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Find It, Fix It, and Thrive: The Impact of Insisting on Proficiency in Prerequisite Knowledge in Intermediate Accounting

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ABSTRACT: Success in upper-level accounting courses depends on adequate prerequisite knowledge because the learning process is sequential and hierarchical (Bentz 1975) and because prior learning provides cues for encoding and combining (Sternberg 1984). Building expertise requires a strengthening and organization of links between knowledge and not just a high volume of known facts (Dreyfus and Dreyfus 2005). Since incoming knowledge matters to later learning, this study investigated how enforcing the prerequisites impacted course outcomes in intermediate accounting. The prerequisites were enforced using a proficiency test administered online in a system that also offered tutoring to remedy any learning shortfalls. Students received all-or-nothing credit (100 percent or 0) for mastering adjusting entries and the financial statements. Students proficient in prerequisite skills earned better project and cumulative final exam scores in non-prerequisite areas. Grades in Intermediate II were also better after adding the proficiency test, compared to the two prior terms. The intrigue of these results goes beyond improved student outcomes in Intermediate I and II, because the testing and remedial instruction used an existing tutoring product, requiring no institutional resources or changes to course preparation, instruction, classwork, exams, or the project.

Keywords: mastery; intermediate accounting; accounting cycle; retention; prerequisites; intelligent tutoring; artificial intelligence.

INTRODUCTION

Intermediate Financial Accounting I (Intermediate I), the first accounting course in the accounting major, generally results in a high failure rate, sometimes as high as 50 percent or more, and is often referred to as the "weed-out" course for the major (Smith et al. 1974; Shoulders and Hicks 2008; Sanders and Willis 2009). The retention goals placed on administrators have increased pressure to improve the pass rates in this first intermediate course, creating pressure to find ways to improve course outcomes without changing academic standards (Sanders and Willis 2009).

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Students struggle in this challenging course for a number of reasons. First, the course is hard (Shoulders and Hicks 2008), requiring either more aptitude than students bring to the course, or more effort than they wish to exert, or both (Smith et al. 1974; Sanders and Willis 2009). Second, many students enter the course without a solid understanding of the accounting cycle, a by-product of low initial learning, the user approach at the introductory level, a feeder school with inconsistent levels of rigor, or long time lags since principle course completion. When students enter the intermediate course sequence without a solid foundation in principles of accounting or with significant forgetting of prior learning, they struggle to keep up with the pace of the course (Smith et al. 1974; Jones and Roberts 2005).

This study examines the impact of an online proficiency test, given at the start of Intermediate I, to insist on mastery of the prerequisite ability to create journal entries, propose adjusting entries, and assemble financial statements.[1]

HYPOTHESIS DEVELOPMENT

Why Prior Knowledge Impacts Learning

There is a substantial literature showing that domain-related knowledge impacts the ability to learn new material in that domain (Gagné and Dick 1983; Anderson et al. 1990; Siegler 2003). Instructional psychology theories have long admitted that learning is rarely a series of independent "single lessons" (Gagné and Rohwer, Jr. 1969). Prior knowledge tunes attention and enables mental processing, impacting the effectiveness of new learning (Gagné and Dick 1983). The expertise literature shows that learning is an accretive process where novices become more expert (Bruer 1993), beginning with acquiring rules and recognizing basic facts (Dreyfus and Dreyfus 2005). Without this base, however, beginners cannot progress because the hallmark of expertise is a strengthening and organization of links between facts, procedures, and concepts, not just a high volume of known facts (Dreyfus and Dreyfus 2005).

There are two main theories about how prior learning impacts new learning. Cognitive load theory argues that learning complex material is compromised when prior knowledge is weak because difficult concepts tax learners' mental resources (Sweller et al. 1998; Ayres 2006; Mostyn 2012). Learning is effortful and uses limited working memory (Anderson et al. 1996; Oberauer et al. 2006). Since novices have not yet organized or "chunked" information into useful knowledge structures, they are easily overloaded (Rittle-ohnson et al. 2009; Mostyn 2012). Once initial learning has occurred, working memory limitations are relaxed because students recall prior knowledge in chunks, called schemas, which efficiently bring forth clusters of related facts automatically (Ayres 2006; Mostyn 2012). Until that learning "consolidation" or automaticity occurs (schema development), the concentration required to recall basic facts can slow learning (Paas et al. 2003; Mostyn 2012).

