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Embedded blended learning within an Algebra classroom: a multimedia capture experiment

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Abstract

This two-group, pretest-posttest, quasi-experimental study compared secondary students' learning of Algebra II materials over a 4-week period when identical instruction by the same teacher was delivered through either embedded blended learning (treatment group; $n = 32$) or a live-lecture classroom (control group; $n = 24$). For both groups, instruction was delivered in a normal classroom setting. A math test and a student survey were used to measure students' learning of Algebra II and satisfaction with the instruction. Students in the treatment group showed significantly greater gains in Algebra II test scores and evaluated their learning experiences significantly more positively than did the control group. The great majority (80%) of students in the treatment group preferred the embedded blended learning over traditional live lectures for future learning of math. Students' responses to open-ended survey questions suggested that students in the treatment group appreciated the: (a) ability to control the pace of instruction; (b) new role of the classroom teacher; (c) lack of distraction in the blended learning environment; and (d) accessibility of the embedded multimedia lessons outside the classroom. This study suggests that screen-capture instructional technology can be used towards establishing a teacher-based, embedded blended learning environment within a secondary algebraic classroom.

Keywords

blended learning, improving classroom teaching, media in education, multimedia/hypermedia systems, secondary education, teaching/learning strategies.

Introduction

It has been estimated that nearly one-third of all public high school students within America fail to graduate (Bridgeland, DiIulio, & Morison, 2006). To overcome these deficiencies, enormous pressures from state and federal governments continue to be placed on the K-12 public school system. Secondary schools throughout the USA repeatedly look for external solutions to address academic achievement. In hopes of finding a quick and easy answer to these systemic failures, online courseware and educational software have been cast as education's new *silver bullet*, similar to past predictions of the radio, film and television (Mayer, 2009). However, unlike these past technologies, new schools are being built solely to facilitate these computer-based curriculums, while traditional brick-and-mortar schools are replacing or reducing the role of the classroom teacher. Three quarters of K-12 school

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districts (74.8%) across the nation have introduced online courses developed by third-party vendors and more than half of the remaining districts (15.0%) are planning to use some form of online instruction in the near future (Picciano & Seaman, 2009).

K-12 schools throughout the nation are rapidly implementing new online instructional technologies; however, there is little assurance that student learning will result (Figlio, Rush, Yin, & National Bureau of Economic Research, 2010). A meta-analysis of empirical studies found a lack of conclusive evidence supporting the learning outcomes of online instruction within the K-12 environment (U.S. Department of Education, Office of Planning, Evaluation, and Policy Development, 2010). To this effect, the National Education Policy Center (Molnar *et al*., 2014) found achievement gaps of 22% points in for-profit online K-12 schools. During the 2011–2012 academic year, less than a third of all students (29.6%) enrolled in the emerging sector of online schools met the state standards compared with half the students (51.8%) in traditional brick-and-mortar schools.

The lower academic achievement of secondary students within solely online schools may be, in part, due to their stage of development in terms of mental capacity. Unlike post-secondary students, adolescent learners are undergoing rapid brain development and may not yet have the ability to entirely balance reason and planning (Woolfolk, 2007). Research suggests that online instruction should be used as part of the classroom experience with high levels of instructor involvement rather than as the exclusive method of instruction (Zhao, Lei, Lai, & Tan, 2005). In contrast to solely online instruction that eliminates classroom practice, online instruction delivered within the blended classroom enables the teacher to guide students through multimedia content and further classroom activities. For example, Griffin, Mitchell, and Thomson (2009) questioned the validity of providing online material to any student without corresponding classroom activities and claimed that a well thought-out integration of face-to-face classroom learning practices with online learning experiences was important for effective teaching and learning. As observed by O'Bannon, Lubke, Beard, and Britt (2011), when an instructor in the college setting was able to deliver his/her lectures in an online manner as the primary method for delivering coursework within the classroom, the teacher no longer needed to provide live-lecture instruction and was free to devote instructional time to more student-centred interactions. Though these studies suggest a teacher can transform his/her live-lecture instruction into digital multimedia lessons within the post-secondary classroom, there is little empirical evidence to suggest a secondary classroom teacher can successfully deliver his/her own online content while simultaneously providing one-on-one supplemental tutoring.

Embedded blended learning

Blended learning has been defined as a course that combines online learning and live-lecture instruction where 30%–79% of the instructional content is delivered online (Allen & Seaman, 2010). Blended instruction has the potential to utilize the benefits of both instructional methodologies, and the ways in which teachers are applying blended/hybrid instruction in the classroom are increasingly broadening. According to Interactive Educational Systems Design, Inc.'s (2014) survey of school district's technology directors, 66.7% of all K-12 schools are likely to soon adopt mobile devices in a 1:1 computer to student ratio with the expectation that the technology will lead to an increase in academic achievement. Yet, most computing efforts within the K-12 classroom have shown little to no effect on academic achievement to date (Figlio *et al*., 2010). Part of the problem is that digital content in blended learning classrooms rarely delivers instructional content as a cognitive tool that supports, guides and mediates the cognitive processes of learners (Kong, 2011). In a typical blended/hybrid classroom, computing initiatives support a teacher's live-lecture pedagogy with supplemental *app-centric* activities. Computers within the K-12 classroom are most often used by students for browsing the Internet, word processing and developing digital media presentations (Suhr, Hernandez, Grimes, & Warschauer, 2010).

