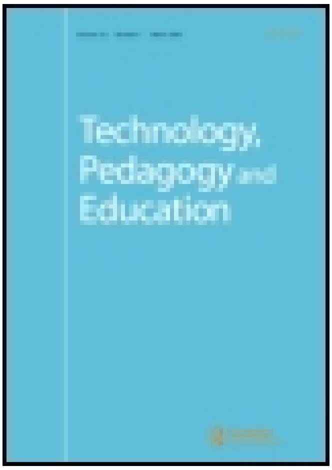

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The effect of blended instruction on accelerated learning

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While online instructional technologies are becoming more popular in higher education, educators' opinions about online learning tend to be generally negative. Furthermore, many studies have failed to systematically examine the features that distinguish one instructional mode from another, which weakens possible explanations for why online instructional technology can be beneficial. The current study isolates three benefits of the authors' particular online instructional technology: (1) providing flexibility in how students learn, (2) offering immediate and targeted feedback and (3) increasing student participation and engagement with instructional material. Maximum benefits were observed when students used the online instructional technology to prepare for their face-to-face class – that is, students with this blended instruction learned twice as much content in the same amount of time in comparison to students with face-to-face instruction alone, without creating an atypically high workload.

Keywords: blended instruction; face-to-face instruction; online instruction; accelerated learning

At the tertiary level, online instructional technologies have rapidly moved into almost every facet of instructor and student lives – for example, PowerPoint as the default mode of lecturing; the ubiquitous learning management systems for distributing readings, quizzes and grades; online libraries of instructional videos (e.g. iTunesU, YouTube); Wikipedia and other distributed knowledge repositories; and in-class clicker systems. As a result, the mode of instruction (i.e. how knowledge or information is delivered to students) ranges from fully online instruction to traditional face-to-face instruction that may or may not use supplemental instructional technology, and can be best represented on a continuum depending on the amount of content delivered online. Definitions of possible instructional modes were developed and utilised in a national survey that has been administered annually for the last 10 years (Allen & Seaman, 2013). At one end of the continuum, face-to-face instruction involves either no online technology (i.e. traditional courses deliver all content in writing or orally) or some online technology to manage a face-to-face course (i.e. web-facilitated courses make less than 30% of the content, usually just the syllabus and assignments, available online). At the other end of the continuum, online instruction delivers most or all (80+%) of the content via online technology, and typically there are no face-to-face meetings. In between, blended (or hybrid)

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instruction utilises online technology to deliver a substantial portion (30–79%) of the content, and interaction with the instructor and other students is usually done through online discussions and some face-to-face meetings.

In the current study, we examine how the use of online technology affects learning – more specifically, we hypothesise that blended instruction combines the benefits of fully online instruction and face-to-face instruction such that students will be able to learn more content in the same amount of time. To test this hypothesis, we supplemented a traditional, face-to-face class with a course that was designed to be a stand-alone online course (i.e. the Logic & Proofs course offered through Carnegie Mellon University's Open Learning Initiative), which maximises the benefits of online instructional technology by providing flexibility in how students learn, offering immediate and targeted feedback to all students, and increasing student participation and engagement with interactive, instructional material.

Benefits of online instructional technologies

Educators must balance various factors when planning to teach a course, such as teaching to large numbers of students while still facilitating individual student learning (Branoff & Wiebe, 2009). Because online instructional technologies can address these factors in a number of ways, more instructors are considering how various technologies that are uniquely afforded in online instruction can be used to improve their courses. Three general ways in which online instructional technologies can benefit education are explored in the current study: (1) by providing flexibility in how students learn, (2) by offering immediate and targeted feedback and (3) by increasing student participation and engagement with instructional material.

First, online instructional technologies can provide flexibility in how students learn, including what content they focus on, the format of the content, and the pace at which they work on the material (Lim, Morris, & Kupritz, 2007). Students are able to spend more time on content they find difficult without holding up other students who are not struggling with the same content. This flexibility allows some students to move more slowly when needed and others to move more quickly, preventing boredom (Moreno, Reisslein, & Ozogul, 2009). Further, the content can be provided in multiple formats, including text, diagrams, audio and/or video. By providing multiple formats of the same content, students can benefit from repeated exposure to the content. Multiple formats could also better meet the needs of a diverse population (Sitzmann, Kraiger, Stewart, & Wisher, 2006).

In addition, online instructional technologies can offer immediate and targeted feedback to all students, rather than just the ones actively participating in class. At strategic intervals, students can be presented with knowledge checks (i.e. questions that encourage students to reflect on the new content before moving on). Ideally, these knowledge checks are accompanied by feedback on the accuracy of the students' response and why the response was correct or incorrect. By integrating knowledge checks throughout the instruction, students are able to immediately determine whether they understood the new content. If a student does not respond correctly to knowledge check questions, specific feedback could address early misconceptions. As a result, receiving immediate and targeted feedback could increase understanding and thus refine learning (Anderson, Corbett, Koedinger, & Pelletier, 1995; Sitzmann et al., 2006).

Finally, online instructional technologies can increase student participation and engagement with material. By providing students with more control over their learning experience, students may better integrate the new knowledge with existing knowledge, thus facilitating deep and rich learning (Hannafin, 1984; Lim et al., 2007; Sitzmann et al., 2006). Furthermore, the asynchronous nature of online instruction can support self-reflection. Without the pressure of responding immediately and in front of peers, students can use additional time to reflect on and more deeply process the content (Means, Toyama, Murphy, Bakia, & Jones, 2009).