For information-processing learning theories (Newell and Simon 1972), prior learning is an important "active ingredient" because the learning process is sequential and hierarchical (Bentz 1975) and because prior learning provides cues for encoding and combining (Sternberg 1984). Learning builds cumulatively, moving from the simple to the more complex, not by linear one-fact-at-a-time remembering but by creating organized clusters of related ideas (schemas) (Ericsson 2005). Because prior knowledge provides cues that help the learner recognize what needs encoding and how the material is related to other knowledge, it impacts the nature and volume of schemas

[1] This study used Quantum Simulations software to test mastery of the prerequisites. Quantum Simulations transactions analysis tutor has been shown to be particularly effective in teaching the accounting cycle (Johnson et al. 2009; Phillips and Johnson 2011), and tutoring was available before or after testing to provide a convenient option for remedying less-than-mastery scores.

developed (Sternberg 1984). Newly learned information is stored by being incorporated into one or more existing schemas in memory (Gagné 1980; Gagné and Dick 1983). Learners with low prior knowledge, with missing or poorly developed schemas, are less able to subsume the new ideas into their knowledge network, diminishing learning. As a result, low prior knowledge leads to more disorientation (Amadieu et al. 2009) and weaker conceptual understanding (Leppink et al. 2012) when new (more advanced) material is presented.

Studies on Prerequisite Knowledge

The literature contains strong evidence that prerequisite knowledge improves course success in subsequent, more advanced, courses. Enforcing prerequisites improved performance in math (Cresswell 2009), biology (McCoy and Pierce 2004), chemistry (Donovan and Wheland 2009), economics (Buschena and Watts 2001), and across the curriculum (Landers and Kangas 1992). In finance and chemistry, a prerequisite test at the onset of the upper-level course predicted course success (Easter 2010; Grover et al. 2010) and the timing and quantity of prerequisite courses influenced upper-level grades in finance (Blaylock and Lacewell 2008) and chemistry (Easter 2010). In statistics, the student-selected prerequisite course (from several options) impacted performance in an upper-level statistics course (Choudhury et al. 2007; Islam et al. 2008). In a graduate organizational behavior course, the grade in the prerequisite course predicted performance (McMillan-Capehart and Adeyemi-Bello 2008). At one community college, waiving prerequisites did not hurt course pass rates (Abou-Sayf 2008), but the grade distribution within the passing range was not analyzed.

Strategies to fix weak prerequisite knowledge, however, have not garnered much attention. In chemistry, prerequisite knowledge was offered during current lessons, using pop-ups and hyperlinks, permitting students to fix weak prerequisite knowledge "on demand," but it did not improve course learning (Alsharif and Henriksen 2009). In marketing, requiring students to "test out" of the prerequisite course improved results in a later course (Kellar et al. 2007). In Intermediate I, passing either a one-credit pre-course or a pretest, improved course results (Huang et al. 2005).

Improving Learning in Intermediate I

Changes to Course Activities

Attempts to improve student outcomes in Intermediate I have generally followed two themes: (1) changing the course activities to improve the learning experience or (2) filtering out students with low readiness to learn and/or weak understanding of elementary accounting. Changes to the course activities designed to improve course learning have had mixed results. The literature contains an array of instructional cases to teach individual intermediate accounting topics (e.g., Carter and Jones' [2011] investment portfolio simulation to teach reporting for investments or Alford et al.'s [2011] cases on revenue recognition) but these single-topic resources target individual skills and do not offer evidence of course-level improvements. Adding course requirements, such as a practice set (Ott et al. 1988) or requiring exams to be worked twice, once individually and once in a group (Gabbin and Wood 2008), did not improve course performance. Altering the quantity and type of homework solutions had no effect on course performance (Lindquist and Olsen 2007). Removing the accounting cycle and present value topics from Intermediate I course coverage, based on the argument that the material was taught in prerequisite courses, hurt performance on accounting cycle questions but increased learning on new intermediate material (Anderson and Boynton 1992). The most promising studies show that formative assessments (practice tests) improve exam scores (Shoulders and Hicks 2008; Wilson 2009).

Adding supplemental instruction, rather than just adjusting activities or assignments, has been associated with better course performance in introductory accounting (Sargent et al. 2011), although the effect sizes have been low for most of the studies (Etter et al. 2000; Jones and Fields 2001; Potter and Johnston 2006). Computer-based intelligent tutoring systems and computer-based learning aids have been shown to improve student performance at the introductory accounting level (Johnson et al. 2009; Baxter and Thibodeau 2011; Phillips and Johnson 2011) and for cost management (Potter and Johnston 2006), but no work has documented uses in the intermediate course sequence.

Filtering Out Less Prepared Students

Methods to filter students with low ability, low incoming knowledge, or both, have included pretesting for prerequisite knowledge, requiring a one-credit course on the accounting cycle, or requiring a certain grade point average to enroll (Hicks and Richardson 1984; Danko-McGhee and Duke 1992; Huang et al. 2005; Sanders and Willis 2009). In information technology (Rondeau and Li 2009) and math (Bashford 2000), a pretest was more effective than a pre-course.