While the app-centric blended model facilitates the classroom teacher's existing live-lecture pedagogy, the emerging blended-online model entirely replaces the teacher's instruction in favor of third-party online courseware. It has been estimated that by the year 2024, 80% of secondary courses will be taught through online instruction developed by third-party sources (Christensen, Horn, & Johnson, 2008). Similar to past improvement efforts that disregard the teacher's role in the educational setting (Cuban, 2003), this use of *canned* online curricula also does little to integrate a classroom teacher's ability to transfer knowledge or contextualize information. Zhao (2009) contends that in hopes of achieving uniformity, homogenized content stifles innovation in favor of overbearing standardization, demoralizes educators and impedes locally relevant curriculum.

The increasing demand to tailor online instruction is driving new technologies for the classroom teacher that provides learner choice and control, thereby eliminating a one-size-fits-all model (Johnson, Adams, & Haywood, 2011). Within a blended learning environment that provides student control over time, place, path and pace of the instruction (Stalker & Horn, 2012), students accessing computer-based multimedia are able to pace their learning in a manner that matches their cognitive ability (Sweller, 2005). Anderson (1993) describes the factual information delivered from computer-based instruction as declarative knowledge held within a learner's working memory. By developing personalized and interactive multimedia learning systems, a user's learning needs and preferences can be achieved (Chrysostomou, Chen, & Liu, 2008). Unlike past practices of the first 1:1 computer-based classroom initiatives of the 1980s (Dunleavy, Dextert, & Heinecket, 2007), a teacher's unique instruction can now be delivered entirely online into the classroom.

Whereas blended learning has been framed as a transition from live-teacher instruction towards a 100% virtual learning model using online courses purchased from software developers (Christensen *et al*., 2008), the classroom instructor now has the capability to capture his/her instruction as an online cognitive tool. In this paper, we refer to this new instructional archetype as 'embedded blended learning' where the teacher no longer provides live-lecture instruction nor provides third-party online courseware, but rather embeds his/her content knowledge within 'embedded multimedia' delivered into his/her own classroom. Embedded blended learning combines a teacher's capture instruction and face-to-face support so the substantial proportion (80%–100%) of the educational content has been developed by the instructor and is delivered online into the classroom in a student-paced framework. Though online and blended courses can substantially reduce face-to-face meetings (Allen & Seaman, 2010), a teacher within embedded blended learning provides concurrent face-to-face tutoring while his/her embedded multimedia is being *pulled* by classroom students.

Educators can be a *value-added* component to the online learning experience within embedded blended learning by eliminating live-lecture's didactic delivery, while still incorporating a classroom teacher's critical contribution of locally relevant knowledge, thought and propinquity. Rather than rely on third-party courseware intended to serve a broader market, a classroom teacher can utilize multimedia capture/movie recording devices to transform their content knowledge into an online cognitive tool that offers immediacy of content in a diacritical, differentiated and self-paced manner. It is noteworthy that during a typical blended classroom session, multimedia lessons are generally contained within 8- to 10-min media segments (Greenburg, Medlock, & Stephens, 2011) that do not need to be combined nor viewed for the duration of the course period, thus allowing time for additional educational activities.

Screen-capture technology

Screen-capture instructional technology (SCIT) is the amalgamative process that enables courseware developers to author, edit and deliver their own instructional multimedia content, with the added feature of user interaction (Smith & Smith, 2012). Though screen-capture technology was initially used to electronically capture computer-screen movements with the simultaneous recording of audio narration (Folkestad & DeMiranda, 2002), today's SCIT authoring tools have evolved considerably. Educators can now appropriate readily available multimedia devices that are provided with screen-capture software, including digital camera projectors, electronic whiteboards and mobile computing devices. The multimedia files are frequently enhanced using media editing applications that can eliminate verbal or visual errors and remove extraneous content. Further courseware development often combines screen-capture with the multimedia capture/movie recording of the teacher's live-lecture instruction, thus enabling deeper cognitive processing through cueing techniques that focus a learners' attention towards relevant information (De Koning, Tabbers, Rikers, & Paas, 2007) and social cues from non-verbal indications (Mayer, 2005).

Cognitive load theory

Cognitive load theory is based on the notion that humans are limited in the amount of information that can be held within working memory at one time (Mayer, 2009). Working memory refers to the temporary storage of information that is critical for reasoning and learning (Baddeley, 1992). As information is encoded into working memory, knowledge is limited in capacity and duration. Miller's (1956) early work paved the way to much of the foundational research into information processing during a learning activity. Miller found that on average, the memory span holds a limited amount of items simultaneously; 'there is a span of absolute judgment that can distinguish about seven categories and that there is a span of attention that will encompass about six objects at a glance' (p. 91).