Despite these potential benefits for online instructional technologies, Redpath (2012) found that educators' opinions about online learning are generally negative – that is, many educators believe that online learning is inferior to face-to-face learning. In a longitudinal study comparing survey responses across the last 10 years (Allen & Seaman, 2013), less than a third of the respondents reported that their school's faculty accepts the value and legitimacy of online learning – this percentage only slightly increased from 27.6% in 2002 to 30.2% in 2012. More concerning was the increased percentage of respondents who reported not accepting the value and legitimacy of online learning – that is, it increased from 7.4% in 2002 to 12.6% in 2012. Therefore, it is important to examine how well online instruction stands up to the traditional, face-to-face instruction. The next section reviews such experiments.

Research comparing the different instructional modes

A plethora of research comparing instructional modes can be found. Several meta-analyses systematically examined the research conducted in the past two decades (Bernard et al., 2004; Means et al., 2009; Shachar & Neumann, 2010; Sitzmann et al., 2006). The context of these prior studies was comparable to the current study's context. Most of the courses were full courses offered at the college level, including university and community colleges. In addition, the courses covered a variety of domains, such as business, mathematics, computer science, dental hygiene and many others.

In an examination of 318 achievement effect sizes in 232 studies of students from kindergarten through college, Bernard et al. (2004) found that distance education – which they defined as including both fully online instruction and blended instruction – was comparable to face-to-face instruction. However, there was notable variability in the effectiveness across the two groups. While students in various face-to-face classes outperformed those in distance education settings, students in many distance education settings outperformed those in the face-to-face classes. These results likely indicate that other variables in addition to instructional mode could better account for learning gains. One such variable that was examined was whether distance instruction was synchronous (i.e. simultaneous communication between teacher and students) or asynchronous (i.e. lack of simultaneous communication). When examined separately, instructional mode had an effect on learning – that is, students in face-to-face classes outperformed those in distance education settings when instruction was synchronous, and students in distance education settings outperformed those in the face-to-face-classes when instruction was asynchronous. Other variables that helped to explain the large variability were particular methodological and pedagogical features of the studies.

In several meta-analyses of adult learners, fully online instruction was on average more effective than face-to-face instruction (Means et al., 2009; Shachar &

Neumann, 2010; Sitzmann et al., 2006). While similar results were found in studies of college students since these meta-analyses – students who received online instruction (Ashby, Sadera, & McNary, 2011) performed better than those who received face-to-face instruction – it is also important to note that quite frequently specific studies found no differences for online instruction (Lovett, Meyer, & Thille, 2008; Neuhauser, 2002; Nichols, Shaffer, & Shockey, 2003). While these results may suggest that face-to-face instruction can be adapted to an online platform and produce equivalent learning results, one possible explanation for the lack of differences is that some researchers modified the face-to-face instruction to make it more comparable to the online instruction. For example, in the Neuhauser (2002) study, the face-to-face activities were altered to include email activities so that an equivalent richness of instruction was provided. Rarely, students who received online instruction performed more poorly than those who received face-to-face instruction (Schwartz, 2012; Xu, 2011). Given the contexts of Schwartz's and Xu's studies, these results may be limited to community college locations, introductory courses in general or specific courses (e.g. online tax courses).

Similarly, the meta-analyses also concluded that blended instruction was on average more effective than face-to-face instruction (Means et al., 2009; Sitzmann et al., 2006). In more recent studies of college students, similar results were found – students who received blended instruction (Klein, Noe, & Wang, 2006; Vernadakis, Antoniou, Giannousi, Zetou, & Kioumourtzoglou, 2011) performed better than those who received face-to-face instruction. However, more frequently specific studies found no differences for blended instruction (Branoff & Wiebe, 2009; Delialioglu & Yildirim, 2008; Lim et al., 2007; Napier, Dekhane, & Smith, 2011). An explanation that Branoff and Wiebe (2009) provided for these results was that some students were not utilising all of the online instructional resources, and therefore, were not benefiting as much from the blended instruction as they could have. Unlike research comparing online instruction to face-to-face instruction, no researcher observed students who received blended instruction and performed more poorly than those who received face-to-face instruction.

One may wonder why so many studies do not show any differences between instructional modes. One possible explanation for this finding is that many studies failed to isolate the features that distinguish one instructional mode from another (Clark, 1983, 1994). For example, Abdous and Yoshimura (2010) compared courses offering the same content via three different instructional mediums: face-to-face, satellite broadcasting and live video streaming. In all three cases, the communication was synchronous, though it was accomplished by a different method in each case. In the face-to-face section, students interacted face-to-face with the instructor and their peers. The lecture was video-recorded so that it could be broadcast to the other sections. In the satellite broadcasting section, students watched the live video feed from a remote site. They interacted with their instructor and their peers by using a microphone that was connected to the face-to-face class. Finally, in the live video-streaming section, students watched the live video feed from their own computers. They interacted with the instructor and their peers with text messages sent through the course interface. Not surprisingly, no differences between the instructional mediums were found. This example demonstrates that the medium (i.e. face-to-face vs online) alone is not important when the possible benefits of the instructional mode are not being maximised (e.g. does the online format offer flexibility in how students learn, immediate and targeted feedback, or increased student participation and engagement with instructional material?). Therefore, the current study focuses on a curricular case in which these possible benefits are emphasised.

