculator; (d) how to optimize functions on the calculator. Students commented that getting answers wrong in the online homework helped them understand how to solve inequalities and optimization problems.

For most of the items above, the students said they learned the ideas both in lecture and homework. Their comments indicated lecture exposed them to ideas and homework afforded an opportunity to "have to like remember and go back over how to do it" (Student 3) and have ideas "cemented in my brain" (Student 3).

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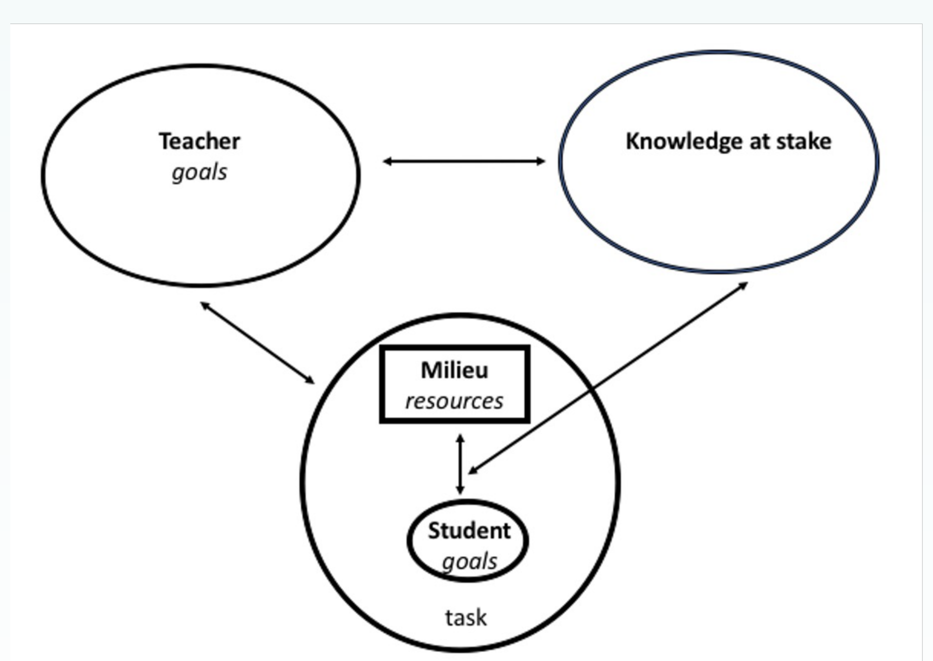
Abstract

Lectures and homework both provide opportunities for students to learn mathematics. Researchers have focused on learning from lectures (e.g., Krupnik et al., 2018; Lew et al., 2016; Lew & Zazkis, 2019) and from homework (e.g., Dorko, 2021; 2020a, 2020b; 2019; Ellis et al., 2015; Glass & Sue, 2008; Kanwal, 2020; Krause & Putnam, 2016; Lithner, 2003; Rupnow et al., 2021). However, these studies have focused on each milieu individually. Dorko and Cook (R&R, 2022) propose attending to learning across the two settings is critical for improving student learning in both settings. To that end, our study addresses the questions (1) *What did two developmental mathematics students learn in lecture and what did they learn from homework?* and (2) *How can we explain why they learn particular things in a particular context?*

Theoretical Perspective

Our work is broadly framed with the instructional triangle, and we make sense of an individual's learning through Piagetian learning theory.

- Instructional triangle (Cohen et al., 2005; Dorko, 2021; Herbst & Chazan, 2012): instruction is the interactions among teachers and students around content, in environments
  - Milieu: a space in which interactions around mathematical tasks occur
    - o Lecture is one milieu; HW is another



- Piagetian learning theory (von Glasersfeld, 1995)
  - Students' schemes entail (among other things) an expected result of applying the scheme.
  - Perturbation occurs when an outcome differs from the expected result.
  - Perturbation may or may not result in accommodation to achieve equilibration.
    - We define learning as accommodation to a scheme.

Literature

Though student learning from online homework is a relatively new focus for undergraduate mathematics education researchers, studies have shown:

- Online homework is as effective as paper-and-pencil homework (Dorko, 2020).
- Most successful US college calculus programs have an online homework component (Ellis et al., 2015).
- Students commonly rely on example problems to complete homework.
  - o In one study, 84.7% of students reported using worked examples while doing homework.

When completing online homework students used reasoning that included (Dorko 2021, 2020)

- Mathematical thinking
- Guessing
- Copying answers from various sources
- Mimicking the steps of a similar problem
- Reasoning based on expectations from experience

Students learn the procedures from online homework problems, but rarely develop the conceptual insights professors hope some problems might promote (Dorko, 2020, 2021, 2019)

Issues that professors face

- Students worry more about the procedure than the concept itself (Lew et al., 2016; Thompson, 2013; Thompson et al., 1994)
- Students only write what the professor writes (Lew et al., 2016)
- Students may miss verbal-only comments (Lew et al., 2016)

Data Collection Methods

Course context
We collected data from a developmental math class at a large US university. The content was from the class period following the first exam to the class period directly prior to the second exam, and the exam itself. The content included creating graphs on a graphing calculator, using the graphs to solve inequality and optimization problems, solving linear equations by hand, and using slope to find horizontal or vertical changes in right triangle problems.