Cognitive load theory stipulates that there are three loads within learning and memory which need to be accounted for when learning from instructional multimedia. 'CLT [cognitive load theory] distinguishes between three types of cognitive load: intrinsic load, extraneous or ineffective load, and germane or effective load' (Paas, Renkl, & Sweller, 2003, p. 65). Sweller (2005) defines intrinsic load as cognitive load due to the natural complexity of information being processed, while extraneous load pertains to unnecessary or redundant information that inhibits learning, and germane load as the process that makes sense of essential material. Instructional multimedia requires that all three cognitive loads be accounted for during a learner's acquisition of information. When working memory is subjected to overly complicated or extraneous instruction, the learner becomes overwhelmed and is unable to process new or essential information. The central goal of cognitive load theory is to therefore anticipate the limitations of working memory and optimize essential instruction. If a student is forced to select, organize and integrate too much information through one channel, the subject will be unable to learn as extraneous processing overwhelms a student's limited cognitive processing ability (Mayer, 2009). The learner's intrinsic cognitive load can be reduced when instruction has been designed in a manner that assumes a limited capacity of working memory (Sweller, van Merriënboer, & Paas, 1998). As noted by Sweller (2005), cognitive load theory can link the needs of human cognitive architecture with the development of multimedia content.

Cognitive load theory asserts that learning is impaired when working memory is overloaded while attempting to simultaneously process overly complex information through the visual and auditory channels and that multimedia content can be designed to optimize learning. Courseware development and the design of multimedia must be created in a manner that anticipates working memory as a key component to learning or the instruction will invariably be deficient (Sweller *et al*., 1998). The interactive principle suggests 'people understand a multimedia explanation better when they are able to control the order and pace of presentation' (Mayer, Dow, & Mayer, 2003, p. 810). Mayer and Chandler (2001) demonstrated that when multimedia is presented in segments under learner control, the learner can understand each piece before going on to the next component, thereby reducing the cognitive overload. The interactive principle reveals that problem-solving skills improve when students are not subjected to continuous and unabated instruction. By providing control over the sequence and pacing, cognitive load can thereby be reduced so the learner processes each segment of new information from within his working memory before acquiring new content. Mayer and Moreno's (2003) segmentation effect claims that by providing built-in breaks with learner-controlled segments, learners gain better understanding from a multimedia explanation over a continuous presentation, as commonly experienced within a traditional live-lecture format.

Research purpose

The U.S. Department of Education, Office of Planning, Evaluation, and Policy Development's (2010) meta-analysis found that blended learning instruction within the classroom can outperform both traditional and online learning, but the results are not fully understood by the authors. Multimedia instruction has been shown to increase overall achievement scores for adolescent learners, yet there is uncertainty about how to develop or integrate the technology into secondary classrooms (Kingsley & Boone, 2008). This experiment sought to compare the academic outcome of secondary Algebra II students in a blended classroom where the teacher delivered embedded multimedia against that of students in a traditional classroom where the same teacher delivered instruction in a live-lecture format. It was hypothesized that secondary Algebra II students in the embedded blended learning classroom would demonstrate significantly higher academic achievement than would students learning in a live-lecture classroom. Student satisfaction with embedded blended learning was also analysed.

Method

Research design

This was a two-group, pretest-posttest, quasi-experimental design comparing secondary students' learning of Algebra II materials over a 4-week period when identical instruction was delivered using embedded multimedia created from SCIT (treatment group; $n = 32$) or through traditional live lectures (control group; $n = 24$). For both groups, instruction was delivered in a normal classroom setting by the same math teacher. In order to fully support students' learning of Algebra II content, one-on-one tutoring was made available to all student participants after the study. The ethical treatment of participants of this study was reviewed and approved by the Institutional Review Board of Saint Mary's College of California.

Participants

Students
Participants were students enrolled in two sections of Algebra II ($N = 56$) at a comprehensive public high school serving 1230 students. Students participating in the study were 9th–12th graders comprising of 5 freshman, 30 sophomores, 14 juniors and 7 seniors, whose ages ranged from 14 to 17 ($M = 16.0$, $SD = 0.9$) years.[1] The ethnicity of the students was 67% White (non-Hispanic), 22% Hispanic, 4% African American, 4% Asian and 3% Indian. In preparation for the 2011–2012 school year, the high school's guidance counselor used *Aeries Student Information System Software* to enroll students into Algebra II classes based on their graduation requirements and student elective preferences. Two of the four high school Algebra II classes were then randomly assigned by the first author of this study to the treatment ($n = 32$) and control ($n = 24$) groups.

Teacher
One experienced secondary teacher taught both Algebra II classes. Though she had taught other math curriculums including Geometry and Pre-Algebra, her area of teaching expertise was in Algebra. At the time of the study, she was in her mid-40s and had 15 years of experience as a high school math teacher. She had nearly 1 year worth of experience with embedded blended learning.

Instructional materials and setting

Curriculum
Instructional materials were developed based on the California Content Standards for High School Mathematics and the school's Algebra II textbook (Holliday *et al*., 2008). Instruction during the 4-week experimental period covered content from Chapter 5 of the Algebra II textbook, which included graphing quadratic functions, solving quadratic equations by graphing, solving quadratic equations by factoring, complex numbers and completing the square.

Online apparatus
The participating math teacher used the following software and apparatus to develop multimedia lessons for the treatment group: digital whiteboard with screen-capture software (SMART technologies), tablet computer (iPad) with an internal multimedia capture/movie camera, external microphone and a PC-based movie-editing software (Sony VegasPro). The media lessons were made available to the screen-capture group through the school's website (Google Drive). Participating students in the screen-capture group accessed multimedia lessons through tablet computers (iPad) and over-ear headphones, which were available to individual students in the classroom. Both groups used the tablet computers in the classroom as enhanced graphing calculators when needed.