Online instruction vs blended instruction

While online instruction can be more effective than face-to-face instruction under some circumstances, one major weakness is less accountability for students to complete the work. Online instruction offers students the opportunity to learn anytime, anywhere, but this potential benefit is only effective if students exhibit enough discipline to complete work in a timely fashion. Unfortunately, procrastination among students is quite common. The consequences of procrastination could be severe, including lower grades on assignments and exams (Elvers, Polzella, & Graetz, 2003; Tice & Baumeister, 1997). Furthermore, the impact of procrastination could be different depending on the mode of instruction – that is, procrastination was a significant predictor of exam performance in an online class, but not in a face-to-face class (Elvers et al., 2003). Elvers et al. (2003) suggested that while the rate of procrastination in both classes was equal, students in the face-to-face class still had distributed exposure to the material during lectures. Therefore, instruction that involves online instructional technologies alone may not be the most effective option.

By contrast, blended instruction combines the potential benefits of online instructional technologies without the procrastination problem. The regular face-to-face meetings in a blended class should provide distributed exposure to the course content, even to those who procrastinate on assigned readings and assignments. Students in the blended class are more likely to keep up with the material. Furthermore, the feedback that instructors receive about how their students are preparing for face-to-face meetings in the online portion of the class could provide a wider flexibility in on-the-fly adaption to the current instructional context. This adaption is especially important because most settings vary widely in student type and prior relevant coursework. As a result, blended instruction can be an effective solution for teaching students with diverse learning styles (Bielawski & Metcalf, 2002). Since blended instruction appears to address a major weakness of online instruction, we expect that students who use online instructional technologies to prepare for a face-to-face class will benefit the most. Prior research supports this conclusion – as reported in a recent meta-analysis, the effect of blended instruction over face-to-face instruction was generally greater than the effect of online instruction over face-to-face instruction (Means et al., 2009).

Accelerated learning

Almost all prior studies have focused on the level of mastery, but a more sensitive measure may be the efficiency of learning. This efficiency (henceforth called accelerated learning) can take one of two different formats: learning the same content within a significantly shorter period of time or learning more content within the same period of time. Online instructional technologies offer opportunities to customise how much content is learned (Anderson, Corbett, Koedinger, & Pelletier, 1995); for true accelerated learning, however, increases in content learned should not just be the result of increases in the total time spent on the course, which may occur when students are given opportunity to explore additional content in greater depth. Therefore, implementing accelerated learning can be very challenging. Instructors and curriculum designers regularly struggle with deciding on the appropriate amount of content to cover in class, and often they choose to sacrifice depth of coverage or omit more advanced topics because they lack the resources to facilitate efficient learning. Furthermore, many students lack the skills to properly manage the workload of multiple classes, and often they use ineffective studying strategies, such as not monitoring their understanding and passively reading new content rather than reflecting and focusing on important information (Gettinger & Seibert, 2002). These issues could possibly be resolved given the benefits of online instructional technologies that were described previously. By providing flexibility in how students learn, offering immediate and targeted feedback, and increasing student participation and engagement with instructional material, students could improve the effectiveness of their studying strategies, which could allow instructors to pursue topics more deeply or incorporate more advanced topics.

In one study that measured accelerated learning, Lovett et al. (2008) explored the efficiency of blended instruction for a statistics course in a top-tier research university. They found that students were able to achieve similar learning outcomes in approximately half the number of weeks, with almost no change in the amount of time spent per week on the course. These results suggest that online instructional technologies may not only improve the depth of learning but also the efficiency of learning. Lovett et al. suggested that this improvement in the efficacy of learning likely occurred because students were more prepared for their face-to-face lectures after meaningfully engaging in the online instruction. However, one may question whether these results will generalise to other teachers and universities. The context chosen for Lovett et al.'s study was at a university that is highly ranked, especially in technological areas. Thus, these students are more likely to be comfortable working with online instructional technologies. Furthermore, the instructor had significant experience with the online instructional technology used in Lovett et al.'s study. This experience could affect how well the instructor utilised the technology in the course. Therefore, we chose a context that had a greater diversity in student ability as well as a teacher that had little experience using online instructional technologies to determine whether the results could generalise to more situations.

In studies to date, pure online instruction versus face-to-face instruction per se has no obvious influence on total time on task or success of accelerated instruction. Instead, the only study finding an accelerated learning effect involved blended instruction, suggesting perhaps that true accelerated learning may require the use of blended instruction.

Our context: Logic & Proofs – an Open Learning Initiative course

Open Learning Initiative

In 2002, the Open Learning Initiative was developed by an interdisciplinary group of researchers at Carnegie Mellon University to create learning environments that integrate expertise from not only the domain experts, but also learning science researchers, software engineers and human–computer interaction researchers. As a result, numerous online courses have been developed that maximally use what we know about how students learn, what can be done with current technology and how the online materials can be presented to best meet students' needs. While these courses can be taken as fully online courses, they are considered to be most effective when used in blended instructional format, specifically to prepare for and reinforce face-to-face class time (Lovett et al., 2008).

