"I want this to be the last time. I don't want to teach myself anymore": Relearning Factorization from Middle school through College

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We report results of a longitudinal case study of one Intermediate Algebra student Sierra's experiences relearning factorization from 8th grade through Precalculus. This data comes from a larger project investigating six developmental mathematics students' perceptions of the experience of relearning individual topics and reflections on relearning across two semesters of college algebra courses. Such a student-centered perspective is critical to developmental mathematics educators who are currently grappling with high rates of failure and attrition in such courses nation-wide. In examining Sierra's learning experience as one of relearning, this report sheds light on how students may use their previous algebra learning experiences to make predictions about the kind of understanding they will come to have about particular topics, and to motivate particular behaviors and affective states during instruction. Furthermore, we illustrate how such topic-level experiences may be used to shape learning experiences in subsequent mathematics courses involving algebra.

Keywords: developmental mathematics, relearning, factoring

This report centers on student perceptions of the experience of relearning, i.e., the experience of learning about content one has already tried to study in a previous course (Amman & Mejía-Ramos, 2022). In particular, we focus on traditional developmental math courses: semester-long courses whose content focus mirrors that of middle and high school pre-algebra to algebra courses. Such courses persist in making up a significant portion of developmental math offerings (Kosiewicz, Ngo & Fong, 2016) and lie at the heart of scrutiny in the developmental math space. We argue that understanding students' expectations and perceptions surrounding the relearning process can help explain their motivations, behaviors, and affective dispositions while learning in courses with previously seen content (Amman & Mejía-Ramos, 2021). While relearning is not exclusive to developmental mathematics courses, it is a uniquely central feature of these courses (due mainly to the prevalence of Algebra in United States middle/high school curricula). This work contributes to a small but growing body of literature that seeks to open up the "black box" of teaching and learning in developmental mathematics courses (Grubb, 2001; Sitomer et al., 2012; Mesa, Wladis & Watkins, 2014) to better understand their historically high failure rates (Chen, 2016) and reputation as deterrents to college completion (Bailey, Jeong, & Cho, 2010).

In a previous report (Amman & Mejía-Ramos, 2021) we discussed students' perceptions of the experience relearning an Intermediate Algebra topic that they had seen in a previous algebra course. Although the topics studied were presented within the first third of the semester, students described having complex relearning experiences. Contrary to current depictions of developmental mathematics students, which collapse their learning needs across individual topics to describe them as needing either a "refresher" of course material or an intensive review of "basic skills" (e.g. Grubb & Gabriner, 2013; Cox & Dougherty; 2019), these students' experiences shifted according to both the sub-topic under discussion and whether the interview was predictive or retrospective. The data presented in the current report come from a larger study motivated by the question of how such relearning experiences might evolve over the course of a semester, as students are exposed to topics of varying complexity, and as their familiarity with

the notion of relearning grows. Specifically, we report findings related to one student's relearning experiences throughout two semesters of algebra-based, college-level coursework. In doing so, we seek to contribute to educational theory concerning the variety of possible impacts of relearning on one's understanding of content seen before, as well as the behavioral and affective associations with relearned content that distinguish it from learning for the first time.

Literature Review

Typical profiles of developmental mathematics students describe them as having a lack of sufficient algebra coursework in high school (e.g. Kinney, 2001; Grubb & Gabriner, 2013; Boylan, 2011). However, current research suggests that many developmental mathematics students completed at least Algebra II in high school, and that a substantial portion were enrolled in mathematics courses for all four years in high school (Benken et al., 2015; Ngo, 2020; Moran, 2008). For instance, in their study of 306 first-year students placed into Intermediate Algebra at California State University, Benken et al., (2015) found that nearly 60% of these students had taken courses beyond Algebra II in high school. Additionally, 66% of participants had taken mathematics all 4 years of high school, and 23% had spent 3 or 4 of those years just attempting to pass coursework at or before Algebra II. Likewise, Ngo (2020) investigated the percentage of college students who take "redundant" math courses, or courses whose content is either at the same or lower level than their highest completed math course in high school (or lower than what they would be predicted to pass given their results on a 12th grade math assessment). He found that while roughly 20% of all college students take redundant math courses, that percentage increases to roughly 40% when looking at developmental math students specifically. This suggests that roughly 40% of students in these developmental mathematics courses had completed coursework above the level of at least Algebra I in high school. Thus, counter to the belief that a sizeable number of developmental math students enroll in such courses because they were never exposed to algebra concepts in high school, these studies suggest that a sizable number of students have taken algebra prior to developmental mathematics enrollment. While these studies do not make explanatory claims to help us understand student outcomes, they provide valuable insights into the widespread nature of relearning in developmental math classes. In attempting to explain phenomenon such as high failure rates and attrition, it would seem critical to better understand student relearning experiences in this context.