The data collected include

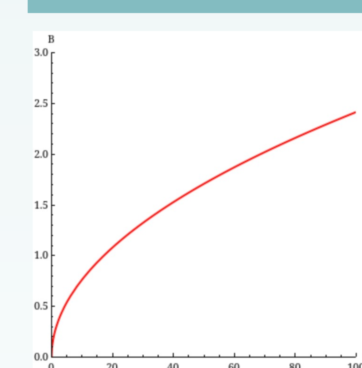
- Videos of eight 75-minute lectures,
- Videos of interviews with students as they completed
  - three written homework assignments
  - six online homework assignments
- The students' exam responses
- An interview with the students about their exams

Data Analysis Methods

Data analysis is ongoing, following a thematic analysis method (Braun & Clark, 2020).

1. Read lecture transcript, make list of the knowledge at stake (e.g. when/how/why to use CALC, INTERSECT on graphing calculator)
2. .Read transcript of HW that covered that content
   - Looked for influences of lecture on HW activity (e.g. doing something that was done in lecture, like using the TI-83 to find an intersection on a graph; using a word/phrase the instructor used, like "isolate" the variable)
3. In HW, identified instances student had to attempt problem multiple times, and sought to unpack how they worked their way to a correct answer
4. Repeat 1-3 for all lecture/HW pairs
5. For exam work and interview, looked at HW problems that covered same content as exam problem and what the student's activity looked like on that problem (e.g. multiple attempts, influences from lecture - see (1))

Example: Student 4 learned…



Online homework task: $B(w) = \frac{\sqrt{210w}}{60}$ gives the body surface area, B, in m^2, for a 210 cm tall man who weighs w pounds. Would weight gain have a greater effect on surface area for a lighter man or for a heavier man? (multiple choice)

Theoretical tenet	Data excerpt	Notes / explanation
Scheme	"I think that it's as someone gets heavier, their surface area increases, so would the weight gain have a greater effect on surface area for a lighter man or a heavier man, I think that means it's going to be heavier."	In S4's scheme for interpreting graphs, the only thing that matters is whether the graph is increasing or decreasing.
Expectation of scheme's outcome	That 'heavier' is correct	
Outcome	'Lighter' is correct	
Evidence of perturbation	[expresses surprise that actual outcome did not match expected outcome	
Evidence of equilibration via accommodation (evidence of learning)	"From 0 to 20 there's a sharper increase than up here…. Because it'll kind of level off somewhere… I think that it's asking more about like the slope and not, not just about the surface area. So I think that's why I got that wrong."	Getting the answer wrong resulted in S4 attending to the graph's rate of change. He modified his scheme to include rate of change as relevant to interpreting graphs.

Results

Preliminary findings indicate students learned (a) how to identify independent and dependent quantities; how to use the calculator to make graphs, (b) how to interpret graphs, (c) how solving an inequality is different from solving an equation, and how to do both on the calculator; (d) how to optimize functions on the calculator. Students commented that getting answers wrong in the online homework helped them understand how to solve inequalities and optimization problems.

- Influence of lecture on HW activity
  - o Taking time to make sense of given information: Like the instructor, S1 took time to make sense of and employ given information
    - Identifying independent/dependent variables
    - Units
    - Labeling graph
  - o Using words the instructor used (e.g. "isolate" a variable, "assign a variable")
  - o Problem contexts
    - Remembered similar problem contexts from lecture and used this similarity to solve HW problems
    - Connected different problem contexts that both had concave up, decreasing graphs
  - o Use of skills: table to set graphing window, table to select correct graph, CALC menu features, using graph instead of table to solve problems
  - o Ways of looking at graphs (steepness for concavity, identifying increasing/decreasing as ways to justify use of procedures)
  - o Applying definitions (recognized an equation as linear based on class definition)
- Learning from HW activity
  - o "Trial and error", "mastery," "putting stuff into practice": student's description of what and how she learned from homework
    - She primarily went through CALC menu features via trial and error, taking several problems to sort out what to use when
  - o Solution to one problem influencing solution method to next problem (e.g., generalizing the practical meaning of an increasing, concave up function)
  - o Quantitative meaning for concavity: computing AROC over different intervals helped her see the changing rate of change and how it influences the shape of the graph

Discussion & Conclusion

- We think students' learning from mistakes can be explained by Piagetian learning theory: seeing an "incorrect" mark perturbs them
- Lecture appears to give students tools, (e.g. features of the calc menu) but they often go through a trial-and-error process in homework figuring out when to use each tool
- Students notice similar problem contexts, as well as abstracting underlying similarities in mathematical structure (e.g. concavity) .

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