Logic & Proofs: course description

The context used in the current study was an introduction to modern symbolic logic course: Logic & Proofs[1] – henceforth called L&P (Sieg, 2013). Based on a set of online surveys and a systematic examination of course catalogues, we found that symbolic logic was frequently taught at all types of universities (e.g. national, liberal arts, comprehensive, historically black colleges and universities and two-year universities, highly vs less selective, private vs public) except tribal colleges. Further, symbolic logic was most commonly a course offered by philosophy departments – thus, we selected symbolic logic courses offered by philosophy departments for the current study. Finally, we found that many instructors were open to using a fully computer-based course, like the one in the current study, as a replacement for an existing textbook, which is a key factor for adoption and generalisability of the obtained results.

The L&P course covers the notions of statement and argument, logical analysis of informal arguments, and syntax and semantics of sentential logic and of predicate logic (with identity). The L&P course emphasises the effective and strategic construction of natural deduction-style proofs. This emphasis is complemented by a systematic tool for finding counterexamples, namely, semantic tableaux or truth trees. Several advanced topics are also included (e.g. derived rules in sentential and predicate logic, sentential meta-theory and the introduction of function symbols in predicate logic). The L&P course was designed with the goal of maximising the benefits of online instructional technology – that is, unlike most comparable face-to-face courses, it provides flexibility in how students learn, offers immediate and targeted feedback to all students, and increases student participation and engagement with instructional material. Each of these benefits is described further below.

First, the L&P course provides students with flexibility in how to learn the course material. The materials are presented in multiple formats, including a complete text with embedded mini-lectures (i.e. videos explaining central concepts or techniques), hands-on practice activities (see Figure 1) and a proof lab environment. When used to support a face-to-face class, students are typically introduced to new topics through the L&P course. This order allows students to work through the material at their own pace – students are able to spend more time on topics they find more difficult and less time on topics they find easy – before discussing the content in class.

Second, the L&P course offers students immediate and targeted feedback in the practice activities and homework assignments. Unlike the face-to-face course, while reading the L&P text, students are prompted to apply the new knowledge. For these tasks, students can access hints when unable to provide a response and receive immediate feedback on their answers. Similarly, rather than completing homework assignments on paper, the L&P course offers a proof lab environment in which students are given the opportunity to complete proofs with immediate feedback (see Figure 2). With this feedback, possible misconceptions can be immediately detected and corrected.

Third, the L&P course not only offers helpful feedback to students, but it also provides just-in-time information to instructors about how their students are performing on the practice activities, homework assignments and end-of-module exams.