In contrast to the lack of research on student perceptions of their experience with developmental mathematics content, there is a growing number of studies that focus on describing how developmental mathematics instructors view students in terms of their readiness for college mathematics and the detriments to their success mathematically. These studies suggest that instructors perceive many developmental math students as lacking in basic skills that are both meant to be formed in high school courses and critical for mathematical success (Er, 2018; Reichwein, Schneider & Onwuegbuzie, 2014; Grubb & Gabriner, 2013). For instance, in their interviews with instructors from over 20 community colleges in California, Grubb and Gabriner (2013) found that instructors perceived the majority of developmental math students as being placed into such a course due to a need for an in-depth review of basic skills, whereas a minority of "brush up" students are misplaced due to a time lapse since their previous mathematics course and a need for only a quick review of the material in order to be college ready. However, instructors surveyed by Benken et al., (2015) thought it was problematic to approach the course as a "review" rather than an "opportunity to learn new content", assuming such an approach stems from an overconfidence in students' skills as opposed to a true need for a quick review. Furthermore, there appears to be inconsistencies in which skills specifically

instructors are referring to. Whereas some studies of instructor perceptions relate a lack of basic skills toa likelihood to engage in unproductive learning behaviors such as self-handicapping strategies (Mesa, 2012), others note poor study skills (Reichwein, Schneider & Onwuegbuzie, 2014), while still others note basic mathematical skills related to arithmetic and algebraic procedures (Grubb & Gabriner, 2013).

An interesting question is how instructors' perceptions relate to those of their students. For instance, Cox and Dougherty's (2019) interviews with 25 community college pre-algebra students indicated that while many students perceived the course to be useful in "refreshing" their memory, others found 'reviewing' to be a waste of time given their prior experience with the content. Consistent with findings reported by Mesa (2012), 18 students indicated that they "wanted to 'really understand'" the reasoning behind their use of procedures in the course in way that they had not accomplished previously (p. 256). However, it was relatively uncommon for students to indicate that they felt this had been accomplished by the end of the course. Indeed, a critical finding of Mesa (2012) was the vast discrepancy she found between instructor perceptions of students and students' perceptions of themselves. Namely, she found that students indicated preferring mastery over performance goals, a lack of engagement in self-handicapping behaviors, a disposition towards hard work, and an expectation that instructors would challenge them. As illustrated above, instructors perceived students in a near complete opposite manner. The results of these studies raise interesting questions about how student perceptions of their own learning needs, behaviors, and affective dispositions relate to those of their instructors. These results, as well as the muddling of "refresher" students and "basic skills" students led us to conduct the current investigation into student perceptions of their experience learning about content seen before.

Theoretical Framework

Consistent with Amman and Mejía-Ramos (2021; 2022), we conceptualize the experience of relearning as broader in scope compared to previous work on memory in cognitive psychology (Ebbinghaus, 1885; Bahrick, 1979; Rawson, Dunlosky & Janes, 2020) and mathematics teacher education (Zazkis, 2011). We define relearning in mathematics as the experience of learning about content (T1) one has already tried to study in a previous mathematics course (T2). Importantly, the target content must remain stable across the two learning experiences. That is, the mathematical content in the second learning experience cannot be simply reviewed or relevant for the purpose of teaching something else. In such scenarios, we typically consider students to be using their *prior knowledge* in service of learning about new content. The definition of relearning used here is broader in the sense that it does not require specific learning outcomes at T1 or T2 (e.g., work on memory in cognitive psychology traditionally requires content to be fully memorized and recalled in order for relearning to occur). Similarly, this definition does not characterize specific relearning experiences as successful or unsuccessful. Instead, it is deliberately general to allow researchers to more broadly describe how students' existing understanding of content can be (or be perceived to be) impacted by relearning, without a predetermined framing in mind.