Multimedia lesson development
The math teacher developed digital multimedia lessons for the screen-capture group prior to the day of instruction. For each lesson, the teacher demonstrated how to graphically solve algebraic equations on her classroom's digital whiteboard or tablet computer, while the screen-capture software recorded the screen markings. The teacher's coinciding audio narration was

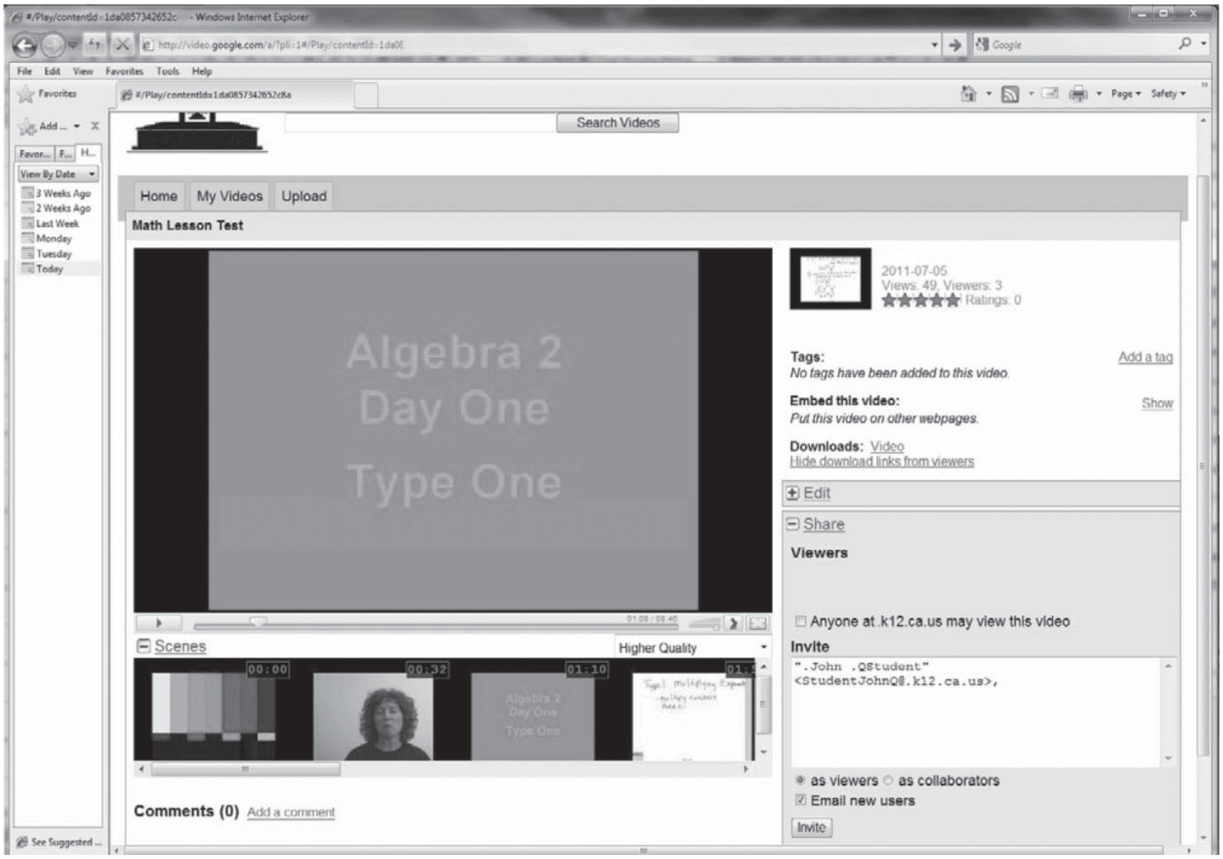

Figure 1 Embedded Multimedia on the Teacher's Website

simultaneously recorded via an external microphone plugged into the digital whiteboard or tablet computer. Finally, the screen-capture software automatically merged the audio and video recordings into a single digital movie file. Then the movie file was enhanced by the insertion of a title and the math teacher's introductory lesson commentary, which the teacher captured herself using a tablet computer's front-facing capture/movie camera or a separate movie camera facing the classroom teacher. Finally, movie-editing software was used to combine all three – multimedia/movie file containing the teacher's introduction, lesson titles and the screen-capture Algebra II lesson – into a single multimedia digital file. A unique multimedia lesson, which averaged 7–10 min in length, was created for each day of instruction. The math teacher uploaded the multimedia files onto the school's website (Figure 1) prior to each class period, enabling students in the screen-capture group to gain access to the embedded multimedia.

Classroom setting and procedure

Because of a modified block schedule, each Algebra II class met 4 days during the week. The study began 7 weeks into the new school year for 16 consecutive classroom periods during a 1-month period, permitting for a total of 13 days of instruction and 3 days of assessment (pre-test, post-test, student survey). Students in both the live-lecture and screen-capture groups met in the math teacher's regular classroom. The pre-test/post-test was also developed to provide letter grades for both groups of students.