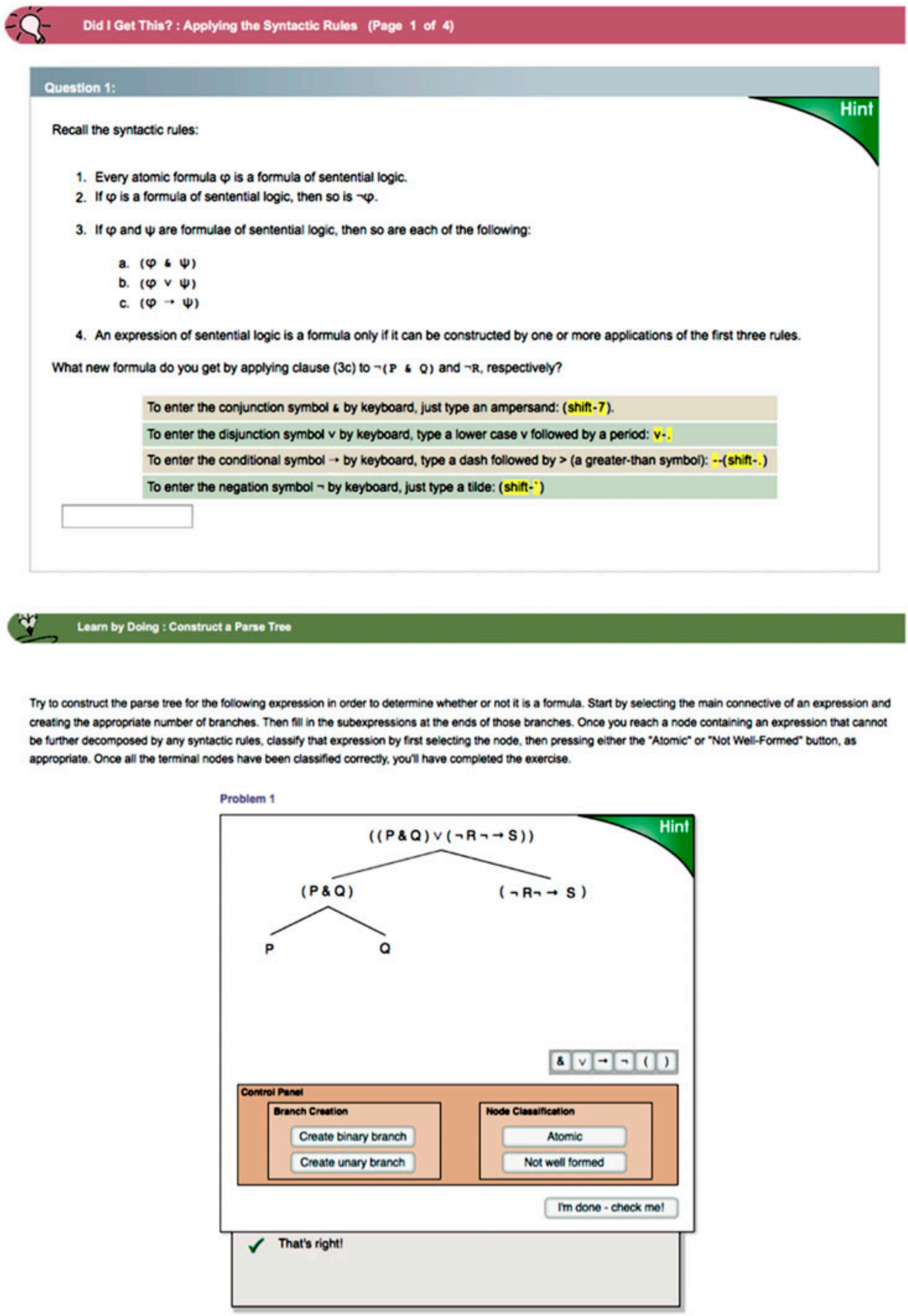

Figure 1. Hands-on practice activities: Did I Get This?, and Learn by Doing.

Because all activities are graded immediately and automatically, teachers can access this information to determine which topics are most difficult for students.

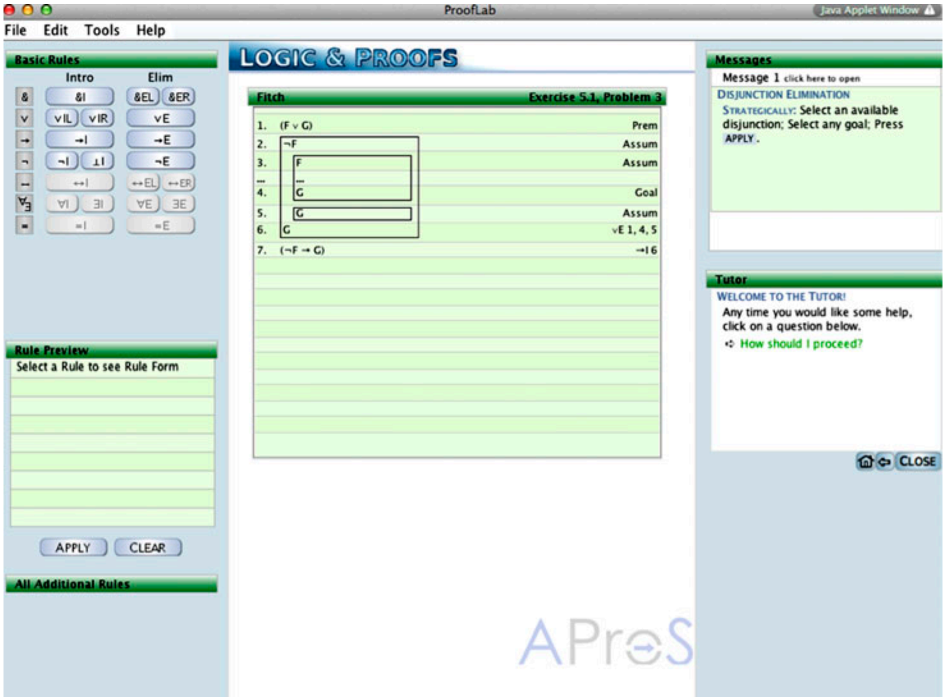

Figure 2. L&P ProofLab.

Consequently, they can tailor the class time to focus on these difficult topics – making the limited face-to-face time more efficient and effective.

As a result of the flexibility and feedback, the L&P course increases student participation and engagement with instructional material. Increased participation and engagement is likely to lead to increased understanding and thus refines learning. To test this hypothesis, we compared blended instruction with L&P to traditional face-to-face courses.

Findings from pilot studies

First, we compared a completely online version of the L&P course to a traditional face-to-face class across two semesters at a large, top-tier, public national university. The same instructor taught both semesters. The instructor was a full-time lecturer with not only significant research and teaching experience in symbolic logic, but also significant experience using various tools for online instruction.

Pilot Study 1

In Pilot Study 1, the 97 students (53% female; 8% freshman, 57% sophomore, 21% junior, 12% senior) chose either the online section ($N = 45$) or the face-to-face section ($N = 52$) of the Introduction to Symbolic Logic course. Overall, relatively low final exam performance was observed across the board, which likely reflected the rigorous content, the overall low levels of engagement and an institutional policy to maintain

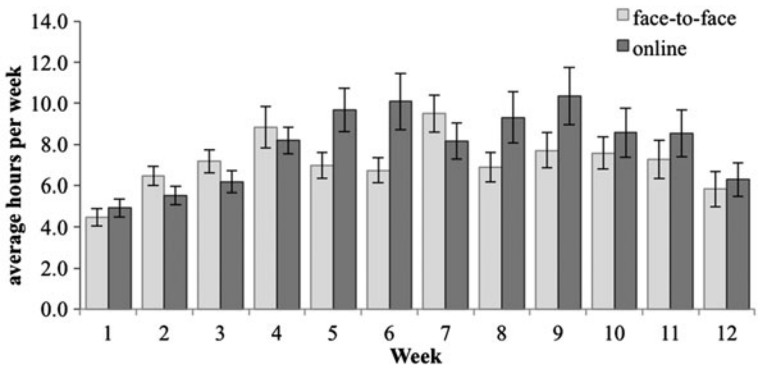

Figure 3. Self-reported total time-on-task in Pilot Study 1.