In developmental mathematics courses, relearning occurs at multiple levels. The results presented here consider two such levels. The first is what we refer to as "topic-level" relearning in which the focus is on a student's experience relearning a single topic (e.g., the content of a single chapter or unit) in an algebra course. Topic-level relearning was the sole focus of our earlier work (Amman & Mejía-Ramos, 2021), in which we asked questions about what it was like for students to relearn content from one of two specific textbook chapters in an Intermediate

Algebra course. In the results of that study, we provided preliminary descriptions of student perceptions of the impact of relearning on their understanding of a particular topic, such as *confirming my understanding, jogging my memory,* and *reconstructing my memory with guidance*. These perceived impacts of relearning were used to guide the current investigation while still allowing for such descriptions to be expanded or refined (see Amman, 2022 for details). The second level pertains to "course-level" relearning. Course-level relearning experiences focus on holistic perceptions of what learning is like overall in a course, and is the perspective more commonly taken by studies that ask about student perceptions of their course experience, without focusing on any particular piece of content (e.g., students got a "refresher" of the subject of algebra in Cox & Dougherty, 2019). However, as demonstrated by the current study, course-level relearning perceptions are not necessarily simple aggregates of topic-level experiences formed at the end of a course, but may also already be formed by students early on in the semester and may help explain subsequent patterns in topic-level experiences. In the current study, we present findings that describe the relationship between one student's topic-level and course-level perceptions of relearning as she continued to encounter content involving the sub-topic of factorization throughout a developmental math course.

Methods

We conducted six longitudinal case studies each spanning two semesters between Spring 2021-Spring 2022 enrolled in either Elementary or Intermediate Algebra at a four-year university. Elementary and Intermediate Algebra are non-credit-bearing courses whose syllabi reflect those of a typical high school algebra course. Sierra, the pseudonym given to the participant whose data is the focus of this report, began the study as a freshman Intermediate Algebra student in Fall 2021 followed by Precalculus in Spring 2022. All participants were recruited at the beginning of the semester via email for a series of paid interviews focused on their experiences with relearning in their current math course and in the following semester. Interested students were given a recruitment survey in which they were shown topics that would be taught in their current course and asked to describe how well they remembered and how confident they were in their understanding of them. Participants were chosen to reflect an even distribution of starting course, memory, confidence in understanding of each topic, and semesters of experience with college algebra courses. Sierra, like the other participants, indicated that she knew she had learned *about* each course topic before, even if she could not always remember exactly what she had learned, and she had previously completed Algebra II, and Precalculus in high school. This indicated that much of her upcoming learning experience was likely to be characterized as relearning. Data collection consisted of six one-hour interviews per student, surveys and, when possible, responses to questions on course exams. For the sake of space, we describe only interviews 1-4, those focused on topic and course-level relearning, for this report.

Interviews 1-4 occurred in the first semester of study enrollment. In order to understand how previous learning experiences influenced students' relearning experiences, each interview contained sections for students to both predict and reflect on aspects of upcoming and recent relearning experiences, respectively. Specifically, students were asked to predict how their memory and current understanding of a topic would influence how they approached the task of relearning that topic in class (behaviorally and affectively) and what the anticipated impact of that relearning experience would be on their understanding. In terms of reflections, students utilized their own exam responses and their predictions from previous interviews to reflect on their relearning experience. At the end of every interview, we asked students to reflect on their course-level relearning experience by describing, overall, how they thought the experience of

relearning had been different from learning new content in mathematics for the first time. Responses to this item were carried over to subsequent interviews for further reflection in order to understand students' evolving perception of relearning throughout the semester.

Formal analysis proceeded in multiple rounds. The first round focused on building descriptions of individual cases utilizing the main variables outlined in the theoretical framework. They are: perceptions of similarity to and confidence in understanding from the T1 learning experience, predictions and reflections of the impact of relearning on understanding, behaviors associated with relearning, and affective dispositions associated with relearning. The second stage involved cross-case comparisons resulting in preliminary themes that either connected variables within a type of relearning or helped explain linkages between variables across different types of relearning. This process involved engaging in explanation-building utilizing all data sources for an individual participant, then moving to the next participant in order to locate commonalities across experiences and produce evidence of rival explanations if that participant experienced a similar outcome despite different combinations of the study variables (Yin, 2009). The result of this stage of analysis was a set of preliminary themes that were refined over a period of several further rounds of analysis for consistency.