In accounting, preventing under-prepared students from enrolling has been especially needed when a large transfer population is expected because administrators cannot easily determine the rigor in the introductory course sequence at feeder schools (Laband et al. 1997). The school at which the principles courses were completed is a significant predictor of success in Intermediate I (Laband et al. 1997; Turner et al. 1997). However, pretests, GPA hurdles, and accounting cycle pre-courses can create resentment among students barred from enrolling or friction from feeder institutions, and are not perfect measures of who will and will not succeed (Hicks and Richardson 1984).

A New Approach: Students Responsible for Finding and Fixing Weak Incoming Skills

Instead of culling prior to enrollment or attempting to teach the prerequisite skills to the whole class, the proficiency test gave students an opportunity to check their own readiness, find and fix their own learning shortfalls (i.e., upgrade from "I have had it before" to "I can do the full range of entries without flaw"), and respond to the higher expectations (Jussim and Harber 2005). The proficiency test was graded as "all-or-nothing" (either 100 percent or 0, with no partial grading). Students had to demonstrate proficiency, mastering debits and credits, recording adjusting entries, and creating financial statements perfectly for two sets of client data, to get credit for the test. If they missed an element, they had to remedy the problem (find the misconception or relearn the concept), and then retest with new transactions on the missed element(s). No prior work has documented the effect of insisting on mastery of prerequisites on performance in upper-level accounting courses.

Intelligent Tutoring Systems

This study used an artificial intelligence (AI) online tutoring product to measure prerequisite knowledge and offer tutoring to students who fell short of the mastery goal. The product, Quantum Simulations,[2] was commercially available and had a history of helping novice accounting students learn to journalize transactions (Johnson et al. 2009; Phillips and Johnson 2011). While students were required to sign into the software for testing, they were not required to launch the transaction analysis tutor. Since students could learn using any resource they wished (e.g., Quantum Simulations, review lectures, office hours, textbook, publisher resources, or a combination of any of these), this work does not measure of the effectiveness of AI tutoring.

[2] Available at: www.quantumsimulations.com

TABLE 1

Participant Attributes
Mean (Std. Dev.)

Attribute	Unknown Prerequisite Skills	Proficient Prerequisites
Number of participants	259	156
Percent male	48.3%	51.3%
SAT Verbal[a]	488.31	484.81
	(82.48)	(82.42)
SAT Math[a]	542.37	539.38
	(74.73)	(79.46)
Cumulative GPA	3.12	3.11
	(0.59)	(0.68)
Credit hours earned	105.08	109.23
	(44.30)	(36.17)

[a] Excludes transfer students, for which SAT scores were not available (n = 141 or 54.4 percent in unknown-prerequisite-skills term and n = 75 or 48.1 percent in proficient prerequisites terms).

Given that insisting on fully mastered prerequisite skills in the accounting cycle should improve course grades for intermediate accounting, I hypothesize:

H1: Students required to demonstrate proficiency will have higher project and exam grades.

Given the substantial literature showing that domain-related knowledge impacts the ability to learn new material, I hypothesize:

H2: Students required to demonstrate proficiency will have higher scores in non-prerequisite areas (new topics).

METHOD

The research was conducted as a quasi-experimental nonequivalent control group design without pretest (Campbell and Stanley 1963), comparing sections of Intermediate I taught by the author in Fall 2009, Fall 2010, and Spring 2011, keeping the course features constant except for the addition of a proficiency test in Fall 2010 and Spring 2011.

Participants

Participants were 415 students enrolled in the author's Intermediate I sections in Fall 2009 (unknown prerequisite skills) and Fall 2010/Spring 2011 (proficiency in prerequisite skills required) at a large public urban research university in the southeastern United States with average SAT scores of 1050, an average acceptance rate of 53 percent, and a highly diverse student body (approximately 34 percent African American and 33 percent international students). See Table 1 for attributes of participants for Fall 2009 (unknown prerequisites skills) and Fall 2010/Spring 2011 (proficient prerequisites).[3] The groups did not differ significantly on any of the attributes.

[3] The author taught six sections in Fall 2009, three sections in Fall 2010, and one section in Spring 2011.