Each day for the following 4 weeks, the math teacher provided new identical lessons to the live-lecture and screen-capture groups. As the lessons were presented, both groups were instructed to follow the standard classroom procedure, which required students to take handwritten notes on the new algebraic instruction. Then students spent the next 20 min or so working independently on Algebra II workbook activities assigned by the teacher. Students in both groups were allowed to ask questions during instruction and to receive one-on-one assistance with the workbook activity from the math teacher. Students in both groups were given identical classroom activities and homework assignments, with the exception of an optional activity of posting online comments about the multimedia content through the school website, which was only available for screen-capture students. After 4 weeks of instruction, both groups were given an Algebra II post-test in class.

While each day's lesson was delivered in person by the math teacher for the live-lecture group, students in the screen-capture group individually accessed each day's embedded multimedia lesson using the tablet computer and earphones that they received when entering the classroom. Students in the live-lecture group also used the iPad tablets as needed for its graphing calculator function throughout the duration of the study, as did the screen-capture group. The content of the embedded multimedia lesson was identical to the 7- to 10-min lectures offered to the live-lecture group. Unlike the conditions of the live-lecture group, however, students in the screen-capture group were able to individually rewind, pause, fast-forward or play back the day's instruction at any time during class. The screen-capture group students had access to the embedded multimedia lessons after the initial viewing inside and outside of class through the password-protected school's website as long as they had an Internet connection.

Data collection instruments

Algebra II performance test

The performance test incorporated the teacher's Algebra II textbook's testing material. The teacher administered the textbook's Chapter 5 test to all participating students at the beginning (pre-test) and end (post-test) of the study. This multiple-choice test contained 20 items (5 points each for a total of 100 points), and four answer choices were given for each item.

Student surveys

To measure students' evaluation of the Algebra II course with the classroom materials, an anonymous student survey was developed and administered to all participating students at the end of the study. Six questions that rated the effectiveness of the instruction using a 5-point Likert-type scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*) were developed from Appleton, Christenson, Kim, and Reschly's (2006) self-rating model that 'includes less observable, more internal indicators, such as self-regulation' (p. 429). These questions measured the frequency each student checked for understanding during the math instruction, the curriculum's relevancy and student control over their own learning. Both groups answered two open-ended questions that asked all students to describe anything that helped or hindered their learning of the Algebra II materials.

Participants in the screen-capture group completed five additional 'yes' or 'no' satisfaction questions with corresponding spaces to explain their answers. Additionally, eight open-ended satisfaction questions were designed to elicit responses from the screen-capture students' experiences interacting with the online or regular math instruction. These questions elicited students' satisfaction of instruction and inquired about online instruction for homework (*flipped*), technical problems and whether the teacher should develop more online lessons. Ten final questions elicited students' experiences with the online multimedia that include the frequency of use, type of interaction and viewing locations.

Results

Data analysis

Quantitative analysis

Analysis of covariance (ANCOVA) was used to measure the extent to which students in the two groups (i.e., lecture vs. screen-capture) performed differently on the Algebra II post-test while controlling for their pre-test scores. Students' survey ratings were analysed using descriptive statistics and independent-samples t-tests.

Qualitative analysis

In analysing students' responses to open-ended survey questions, a cross-tabulation was conducted to examine students' learning experiences in the live-lecture and screen-capture classes. Using an *Effects Matrix* procedure (Miles & Huberman, 1994), a chart was created to organize the open-ended questions from the student survey. Responses applied to the effects matrix can

Table 1. Algebra II Performance Test Score Results ($N = 56$)

	Live-lecture ($n = 24$)		Screen-capture ($n = 32$)	
	M	*SD*	*M*	*SD*
Algebra II pre-test score	26.46	13.31	20.47	14.50
Algebra II post-test score	70.63	20.13	81.56*	15.26

*$p < 0.05$.

then be used to determine conclusions and/or inferences from a mixed methods design (Collins, Onwuegbuzie, & Jiao, 2007). According to Miles and Huberman (1994), effects matrices are valuable in determining 'ultimate' outcomes with a basic principle that focuses on dependent variables (p. 137). Random identifiers were written in a vertical column, located on the left side of a matrix chart. To the right of each identifier, open boxes were created below each open-ended survey question. From the completed role-ordered matrix, a separate display device was created to organize the findings into categories, patterns and themes. Verbatim excerpts from students' open-ended responses are presented in italics inside double quotation marks throughout this paper.

Learning of Algebra II

A one-way ANCOVA was conducted to measure the group mean differences in Algebra II post-test scores between the live-lecture and screen-capture groups using their Algebra II pre-test scores as a covariate (Table 1). The two groups did not differ on their pre-test scores, $F(1, 54) = 2.51$, $p = 0.119$; however, students in the screen-capture group scored significantly higher than did the live-lecture group on the Algebra II post-test after controlling for their pre-test scores, $F(1, 53) = 4.86$, $p = 0.032$, partial $\eta^2 = .08$. Partial η^2 of .08 indicates a moderate-size main effect of instructional method (Cohen, 1988).