high standards in exams. Students in the online section (M = 60.2, SD = 17.7) performed comparably to students in the face-to-face section (M = 60.3, SD = 19.4), $t(95) < 1$, p = 0.99. In addition, self-reported time-on-task was examined. Overall, students in the online section (M = 7.8, SD = 4.6) did not spend significantly more time on the course than students in the face-to-face section (M = 7.1, SD = 4.0), $t(95) < 1$, p = .42; however, there were several spikes in reported time-on-task for weeks 5, 6, 8 and 9 (see Figure 3). During these weeks, students were introduced to more difficult proof constructions or to more complex syntax. As a result of these reported spikes in effort, the homework content was adjusted for the following semester.

Pilot Study 2

In Pilot Study 2, the 176 students (44% female; 19% freshman, 38% sophomore, 21% junior, 17% senior) registered for the online section (N = 50) or the face-to-face section (N = 126) of the Introduction to Symbolic Logic course. Similar to Pilot Study 1, students in the online section (M = 22.0, SD = 7.7) performed comparably on the final exam to students in the face-to-face section (M = 21.1, SD = 7.8), $t(174) < 1$, p = 0.47. The difference in time-on-task between the online section and face-to-face section for weeks 5, 6, 8 and 9 was reduced in Pilot Study 2, which reflected the successful adjustments in the homework.

Current study hypotheses

Based on the pilot studies, students appeared to benefit from the L&P instruction as a stand-alone course. However, we hypothesise that the maximum benefits will be seen when students use the L&P instruction in advance of face-to-face classes (i.e. blended instruction). The flexibility and feedback that the L&P course has to offer are expected to refine learning by actively engaging students with the material and increasing their understanding. Given that the L&P course was designed to optimise student learning, we further hypothesise that students using the L&P instruction would demonstrate accelerated learning (i.e. learn more material in the same amount of time) than students with face-to-face instruction alone.

Method

Course context

To test whether students could learn more material in the same amount of time than students who were not exposed to the online instructional technology, we chose a context in which the amount of material typically covered was noticeably lower than the L&P course.

In the US, a large proportion of students going on to tertiary education attend at least some community college classes, and many students attend only community college classes – there are almost 10 times as many community colleges as there are four-year colleges (Carnegie Foundation for the Advancement of Teaching, 2013). Lower admission standards, convenience of location and very low tuition are factors that account for high enrolments in community colleges. The lower admission standards produce a high diversity of student skill (in both core content and general study skills), and thus, there is likely a greater need for differentiated instruction. The large distribution of locations and low cost is made possible by having full-time instructors with very high teaching loads and part-time instructors with relatively little teaching experience and often with another full-time job. Given the relatively low prestige and low pay, these instructors are often teaching content outside of their focal area of expertise. All of these student and instructor factors likely affect the amount of material covered in community college courses, which tends to be noticeably lower (and with lower standards) than course material in university college settings (Arum & Roksa, 2010).

For this study, data were collected from an Introduction to Symbolic Logic course offered in two semesters at a mid-western US community college. Each semester, students could register for one of three sections of the course. The same instructor taught all three sections in both semesters. As would commonly be the case in this context, the instructor had a high teaching load (four courses/semester) of moderate-size courses (25 to 30 students), no research experience with symbolic logic, modest teaching experience with symbolic logic and little experience with online instructional technology.

Participants

Participants included 141 students enrolled in the course – 73 students completed the course in one semester (i.e. the *face-to-face instruction* condition) and 68 students completed the course in the subsequent semester (i.e. the *blended instruction* condition). Based on a background survey and pre-test that was administered in the blended instruction condition, 46% of the participants were female and mostly lower-level undergraduates (29% freshman, 52% sophomore, 17% junior, 0% senior). Many of the participants (69%) did not major in areas that are usually associated with symbolic logic (e.g. 2% philosophy, 4% mathematics, 4% computer science/engineering or 21% natural sciences). In addition, the majority of the participants had no prior experience in formal/symbolic logic, history of logic or rigorous proofs (only 37% had formal logic courses, 13% had history of logic courses and 16% had rigorous proofs courses). Overall, the participants reported average grade point averages (8% A, 28% B, 91% C). Furthermore, the participants did not do well on a pre-test that involved a range of basic logic concepts (see Appendix 1 for the pre-test; $M = 4.94$ out of 16; $SD = 1.6$).

While this demographic information was only collected in the blended instruction condition, the instructor reported that these data were representative of students typically enrolled in this course.

Procedure

In the face-to-face instruction condition, students received typical face-to-face instruction with two face-to-face lectures per week. The course covered less than half of the full L&P course: it included only sentential logic, and no thorough treatment of proof construction was given even within sentential logic. Students had three midterm exams and an optional final exam.