TABLE 2

Course Requirements and Percent Weighting in Course Grade

Course Requirement	Unknown Prerequisite Skills	Proficient Prerequisites
All-or-nothing proficiency test	NA	5%
Exam 1, 2, and 3 (weighted evenly)	58%	54%
Cumulative final exam	22%	23%
Project	20%	18%
	100%	100%

Procedure

The intervention, an all-or-nothing proficiency accounting-cycle test, was added in Fall 2010 as a retention project to improve the historically low pass rate in Intermediate I. Students in all terms were unaware that they were participants in a study.[4] Intermediate I on the study's campus is a two-credit course covering six chapters: four chapters reviewing the accounting cycle, accounting concepts, accrual accounting, extraordinary items, earnings per share, and preparation and reporting of financial statements; a revenue recognition chapter; and a time-value-of-money chapter. The course included:

(1) six to ten ungraded back-of-the-chapter problems per chapter (discussed in class and solutions provided online in course management software for self-grading),
(2) three to five in-class activities per chapter,
(3) a project (which included an accounting-cycle practice set),
(4) three exams, and
(5) a cumulative (departmental) final exam.

In Fall 2010/Spring 2011, one additional requirement was added, an all-or-nothing (100 percent for mastery or 0 for less than mastery) proficiency accounting-cycle test. Students could test at their convenience (by logging into the testing software) but the deadline to attain a perfect score was the course mid-point (just after the second exam and before the project commenced). Table 2 shows the weighting of course elements before and after adding the proficiency test.

The proficiency test required students to subscribe to an online intelligent tutoring system that offered both testing and tutoring in transaction analysis skills and preparing financial statements. Students in the intervention group had to log in and complete nine adjusting journal entries and financial statements from two different sets of business transactions as evidence of their mastery of the accounting cycle.[5] Students were free to attempt to "test out" at the onset or explore the tutor and then attempt to demonstrate proficiency. Students had an unlimited number of attempts to get their perfect score but the transaction details for each testing event changed. One week prior to the deadline, students who had not reached "proficiency" were sent an email reminding them of the all-or-nothing grading and indicating what transactions or statements were still not mastered.

[4] The campus institution review board approved this work as an archival study.
[5] All test questions required students to select accounts from a pull-down menu and type in an amount in a box to create journal entries and financial statements.

Materials

All-or-Nothing Proficiency Test

Students purchased Quantum Simulation's online transaction analysis intelligent tutoring system as part of their required course materials.[6] The tutoring system guides students through posting business transactions in the accounting equation, journalizing transactions, completing adjusting entries, and creating financial statements.[7] The software sends reports to the instructors showing transactions attempted, transactions completed correctly, total minutes using the system, and mastery status (reached/not reached) by task and by student. Mastery status was defined as completing each transaction correctly twice in a row to avoid lucky guesses as counting toward mastery. These reports were the basis for course credit.[8]

Students could work toward mastery as a diagnostic process, getting tutoring only in areas where they encountered difficulty, or work the full instructional tutor from start to finish and then "test out." This product was selected based on research showing its effectiveness (Johnson et al. 2009; Phillips and Johnson 2011) so that students who did not learn the accounting cycle in principles, or completed the principles courses years ago, could learn (or relearn) in order to "test out" and receive credit for proficiency.

Students with strong skills completed the proficiency test in less than two hours (16.9 percent of the students). The average time using the tutor was 6.3 hours with a standard deviation of 3.9 hours and range from 13 minutes to 24.2 hours. Some students completed the equivalent of a one-credit online self-study course (with a perfect score). Of the students still enrolled at the course midpoint, only four did not achieve the full 100 percent credit for the proficiency assignment. Proficiency was not required to continue with the course (they could take their 0 for this portion of the course grade).

Project. The project simulates a small residential and commercial plumbing company run by two plumbers that started a partnership together two years ago. The course project has two parts. The first part is a classic "shoe box" accounting-cycle practice set. Students are given haphazard client records and the script of an interview with the client, and are asked to record the full-year's activity, record the adjusting entries, and create formal financial statements for the bank. The second part requires students to analyze the business and give the owners advice based on the financial information produced in the first part of the project. This project is a capstone for the first four chapters and requires understanding of the accounting cycle, how to read and interpret the financial statements, and how certain actions alter the financial complexion of the business. The plumbing business is unable to repay its debt, has excessive inventory, and is selling some jobs at less than sales price, all of which students must bring to the client's attention after studying the financial statements created. The students must write the client a letter giving business advice to describe the problems they found and suggest ways to avoid or improve the detected troubles.

Measures

Independent Measure

The independent variable is the prerequisite condition. That is, students had either unknown prerequisite skills (control group) or the proficient prerequisites (treatment group).

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[6] Available at: www.quantumsimulations.com for $29.95 for a six-month subscription.

[7] The intelligent tutoring system is "textbook neutral" and works with any accounting textbook using debits and credits.

[8] During Fall 2010 and Spring 2011, the mastery report was available only to instructors so the instructor had to notify students about their level of mastery. After Spring 2011, the product included a "How Am I Doing?" screen so students could track their own proficiency online in real time.