Students' evaluation of their learning experiences

Both the screen-capture group and live-lecture group students answered 5-point Likert scale questions developed from Appleton *et al.'s* (2006) self-rating model (Table 2). Independent-samples *t*-tests indicated that students in the screen-capture class agreed significantly stronger to two of the six statements when compared with those in the live-lecture class: 'I understand all the new math concepts taught in Chapter 5', $t(50) = 2.531$, $p = 0.015$, and 'The Chapter 5 math teaching was clear and easy to understand', $t(50) = 3.737$, $p < 0.001$.

Table 2. Students' Evaluation of Their Learning Experience ($N = 52$)

Survey items	Live-lecture ($n = 22$)		Screen-capture ($n = 30$)	
	M	*SD*	*M*	*SD*
1. I understand all new math concepts	3.68	0.89	4.23*	0.68
2. Teaching was clear and easy to understand	3.64	0.95	4.53***	0.78
3. Pacing of instruction was too slow	2.00	0.98	1.90	0.92
4. Pacing of instruction was too fast	2.73	1.16	2.27	1.11
5. Good transitions from previous lesson	3.73	0.94	4.13	0.73
6. Teacher answered all my questions in class	4.05	0.90	4.53	1.04

Note. Responses were made on a 5-point scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*). Four students were unable to complete the survey because they were absent from school due to illness.
*$p < 0.05$. ***$p < 0.001$.

Screen-capture students' satisfaction of instructional method

Students in the screen-capture group answered additional survey items regarding their satisfaction of embedded blended lessons to live-lecture lessons (which they had experienced prior to this experiment). When asked which type of instruction ('regular teaching' vs. 'teacher's online lesson') the screen-capture students would prefer in the future, 80% ($n = 24$) of the students preferred the teacher's online lesson over regular teaching. Seven per cent ($n = 2$) chose the traditional live-lecture method while 13% ($n = 4$) said it depends. Of the four students who selected *depends*, two further explained their responses. One stated that online would be favorable if he/she could stay at home, and the other indicated he/she would be in favor of the teacher's online lessons if they could be used in conjunction with the traditional live lectures.

Within the student satisfaction rating, students enthusiastically indicated they preferred the online lessons created from the screen-capture technology. Students selected the option to have their teachers make more online lessons for another math chapter. To illustrate their eagerness for the online instruction, some of the students' 'yes' responses were followed with multiple underlines, explanation points and statements such as 'Please!, Please!' written all around the checked box. Almost all students (93%, $n = 28$) agreed that they would like their teachers to make more online multimedia lessons for another math chapter.

Analysis of students' responses to the open-ended survey questions yielded four themes that were categorized into reasons why students preferred the multimedia lessons rather than traditional classroom lectures: (a) ability to control pacing of instruction; (b) new role of the classroom teacher; (c) lack of distraction in the blended learning environment; and (d) accessibility of the embedded multimedia lessons outside the classroom.

Ability to control pacing of instruction

Students in the online class were able to individually control the pacing of their instruction by pausing, fast-forwarding, slowing down or replaying the embedded multimedia. The ability to control the pacing of instruction was the dominant response to the instructional method questions. Pacing or references to manipulating the speed of the multimedia's content were referenced by 20 (66%) of the screen-capture students responding to what they liked about the teaching with comments such as 'when taking notes, I could pause them so I didn't miss anything.' While three of the screen-capture students attributed their improved learning to reasons such as viewing the lessons at home, 24 (80%) of the screen-capture group's responders solely attributed their improved learning with the control they had over the instructional pacing through words such as 'pause', 'rewind' and 'pace'. When asked to explain if the online math lessons improved their learning, students made comments such as: 'Yes, because I could take all the time I needed to write down my notes' and 'I think it did because I got to take my time to understand each thing she was saying while taking my notes.'

New role of the classroom teacher

Another theme that emerged out of the students' responses to open-ended questions was the new role of the teacher within the classroom. Six of the 30 (20%) screen-capture students raised this as a reason they preferred the online lessons. Students enjoyed '. . . having her be free to answer my questions' and 'if we still didn't understand it the teacher would be free because she wasn't teaching the lesson.' This theme also emerged when students described which method they would prefer in the future. The frustration with the teacher's traditional role with her live-lecture math instruction was also revealed in five (16%) of the students' responses. As they discussed the teacher in the blended classroom, the students commented 'seems like you're the only student' and 'I felt I could easier get individual help.' The teacher's inability to manage the needs of everyone within the live-lecture classroom was a common theme. The new role of the teacher within the embedded blended learning environment was best summarized in the statement, 'It's kind of one on one teaching.'

Lack of distraction in the blended learning environment

Students appreciated the lack of distraction or interruptions in the embedded blended classroom and their comments were noted throughout the responses. The self-paced nature of the class created a quiet environment that was conducive to learning: 'It kept the class

Table 3. Screen-Capture Students' Self-Reported Use of the Embedded Multimedia ($N = 30$)