In contrast, the instructor's goal for the blended instruction condition was to cover as much of the full L&P course as possible using blended instruction: one face-to-face lecture per week with students experiencing primary instruction through online materials and practice. Students had one midterm exam (equivalent to the first midterm from spring 2008) and one required final exam (equivalent to the second and third midterms from spring 2008 plus new content not covered in the previous semester). The new content included strategically constructing proofs, constructing truth trees and translating in predicate logic.

Results

Overview

To examine whether students who received the blended instruction could learn more material in the same amount of time than students who were not exposed to the online instructional technology, we first compared exam performance between students in the face-to-face instruction condition and the blended instruction condition. Then, to verify that the students who received the blended instruction did indeed spend the same amount of time on task, we measured self-reported workload, difficulty and amount of material covered in this course compared to other classes they were taking.

Exam performance

Because students in the blended instruction condition covered more content than students in the face-to-face instruction condition, the same exams could not be used. Therefore, for these analyses, we first identified overlapping content areas on the exams used in both conditions – that is, the first exam in the face-to-face instruction condition overlapped in content with the midterm used in the blended instruction condition, and the content on the second and third exams in the face-to-face instruction condition overlapped with part of the final exam in the blended instruction condition. Next, we identified the additional content areas that were tested on the final exam in the blended instruction condition. While the exams were not formally assessed for validity and reliability, the exams have ecological validity because they were designed by an instructor who had modest experience teaching symbolic logic.

Overall, students who received the blended instruction demonstrated satisfactory performance on overlapping and extra material (see Figure 4), which suggests that blended instruction helps students to learn the base material in less time given that

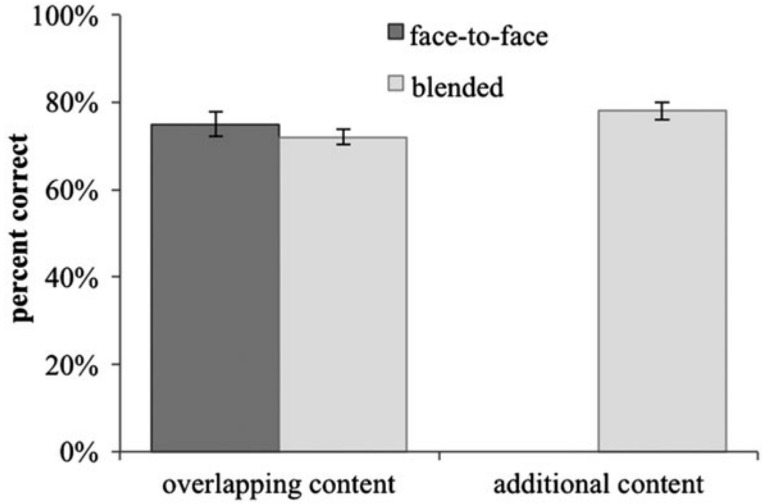

Figure 4. Performance on overlapping questions and extra questions on the final exam.

the same total time was spent learning the base material plus the advanced material. There were no significant differences between the face-to-face instruction condition (M = 75%, SD = 26) and the blended instruction condition (M = 72%, SD = 16) on material that was covered by both conditions, $t(150) = 0.72$, $p = .47$. More importantly, those who received blended instruction (M = 78%, SD = 18) also demonstrated adequate performance on the additional material covered this semester.

Time-on-task

At the end of the semester, students in the blended instruction condition were asked to rate the workload, difficulty and amount of material covered in this course compared to other classes they were taking. A 5-point scale (–2 to 2) was used, with negative numbers indicating less than other classes and positive numbers indicating more than other classes. To examine whether the revised course involved an atypically high workload, a one-sample t-test was used to compare the average of students' perceptions about the blended instruction (see Table 1). None of the averages were significantly different from 0, indicating that the workload, difficulty and amount of material covered were the same as in other classes. Further, while there was a trend towards a higher than average level of difficulty and amount of material covered, there was a trend towards a lower than average workload (critical for accelerated instruction – more material in the same amount of time).

Table 1. Students' perceptions of blended instruction in comparison to other current courses.

	M	SD	t	p
Workload	–0.18	(1.14)	–1.23	0.22
Difficulty	0.25	(1.15)	1.67	0.10
Amount of material	0.16	(1.01)	1.26	0.21

General discussion

Summary of results

In a community college context, accelerated learning was achieved using blended instruction: the previously covered content was learned at an acceptable level and a considerable amount of additional, advanced content was also learned at an acceptable level. This gain in content learning took place over the same length of time, without creating an atypically high workload.

Theoretical & practical implications

While many studies failed to emphasise the features that distinguish one instructional mode from another (Clark, 1983, 1994), the current study carefully theorised and documented three benefits of online instructional technologies, and showed that a course could achieve significant accelerations in learning when such technologies were included. While the core structure of both sections was essentially the same – that is, both sections were assigned readings from a text and weekly homework assignments – the L&P course was able to (1) provide flexibility in how to learn the course material by presenting the material in multiple formats; (2) provide immediate and targeted feedback in the practice activities and homework assignments; and (3) increase student participation and engagement with instructional material.

After 15 years of teaching logic without major use of online instructional technology, the instructor in the current study noted, 'There seemed to be something about the mode of presentation that encouraged the students to take more individual responsibility for their learning.' Upon further reflection, the instructor observed, 'The interactive nature of the text seemed to engage the student in a way that a standard text does not and cannot.' As expected, the flexibility and feedback that the L&P course provided increased engagement with the material. She also observed, 'Because of the way in which L&P enables the student to work through the material step by step, I no longer found myself needing to "spoon feed". I actually found that the students had done the reading and the practice exercises prior to coming to class.' By using the L&P course to introduce new material before class, the instructor was able to spend class time more efficiently, thus covering more content in the same amount of time.