TABLE 3

Student Evaluation of Instructor by Condition

	Unknown Prerequisite Skills	Proficient Prerequisites
Overall evaluation of instructor**	3.93	4.30
Overall worth of course*	3.68	4.52
Reasonableness of course assessments	3.73	4.15
The instructor made me work harder	4.36	4.67
The instructor motivates me to do my best work**	3.94	4.47

*, ** Difference is significant at $p < 0.05$ and $p < 0.001$.
1 = Not at all effective, 5 = Extremely effective.

Dependent Measures

Project grade. The project was graded in two parts: 50 percent for the practice set, and 50 percent for the client advice memo. The practice set portion was an all-or-nothing grade (50 points or 0 points) matching the grading pattern on the proficiency test. The 50 points for the client advice memo measured the student's ability to communicate the financial issues and suggest reasonable alternatives to improve the client's financial outlook.

Final exam. The cumulative final exam was identical in all terms.[9] It was 80 percent multiple-choice questions and 20 percent problems and contained questions devoted entirely to the accounting cycle (e.g., propose the needed adjusting entry) and questions independent of the accounting cycle (e.g., compute loss on percentage-of-completion contracts or earning per share on discontinued operations).

Student perceptions about assessments and course. Students' evaluation of the instructor, worth of the course, reasonableness of assessments, workload, and motivation were part of the institution's online standard end-of-the-course student evaluation of instruction survey (Table 3). The student responses to these questions were used to measure changes in their perception of the course before and after adding the proficiency test.

Control Measures

Cumulative GPA. The students' cumulative grade point average (GPA) was used to measure prior academic achievement. The GPA included the grades for the term in which the study occurred.

Total credit hours earned. Academic maturity was measured using total credit hours earned. This included credit earned at the current institution and any transfer credit hours earned and included hours for the term in which the study occurred.

Math and verbal aptitude. Math and verbal aptitude were measured with Math and Verbal SAT. SAT scores are not required for transfer students. Therefore, the study was able to obtain SAT scores for students entering the university as first-term freshmen (n = 199, 48.0 percent) but not for students transferring from other institutions (n = 216, 52.0 percent).

[9] The mid-terms in the proficient prerequisites term contained three difficult questions not included in the mid-terms in the unknown-prerequisite-skills term. Exams were no longer available to remove the non-equivalent questions, so they were not used for analysis.

TABLE 4

Course Outcomes
Mean (Std. Dev.)

Course Outcome	Unknown Prerequisite Skills	Proficient Prerequisites
Number of students dropping out of total	109 out of 259	67 out of 156
Percent of students dropping	42.1%	42.9%
Project grade[a]	69.05	86.84
	(29.60)	(14.20)
Cumulative final exam score[a]	71.69	76.22
	(14.98)	(15.87)

[a] Difference is significant at $p < 0.001$.

RESULTS

The data met the basic assumptions of normality with no range restrictions or outliers noted. Because students' prior achievement and college experience may impact their grades independent of the prerequisite condition, I included *cumulative GPA* and *credit hours earned* as control variables in the analyses. The project and final exam scores and drop rates are shown in Table 4. The course grades assigned in both prerequisite conditions are shown in Figure 1.

H1—Project and Final Exam Grades

In a regression on project grades, with prerequisite condition as the independent variable and *cumulative GPA* and *credit hours earned* as covariates, students in the unknown-prerequisite-skills group scored significantly worse on the project than the proficient prerequisites group (Table 5, Panel A). After controlling for covariates, students with the proficient prerequisites scored, on average, 18.4 points higher (out of 100 points), a large practical effect size of almost two letter grades. Adding Math and Verbal SAT as covariates, which eliminated transfer students, did not change the result.

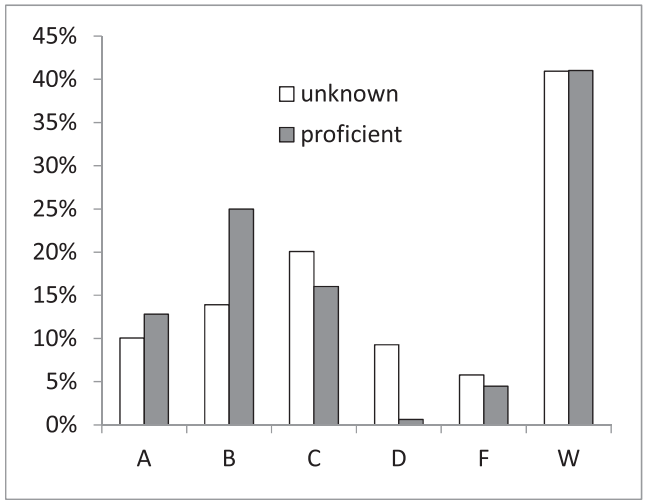
In a regression on cumulative final exam scores, with prerequisite condition as the independent variable and *cumulative GPA* and *credit hours earned* earned as covariates, students in the unknown-prerequisite-skills group score significantly lower than the proficiency assignment group (Table 5, Panel B). The advantage on the final exam was moderate, on average 4.837 points higher (out of 100 points), about half a letter grade. Adding Math and Verbal SAT, which eliminated transfer students, did not change the result on exam scores, but did increase the effect size to 6.3 points out of 100. These two regressions support the first hypothesis.