Results

How Relearning at the Topic-level Influences Behavior and Affect

Sierra came into her first interview with a vivid memory of a frustrating history with learning (and relearning) how to factor polynomial expressions. She recalled missing the first day of math class in 8th grade when factorization techniques were introduced. To quickly catch up, Sierra went online to "whatever was available" to teach herself what she had missed. While she performed well in Algebra I, her technique for learning about factorization did not allow the content to "stick"; she forgot everything when she reencountered the topic in her high school Algebra II class. Once again, Sierra felt she needed to catch up to the rest of the class and turned to outside sources to re-teach herself the factorization techniques that she was expected to already have learned. She then promptly forgot these techniques and relearned them again in her high school Precalculus course. Sierra was looking forward to using her time in Intermediate Algebra to end this cycle. In her first interview, she stated, "I want this to be the last time. I don't want to teach myself anymore." Sierra consistently received good grades in high school and was a member of an honors program at the University—she was confident that her main concern was not whether she could reteach herself factorization and perform well on assignments, but on her inability to recall any of what she had taught (and retaught) herself concerning this subtopic in the past. Specifically, she identified her behavior of inconsistently turning to various sources outside of the class each year as resulting in her struggle to remember what she had learned the following year. She predicted that by closely adhering to her professor's approach to factoring, she would be able to reorganize her knowledge in a way that would make it easier to remember in the future (Amman, 2022, termed this particular relearning outcome *Reorganization*).

Unfortunately, Sierra's anticipation of this change in behavior and subsequent change in understanding was not realized. Sierra found that she *remained stuck in her previous understanding* (Amman, 2022). In her second interview, Sierra reviewed her responses to items on the first exam involving factoring, almost all of which she received full credit for. Despite her high performance, Sierra lamented that she found herself stuck in her old relearning approach in which, "I just had to learn it [myself] again, like every time when it comes to factoring." Just as before, she found herself turning to outside sources to reteach herself, and once again did not feel

she had addressed the root cause of her memory issues. Indeed, when encountering future problems involving factorization in class, she remarked in later interviews, "[my memory] wasn't really helpful...I kind of knew I was on the right track because I remembered seeing it, but it didn't help me in terms of solving the actual problem." As a result, Sierra found that her understanding of factoring after relearning was, "the same. I just get there faster [every time I learn it]." Sierra explained that she was able to pick up on factoring techniques more quickly than in previous algebra courses, but this was not accompanied by a feeling of improved understanding that could have come from the implementation of a more conceptual organizing principle of content that she had hoped for. When asked what had made her feel like she needed to use her old relearning approach again, she stated, "I think it's more to like a mental thing. Like once I see the word factoring, I'm like, 'oh I know I'm not going to do well on this unless I teach myself again.'" Here, we see that Sierra's previous experiences with factoring triggered a prediction ("I'm not going to do well") concerning the outcome of her topic-level relearning experience before her instructor had even begun the first lesson on factoring. This prediction was then used to motivate behaviors ("unless I teach myself again") that impacted how she decided to approach studying this topic. Sierra's previous experience learning this material also had an impact on her affective response to relearning it. She mentioned feeling discouraged from the moment the class had begun the factoring sub-unit and struggled with these negative feelings associated to her previous experiences throughout the rest of the classes in which factoring was mentioned. For instance, while reviewing for her first exam, she questioned, "why am I still doing this in college? That's what I was asking myself a lot while I was studying…I feel like every time I revisit this topic it's a little bit discouraging. Because it's not sticking and I don't know why." In this way, Sierra's ability to recognize previously learned material and make predictions surrounding the outcome of relearning had significant consequences for her (and other participants) in terms of her behaviors and affective states during course instruction.