	Never (%)	Once (%)	Twice (%)	Three times (%)	Four or more times (%)
7. Paused each online lesson	7	20	20	17	37
8. Re-watched each online lesson to solve workbook problem	50	23	13	13	–
9. Used notes to solve workbook problems	3	3	27	7	60
10. Posted online comments	3	7	23	20	47
11. Watched online lesson outside of school	17	33	23	23	3
12. Watched online lesson at school but outside of class time	63	23	7	–	7
13. Watched online lesson on own mobile device	90	10	–	–	–
14. Parents watched online lesson	70	30	–	–	–
15. Used online lesson when studying for final test	53	17	20	7	3
16. Used notes when studying for final test	17	–	7	20	57

room [sic] quiet making it easier to focus' and '[n]ot hearing side convo's so you can't pay attention (focus).' Six (20%) of the screen-capture students complained about the noise level of a regular math classroom and implied that it disrupted their learning: 'People are loud making it hard to hear' and 'Can't hear well all the time.' The fact that individual student's pacing was not compromised by the needs of others also meant that students were now free to ask questions without worrying about the effect it has on others. Students shared 'We can pause & ask questions without disrupting everyone else' and 'If I didn't understand something I would go back and check without disrupting the pace of others.' Students liked that '[e]veryone can learn and ask questions without interfering with others'. As one student stated, 'No distractions! Just me and my iPad.'

Accessibility of the embedded multimedia lessons outside the classroom

Students appreciated their ability to access the embedded multimedia lessons from outside the classroom, and some attributed their improved learning due to this factor. Four (13%) of the students stated that being able to access the instruction from home was what they liked most about the online instruction. Students wrote, 'If I didn't get something down, I could watch it at home' and 'I can replay a part I don't understand, I can view at home.' Students also valued the accessibility of the multimedia lessons, which they could use to catch up after an absence: 'If I was absent it was like I didn't miss class because I still could learn the lesson.'

Viewing embedded multimedia in a classroom versus home setting

Students in the screen-capture group generally appreciated being able to view the lessons at home; however, the vast majority (87%, $n = 26$) preferred to view the lessons with their teacher in the classroom rather than at home as homework assignments which would be the case in a flipped classroom. When asked to explain their answers, students valued the opportunities to seek the teacher's face-to-face explanation while watching the embedded multimedia lessons: 'Because if I have a question I can just ask in class and you cannot do that @ home if you are listening to the video.' Other students commented, 'I feel like watching them in class is better so if you have questions you're able to ask' and 'We could ask questions right away if the videos had something we didn't understand.' Thirty per cent of the students did, however, report the embedded multimedia was viewed by a parent at home (Table 3).[2]

Another common response spoke to the benefit of the lack of distraction within an embedded blended learning environment: 'Sometimes home can be a distracting environment and I only have a very limited amount of time on the comp so I feel rushed, it made class more enjoyable.' Students also referred to the distractions of the Internet: 'When you are online at home you would go to other websites.'

Screen-capture students' use of the embedded multimedia

Using a 5-point rating scale, students reported the average frequencies in which they (or their parents) engaged in particular activities using the embedded multimedia (Table 3). These findings suggest that almost all (93%) students took advantage of the self-pacing function and paused the lesson at least once during class. More than half (54%) paused the embedded multimedia for an average of three or more times. Further, 83% of the students accessed the multimedia lesson from outside the school at least once during the 1-month research period, and 49% did so at least twice. It also appears that the majority of the students used their notes from initially viewing the embedded multimedia lesson to study for the final test rather than re-watch the embedded multimedia lessons.

Discussion

Our hypothesis that secondary Algebra students accessing their teacher's embedded multimedia within the blended learning environment would exhibit significantly higher achievement than students taught in the teacher's live-lecture classroom was confirmed in this study. We found a moderately sized effect of the instructional method after controlling for students' pre-test scores.

Students' control over pacing of instruction

Interestingly, students using embedded blended learning were significantly more likely to report that the teacher's lessons were clear and easy to understand than were the students in the regular live-lecture class, even though the lessons were essentially identical and offered by the same teacher. Students in the experimental group appreciated being able to pause the embedded multimedia while taking notes, which became the main resource for future problem solving and test preparation. Consistent with the interactive principle (Mayer & Moreno, 2003; Mayer *et al*., 2003), problem-solving skills were better when students were not subjected to continuous and unabated live-lecture instruction. In other words, our findings suggest that it was not necessarily the *content* of the embedded multimedia lessons that made a difference in the learning of the two groups, but the student's ability to control instructional pacing – which minimizes cognitive load – translated into positive perceptions of instructional quality and enhanced students' learning.

Advantages of embedded blended learning

Students overwhelmingly appreciated the lack of distractions within the embedded blended learning environment and revealed that 'regular' live-lecture classrooms are full of side conversations and students' questions that slow down the pace of instruction. Rather than trying to listen to and view their teacher's lecture over the noise and disruption of their classmates, the blended students learned in an environment where extraneous stimuli were minimized. The less distracting environment of embedded blended learning facilitated students' ability to focus on their learning.

Availability of content within embedded multimedia

Survey findings (Table 3) indicated that half of the students viewed the embedded multimedia an additional time within the classroom. While half chose not to view the multimedia again in class to complete the classroom workbook activities, half of the students (50%) watched parts of the multimedia lessons again, and a quarter (26%) of the students watched the multimedia at least two more times within the classroom. Without any suggestion, over three quarters (83%) of the students chose to watch the embedded multimedia outside of the classroom, with nearly a quarter (23%) of these learners viewing the multimedia three times outside of class. Our findings are consistent with Tabbers and Koeijer's (2010) measures of interactive behaviour that revealed participants with learner control had an increase in time-on-task when watching and listening to the multimedia instruction over students without user control.