H2—Grades on New Topics

Departmental assessment data collected at the end of the course permitted analysis of the final exam results by individual question.[10] Each final exam question was classified as mapping to proficiency assignment concepts or other course concepts. A proficiency-related score and a non-proficiency-related score was computed. These two separate final exam sub-scores were then used to see if the final exam advantage was isolated to only proficiency concepts. In a regression with

[10] The assessment data did not have student identifying information so the scores could not be mapped to covariates.

FIGURE 1
Intermediate I Course Grades Unknown Prerequisite Skills versus Proficient Prerequisites



prerequisite condition as the independent variable and proficiency-related final exam sub-score as the dependent variable, there was no difference in the performance of unknown-prerequisite-skills students and those proficient in the prerequisites ($t(1,n = 214) = -0.73$, $p = 0.466$). In a regression with prerequisite condition as the independent variable and non-proficiency-related final exam sub-score as the dependent variable, students with proficient prerequisites scored higher ($t(1,n = 214) = 3.64$, $p < 0.0001$), on average 9.2 percent better, a moderate to large practical effect size.

The accounting literature has called for studies documenting multiple course effects (Apostolou et al. 2010). In a second test of learning of new topics, grades in the downstream course, Intermediate II, for two terms after the proficiency assignment ($n = 275$), were compared to grades assigned in the two terms prior to the intervention ($n = 268$).[11] The grades were significantly higher after the proficiency testing was added (χ^2 $(1,n = 543) = 61.83$, $p < 0.001$). The grades distributions for Intermediate II before and after the intervention are shown in Figure 2.

In a regression with prerequisite condition as the independent variable and course grade in Intermediate II as the dependent variable, with *cumulative GPA* and *credit hours earned* as covariates, the prerequisite condition was a significant predictor of grades in Intermediate II (Table 6). The effect size was moderate, an increase of 0.361 in average Intermediate II grade, about a third of a letter grade with A = 4.0, B = 3.0, C = 2.0, D = 1.0, and F = 0.

Post Hoc: Student Evaluation of Course

Student ratings of the course and instructor were available from 60.67 percent of the students in the sections without prerequisites enforced (n = 91) and 65.39 percent of the students with

[11] There were three instructors in Spring/Fall 2010 ("before") and two instructors in Spring/Fall 2011("after") teaching the Intermediate II sections. All five instructors were full-time faculty. Only one of the instructors was the same before and after the proficiency assignment, representing just under half of all student grades. The book, chapter coverage, and senior faculty coordinating the course content and policies were the same across all terms. None of the instructors were aware of the intervention in Intermediate I.

TABLE 5

Impact of Insisting on Proficient Prerequisites on Course Grades

Panel A: Project Grades

Variable	*B*	Std. Error	Beta	t-value	p-value
Constant	41.779	9.626		4.340	0.000
Proficient Prerequisites	18.400	3.065	0.341	6.003	0.000
Cumulative GPA	15.633	2.560	0.346	6.106	0.000
Total credit hours earned	−0.044	0.034	−0.074	−1.306	0.193

$R^2 = 0.242$, $n = 238$, $p < 0.001$.

Panel B: Cumulative Final Exam

Variable	*B*	Std. Error	Beta	t-value	p-value
Constant	38.486	5.688		6.766	0.000
Proficient Prerequisites	4.837	1.788	0.152	2.705	0.007
Cumulative GPA	12.998	1.509	0.482	8.614	0.000
Total credit hours earned	−0.037	0.019	−0.109	−1.939	0.054

$R^2 = 0.272$, $n = 237$, $p < 0.001$.

proficient prerequisites ($n = 58$). These ratings were obtained from an online system that does not release course grades until students rate the course (or indicate they do not wish to rate the course). Ratings were significantly different between groups for the two "overall" measures and the question about motivating effort (Table 3).