How Topic-Level Relearning may Shape Perceptions of Course-Level Relearning

Sierra's experience relearning factorization also came to impact her course-level relearning perceptions. In contrast to the idea expressed by other participants that previous experience must make relearning easier than learning something new, Sierra came to view her previous algebra learning experiences (in middle and high school) as a potential hindrance in the course. Discussions around this perception began in her third interview, after polynomials (and the factoring sub-topic) had been covered and she had experienced the shift from predicting that she would be able to reorganize her knowledge of factorization to subsequently reflecting she had remained stuck in her previous understanding of the topic. At that point in the semester, Sierra described her overall outlook on relearning in the course as, "I feel like as opposed to other subjects, I feel like math is all about confidence…If I don't have that confidence and I'm confident that I don't remember it, past [Sierra] didn't know how to do it, or couldn't figure out how to do it, then it's gonna be a doozy trying to figure out how to solve it." She explained in her fourth interview that her confidence throughout the semester came to be tied to her understanding of factoring, given that subsequent course topics such as combining rational expressions and solving quadratic equations involved factoring as a subtopic. In interview 4 she described changes in her confidence throughout the semester by saying "I was like 'um what are doing?' [every time] factoring came back in," indicating that her confidence would dip down repeatedly every time factoring was reintroduced in a new topic. In essence, Sierra's experience relearning about factorization seemed to have influenced her perspective of what to expect for the course as a whole: she saw an inability to use what she had previously learned as a warning

sign that her relearning experience was about to be difficult and did not allow for the possibility of an improved experience relative to her first time learning these topics. In summary, Sierra's topic-level experience came to inform her overall outlook on relearning in the course, transforming her from a student who in Interview 1 was "looking forward to" intellectually grappling with questions like "Why am I getting this answer? Why do I have to do this step?" to a student who came to view the presence of such questions as hits to her confidence and indicators that her relearning experience would be more difficult than it should.

Sierra enrolled in Precalculus the following semester, another course which she had previously taken in high school. Although she was unable to achieve the impact of relearning on her understanding of factorization that she had predicted, she mentioned hoping that the combination of the short break between Fall and Spring semesters and the increased speed with which she arrived at her understanding of factoring would improve her results next semester. Unfortunately, this was not the case. In her fifth interview she noted that she had done poorly on her first exam, and that, "the ones that I struggled on, it was factoring, of course. The whole entire test was factoring." In this way, Sierra's topic-level experience could be understood as part of a self-reinforcing cycle that comes to inform her experiences with relearning not only within her algebra course, but also in future courses involving said algebraic topics.

Conclusions

By presenting Sierra's case, we intend to contribute to theoretical accounts of the experience of relearning as instantiated in developmental algebra courses. Studies in reforms of developmental math courses have begun to suggest that the most successful reforms are multifaceted in terms of the modifications they make to course experiences (e.g. Hodara, Jaggars & Karp, 2012; Yamada & Bryk, 2016). That is, successful reforms address placement into courses, instruction while students are enrolled in such courses, and alignment with students' overall goals for college after the course is over. Similarly, the results of this study suggest that fully understanding student experiences with relearning in developmental mathematics requires a multifaceted approach. Whereas topic-level perceptions help us to understand the decisions Sierra was making and the impact of the course on her understanding of factoring on a local level, her course-level perceptions allow us to understand the motivations behind patterns in her experiences that were more than the sum of her topic-level perceptions in terms of their impacts beyond one semester. We would argue that in our efforts to better evaluate developmental mathematics courses and understand exactly how they impacting students, we need to be aware of the limitations of taking the perspective of students at any one "level", and ensure that the claims we want to make about student experiences are aligned with this. For instance, co-requisite algebra courses are designed to improve alignment with students' overall goals for college and modify the algebraic content presented in class accordingly (e.g. Logue, Douglas & Watanabe-Rose, 2019). However, there are very few studies that seek to investigate the hypothesis that student *understanding* of algebra in these courses will be improved as a result of an ability to see more directly the purpose of relearning particular algebra concepts related to students' majors. This suggests we would do well to focus on student perceptions of relearning at both the topic- and course-level in these courses: how students view the relearning of specific topics as understanding of these topics is needed in the context of the college-level course, and how they view relearning of algebra as a whole in the special context of a co-requisite course. We suggest that future work seeking to qualify the impact of such courses on student understanding takes into account the particular components of relearning focused on here in order to be able to best explain student approaches to and reflections on course material.

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