Caveats & future directions

Not all online instructional technologies are created equal. The version of the L&P course used in the current study had the benefit of six years of development with input from not only content experts and students, but also learning science researchers, software engineers and human–computer interaction researchers. Furthermore, developing insights on student learning and customising instruction based on those insights could be quite difficult for instructors (Stein, Engle, Smith, & Hughes, 2008). Therefore, the success of blended instruction may be dependent on the tools and support available to the instructors.

While the L&P course focused on computer-based feedback to students, other forms of feedback could also be successfully implemented with the use of online instructional technology. One such example includes synchronous and asynchronous student–student interaction (e.g. peer review, discussion boards or other computer-mediated collaborative learning tools). Additional benefits may occur with peer-centric instructional media.

Finally, the type of content covered in the course might affect how much online instructional technology can benefit learning. The current context, an introduction to modern symbolic logic course, primarily focused on skill-based content. Such content involves step-by-step procedures that have obvious opportunities for feedback. By contrast, more declarative content, such as history or literature, does not have obvious practice opportunities and may benefit more from discussions that typically occur in face-to-face classes. Therefore, online instructional technology that involves student–student interaction may be more beneficial than trying to develop online instructional technology that provides immediate and targeted feedback. Future work should determine how online instructional technology could benefit all types of content equally.

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Note

1. The current version of L&P (http://oli.cmu.edu/courses/free-open/logic-proofs-course-details/) has two significant, additional features: (1) it provides intelligent and dynamic tutoring for proof constructing in the ProofLab; and (2) it provides systematic support for semantic investigations (as the ProofLab did for the construction of proofs) in the TruthLab. Neither of these features was yet available at the time of our experiments.

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Appendix 1. Pre-test

In questions 1–5, the letters P, Q, R, S, and T represent statements, that is, sentences that are either true or false. For example, P could stand for 'Paula likes peanuts,' and Q could mean 'Quincy is quarrelsome.' With that understanding 'IF P THEN NOT Q' would represent 'IF Paula likes peanuts THEN Quincy is not quarrelsome.'

1. Suppose P is true and Q is false.
   What is the truth-value (true or false) of the formula: P OR Q
   A. True
   B. False
2. Suppose P is true and Q is false.
   What is the truth-value (true or false) of the formula: P OR NOT Q
   A. True
   B. False
3. Suppose P is true and Q is false.
   What is the truth-value (true or false) of the following logical formula: IF P THEN Q
   A. True
   B. False
4. Suppose P is true and Q is false.
   What is the truth-value (true or false) of the following logical formula: IF NOT P THEN Q
   A. True
   B. False
5. With the understanding of P and Q explained above, decide which logical formula represents the statement 'Paula likes peanuts unless Quincy is quarrelsome.'
   A. IF P THEN Q
   B. IF Q THEN P
   C. IF NOT Q THEN P
   D. IF Q THEN NOT P

For questions 6–9, determine if the series of statements constitute valid arguments or not.

6. Some people are Americans.
   Some people are rich.
   Therefore, some people are rich Americans.
   A. Valid
   B. Invalid
7. All men are mortal.
   Socrates is mortal.
   Therefore, Socrates is a man.
   A. Valid
   B. Invalid
8. All logic students are intrepid.
   All wise persons are intrepid.
   Therefore, all logic students are wise persons.
   A. Valid
   B. Invalid
9. If something is not a canine, it is not a dog.
   All dogs have fur.
   Agnes has fur.
   Therefore, Agnes is a canine.
   A. Valid
   B. Invalid

For questions 10–14, determine whether two formulas are equivalent. Two formulas are equivalent if they always have the same truth value, as indicated with a double arrow <–>.

10. (R OR (S AND NOT S)) <–> R
    A. Correct
    B. Incorrect
11. NOT (R OR S) <–> (NOT R AND NOT S)
    A. Correct
    B. Incorrect
12. NOT (R AND S) <–> ((NOT R) OR S)
    A. Correct
    B. Incorrect
13. (S IF R) <–> (IF S THEN R)
    A. Correct
    B. Incorrect
14. (IF R THEN S) <–> (IF NOT S THEN NOT R)
    A. Correct
    B. Incorrect
15. To prove the conditional, ‘If we continue to burn fossil fuels at the current rate, then the greenhouse effect will do us in,’ one must:
    A. Prove that both statements are true.
    B. Prove that both statements are true and that the first implies the second.
    C. Assume the first statement and show that it implies the second.
    D. Assume both statements are true and show that they do not lead to a contradiction.
16. To disprove the statement, ‘For all X and Y, if X and Y are numbers, then X + Y > X,’ one must:
    A. Prove that for all X and Y, if X and Y are numbers, then X + Y > X.
    B. Show that for all X and Y, ‘X and Y are numbers’ contradicts ‘X + Y > Y.’
    C. Find one pair of numbers, X and Y, for which X + Y <= X.
    D. Demonstrate that for all X there does not exist a Y such that X + Y > X.