DISCUSSION

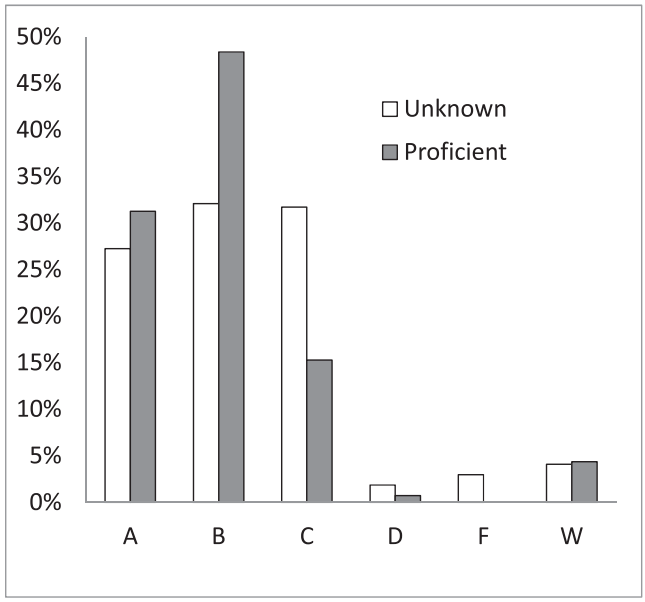
Performance Effects

The addition of a requirement to find and fix any gaps in prerequisite knowledge did not change the percent of students dropping the course prior to the midpoint. This indicates that insistence on proficient prerequisites did not put off students from trying to meet course requirements. Student evaluations of both the course and instructor were significantly better after the prerequisite test was added, indicating that the insistence on a perfect score was not received as overly harsh. In fact, students were more likely to agree, "The instructor motivates me to do my best work" when the prerequisites were enforced.

The grades on the project were considerably higher after requiring proficient prerequisites, nearly two letter grades after adjusting for covariates. The number of students that did not achieve full credit for the practice set portion of the project went from eight students in the unknown-prerequisite-skills term to none in the proficient prerequisites terms. This result was not a surprise since the practice set portion required understanding the accounting cycle, skills specifically targeted on the prerequisite test. More importantly, the interpretation portion of the project improved with mastery of the accounting cycle.

For cumulative final exam scores, students proficient in the prerequisites scored significantly higher than students in the unknown-prerequisite-skills term. The advantage, however, was isolated to performance on new topics, perhaps reflecting a ceiling effect on prerequisite skills. The better

FIGURE 2
Intermediate II Course Grades
Terms with Unknown Prerequisite Skills versus Terms with Proficient Prerequisites



grades on the advice-giving portion of the project and non-prerequisite questions on the final exam support the theory that prior knowledge improves new learning (Gagné and Dick 1983; Anderson et al. 1990; Mostyn 2012).

The big news of this work is that enforcing the prerequisites improved scores on non-prerequisite knowledge. Students in the term where the proficiency test was required outperformed their counterparts on interpreting the financial statements on the project and on new topic questions on the cumulative final exam. Further, in the downstream course, Intermediate II, the course grades were better for the cohort completing the proficiency test. While the better grades in areas of content overlap would make sense (although we did not find this), better grades in downstream courses and on different topics signal something different. The discussion that follows will present several potential factors contributing to this learning advantage, starting with the least likely first, and progressing to the most likely.

There is evidence that intelligent tutoring improves student help-seeking behaviors, a type of self-regulation (Aleven et al. 2010). The hours spent within the intelligent tutoring system may have influenced their ability to self-monitor and recognize when help seeking is needed. These behaviors may have spilled over into the rest of the course, improving other academic outcomes.

Another possible explanation for the better final exam scores on new topics is the innovative grading format. The all-or-nothing grades, for both the proficiency assignment and the practice set portion of the project, forced all students to act like "A" students, and this may have created some change in goals, interest, or expectations. That is, positive reactions from attaining a new level of proficiency may have led students to adopt more mastery approaches to learning tasks, and mastery goals have been associated with better learning outcomes (Linnenbrink 2005). The grading model (100 percent or 0) may also have changed student confidence to perform at high levels (self-

TABLE 6

Course Grades[a] in Intermediate II as a Function of Intermediate I Experience

Variable	*B*	Std. Error	Beta	t-value	p-value
Constant	0.096	0.190		0.505	0.614
Proficient Prerequisites	0.361	0.057	0.208	6.304	0.000
Cumulative GPA	0.935	0.051	0.601	18.168	0.000
Credit hours earned	−0.002	0.001	−0.132	−3.988	0.000

$R^2 = 0.440$, ($n = 518$, $p < 0.001$).
[a] Omits students that withdrew since no grade was assigned.

efficacy). Self-efficacy has been shown to have powerful effects on course performance (Schunk 1991; Linnenbrink and Pintrich 2003). Teacher expectations can become self-fulfilling prophecies (Jussim and Harber 2005) and so the students may have adjusted their level of effort to match the instructor's expectations. Therefore, the better final exam and downstream grades may reflect changed self-confidence, academic goals, or an increased level of effort. The unknown-prerequisite-skills group had some exposure to all-or-nothing grading (half the project), but the proficiency group had a greater proportion of the course grade with this format.