Even though half of the screen-capture students in this experiment reported viewing parts of the teacher's embedded multimedia more than once during classroom time, the screen-capture students still appreciated using the multimedia instruction. While the teacher would need to invest time in the beginning to develop embedded multimedia, the actual classroom time was used more efficiently in favor of student learning, because the teacher, using embedded blended learning, could devote her time solely to answering individual questions and offering one-on-one tutoring. Students in the embedded blended learning classroom also appreciated the teacher's presence as they viewed the multimedia lessons, because their questions could be answered immediately through face-to-face, individualized instruction.

Implications for practice

Blended learning has become a ubiquitous term that implies the use of computers within the classroom, but is rather ambiguous in practice. This study only addresses a specific component of the blended classroom by replacing a teacher's live-lecture instruction with his/her nearly identical embedded multimedia content. The results, however, have broad ramifications that question the need for live-lecture performances, which are clearly the dominant vehicle for delivering information in schools (Mayer, 2003). From the standpoint of an instructor who can feel lost in a setting teeming with mobile computing devices, delivering instruction through online multimedia is no doubt alluring. Consequences for students are no less compelling. Learners using embedded blended learning have a more practical and productive means to acquire their teacher's instruction and receive face-to-face direct assistance.

Additionally, learners in this embedded environment are able to transition with their teachers to other academic activities, rather than being captives of the other classmates who are struggling to comprehend a teacher's live-lecture presentation. As suggested by O'Bannon *et al*. (2011), rather than eliminate the traditional classroom setting, the blended classroom can be used for more student-centric activities where the instructor can facilitate instructional time for student-centred interactions. Because mathematics is comprised of varying topical strands that are highly interconnected (Graham, Cuoco, Zimmermann, & National Council of Teachers of Mathematics, 2010), students working on projects that require additional declarative knowledge could easily access their teacher's library of online embedded multimedia content on a need-to-know basis.

Limitations of the study

The results of this 4-week experiment involving 56 high school students offer strong evidence for the positive impact of embedded blended learning on Algebra II students. Nonetheless, the generalizability of these findings may be limited to high school students learning Algebra in similar settings. It may be worthy to study across various subject matters, especially those that are not as graphically intensive as Algebra, such as the social sciences or languages. It would also have been helpful to acquire additional data that provide other plausible explanations, such as data on cognitive load, the amount of extraneous distraction noise, and electronic devices that measured interaction with the embedded multimedia content and also recorded students' time-on-task.

One might suggest a novelty effect with screen-capture students working harder as a result of the new 1:1 mobile technology. However, we have a few reasons to believe that novelty effect was not strong in our study. As suggested by Clark and Sugrue (1988) who found that students' novelty effects reduced rapidly as they became familiar with the medium, we also believe that the 4-week study period was long enough to diminish such effects. In addition, students in the live-lecture classroom were also exposed to the same hardware technology, as they used the iPads in class as enhanced graphing calculators.

Suggestions for future research

Students in the experimental group made positive remarks about their ability to pause (and play back) the embedded multimedia lessons at their own discretion as well as the lack of distraction with the teacher's embedded blended learning environment. These comments suggest that the particular embedded learning environment was successful in reducing their cognitive load and fostering their learning (Mayer & Chandler, 2001). There is also a possibility that the autonomy and freedom granted to the adolescent students to self-pace the instruction and to access the multimedia lessons outside of the classroom facilitated their motivation to learn. Increased opportunities for one-on-one tutoring in the classroom may also have enabled students to safely seek the teacher's help without worrying about classmates' judgment of their 'stupid' questions. Future studies focusing closely on the psychological needs of learners at different developmental stages can also contribute to our understanding of developmentally appropriate multimedia instructions and environments.

While this study focused primarily on *students'* learning and satisfaction, future research focusing on *teachers* will be of great value to the field. The classroom instructor who participated in our study relied on her skill and experience of being a highly effective classroom teacher. The math teacher was a ‘good’ teacher in that she had a wealth of teaching experience, was conscientious of her teaching and was open to using new technology. However, upon viewing her embedded multimedia, the Algebra II teacher felt it necessary to recapture certain segments and remove extraneous material through the movie-editing software. Computer programmer George Fuechsel’s principle, *garbage in-garbage out*, may be somewhat applicable to a teacher’s lesson development using SCIT because bad input generally results in bad output and that the condition can later be addressed through intervention (Lidwell, Holden, Butler, & Elam, 2010), or in our case, through post-production editing.

The extent of the ‘teacher effect’ is unknown in this study because our study did not have multiple teachers. It would be interesting to investigate in the future if teachers of certain characteristics teach better (or worse) using certain types of embedded blended instruction. Moreover, it would be interesting to investigate the effects that the use of embedded blended learning has on teachers and their practices. The math teacher in our study shared with us that her experience of developing embedded multimedia gave her an opportunity to self-reflect her instructional practices, and that the digital multimedia facilitated collaboration with colleagues in the math department (Smith, 2012). These pieces of information suggest the potential of using embedded blended learning not only as a pedagogical tool but also as an instrument for professional development.

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Notes

[1]Birthdates of three students were unavailable and were excluded from the calculation.

[2]Within this school’s active parental community, it is not an uncommon occurrence for parents to monitor and assist their children’s academic assignments.

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