Cognitive load theory predicts that mastery learning, especially for novices, can help free up mental resources for later learning (Clark et al. 2006; Mostyn 2012). Forcing students to *perfect* the accounting cycle (and not just pass it), created schemas—clusters of facts—of how accounts work and interact in the financial statements. Students with solid schemes can recall these knowledge chunks quickly and with little effort, leaving more mental space for thinking about new ideas (Sweller et al. 1998; Mostyn 2012). Therefore, higher levels of proficiency may have made later learning easier because the core accounting cycle concepts came somewhat automatically. Prior work in accounting has shown that students who learned to near perfection performed better on transfer tasks (Johnson and Slayter 2012).

Finally, removing the instruction for prerequisite materials from class time has a secondary benefit—it makes teaching the rest of the course go smoother (Kellar et al. 2007; Baxter and Thibodeau 2011). In other words, the increased learning of concepts not contained in the proficiency work may result because there is less time instructing or correcting the accounting cycle concepts and, therefore, more time on other course goals (Anderson and Boynton 1992). In effect, the proficiency assignment became a way to get students to self-teach and self-correct, relieving the instructor of this burden, and permitting the instructor to reallocate energy and time within the course.

Overall, this assignment solved a perennial issue in Intermediate I—students arriving at the onset of the course with a wide variety of ability in the prerequisite skills—using readily available on-demand technology. The students self-assessed and solved prerequisite lapses, improving the course outcomes and the outcome of the downstream course.

Student Reaction

Since this study was an archival study, the students were not available to ask about their experience with having the prerequisites enforced. Student evaluation of the course and instructor indicate that the overall worth of the course and instruction was better after the proficiency test was added. Further, students felt more motivated in the terms where prerequisites were enforced.

Anecdotal evidence indicated that students found the guidance offered by the AI tutoring system a great help, with no students complaining about the all-or-nothing grading, the cost of purchasing the subscription, or difficulty working the software. If there was a student reaction to the insistence that the incoming skills be mastered, it was a favorable one.

Learner-Centered Solution

On average, students spent over six hours working in the AI tutoring software, half the time required for a co-requisite one-credit hour course. This self-directed remediation, amounting to self-administering a mini accounting-cycle course, is an attractive feature of this innovative enforcement of the prerequisites. The test required no institutional resources, an attractive alternative when academy budgets and retention statistics are both under attack. Furthermore, this software permitted students to self-diagnose and self-select the amount and specific topics for remedial instruction. Finally, making students responsible for remedying any shortfalls in their prerequisite knowledge may represent a step forward in preparing students for responsibilities of the professional world.

WEAKNESSES AND FURTHER WORK

The all-or-nothing grading may have been a powerful force. Repeating this study where traditional homework is not accepted for credit until it is perfect (all-or-nothing grading format) might reveal if forcing students to behave like "A" students has an impact independent of the proficiency test. Alternatively, the proficiency test may be graded traditionally, awarding partial credit for less than mastery, to see if the impact remains.

The instructors in Intermediate II were not identical in the pre- and post-intervention terms and so some of the effects found may have been due to inconsistencies in rigor in course assessments and weighting of course elements in determining final grades.

Future work might experiment with requiring students to "test out" using the Quantum Simulations Accounting Cycle Tutor prior to enrolling, using it as the pretest instead of a mastery assignment toward course credit, and seeing if the results hold up.

CONCLUSION

This work is the first to document the effects sizes and far-reaching impact of finding and fixing lapses in prerequisite knowledge in Intermediate I. This intervention improved course performance by requiring students to demonstrate (or go acquire) mastery of prerequisite skills. The results show that students proficient in the prerequisites performed better than prior cohorts on *new* intermediate topics, even as far away as the next course in the intermediate accounting sequence.

The intrigue of this study goes beyond the improved student learning in Intermediate I and Intermediate II. Because the intervention was an existing educational product, it required no institutional resources and involved no changes to instruction, classwork, exams, or the project. This study is good news for schools that cannot impose a pretest, a one-credit accounting cycle course, or high grade point average requirement for enrolling in Intermediate I.

This work presents an encouraging picture for all constituents. Students have a convenient, face-saving, and effective way to find and fix their weak prerequisite knowledge. For Intermediate I faculty, their course does not need revision to take advantage of these findings. For Intermediate II faculty, students may come better able to learn. For administrators, this presents an attractive and low-cost way to increase course success. In an age when many majors are coming to the intermediate series with a variety of backgrounds, this study presents an innovative and painless way to bridge students into the rigors of the intermediate course series.

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