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Predictors of adolescents' science learning in blended learning: Prior knowledge, reading proficiency, self-efficacy and regulation

Harmanlanmis öğrenmede ergenlerin fen öğrenimini öngören faktörler: Ön bilgi, okuma yeterliliği, ve öz yeterlilik

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ABSTRACT

The goal of this study was to explore effects of using blended learning with a science unit in middle school students. We examined how student characteristics were related to learning outcomes as measured by a posttest and an exit survey. Seventh-grade students from a low SES school were taught heredity unit with blended learning. Students completed some tasks digitally on their own, followed by activities and discussions in the classroom. The students performed better on the posttest if they had higher reading proficiency, better background knowledge and higher self-efficacy and regulation, thus replicating the usual patterns found with traditional learning contexts. The affective outcome (enjoyment, interest) was predicted by both reading proficiency and self-efficacy and regulation, but not prior knowledge. These results indicate that benefits of technology may vary as a function of student characteristics.

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ÖZ

Bu çalışmanın amacı harmanlanmış öğrenme yöntemiyle işlenen bir fen konusunun ortaokul öğrencileri üzerindeki etkilerini araştırmaktır. Amerika'da, çoğunluğu düşük sosyoekonomik düzeylerden gelen yedinci sınıf öğrencileriyle harmanlanmış olarak kalıtım konusu işlenmiştir. Bu eğitimde öğrenciler bazı etkinlikleri çevrimiçi ve bireysel olarak tamamlarken, bazi etkinlikler ve tartışmalar sınıfta yüzyüze yapılmıştır. Genel olarak eğitim araştırmalarında bulunan örüntüler burada da tekrarlanmıştır. Öğrencilerin son testteki performansları okuma yetenekleri, konu hakkındaki ön bilgileri ve öz yeterlikleri ile doğru orantılıdır. Öğrencilerin konuya duygusal yaklaşımlarını (ilgi ve beğeni) öngören değişkenler ise öğrencilerin önbilgileri değil, okuma yetenekleri ve özyeterlilikleridir. Bu sonuçlar, teknoloji ile zenginleştirilmiş eğitimlerin faydasının öğrenci özelliklerine bağlı olarak değişebileceğini göstermektedir.

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INTRODUCTION

Information and communication technologies are becoming essential tools in educational settings. In grades K-12, schools are using individual electronic devices and using learning management systems to deliver curriculum instead of, or in addition to the traditional textbooks (Picciano & Seaman, 2009). Although there is no clear consensus, blended learning is usually defined as the combination of face-to-face instruction with computer-mediated instruction (Bonk and Graham, 2006). Expanding this definition, Horn and Staker (2014) added that blended learning is any education program in which there is at least some online learning, with students having control over time, place, path, and/or pace of the course. Finally, flipped classrooms can be considered a type of blended learning (Akçayır, & Akçayır, 2018). In flipped classrooms, the learners get the basic information online, but do the application, integration and extension of this information in face-to-face activities. Blended learning is becoming more common, especially with K-12 students. In Wang, Huang and Omar's (2021) survey of blended learning practices, of 643 blended learning projects 75.6% of them were implemented at K-12 level.

Blended learning provides learners with more self-reliance, self-pace, flexibility, and more individualized instruction by combining elements of online learning with the elements of traditional learning (Frazier, 2020). Students of blended learning models learn online part of the time, but they still receive benefits of face-to-face instruction such as being able to ask their classmates and peers for help and being able to discuss with them face-to-face. Blended learning helps students to be more self-directed learners as it creates moments that require students to log on to their LMS, do an activity or take a quiz by themselves. It provides a more student-centered curriculum as it enables students to, for example, spend more time on a quiz or an activity and post a question online to ask for help or for more clarification. This is beneficial to especially shy students who would rather not to talk in front of others. Since learners are given more opportunities to be more self-directed, students are more likely to feel greater agency. Existing research provides some evidence for effectiveness of blended learning (Powell et al., 2015). However, implementation of blended learning can be quite diverse depending on the content area and grade levels. In addition, most research on effectiveness of blended learning relies on case studies (Fazal &Bryant, 2019).

The goal of our study was to evaluate blended learning by using quantitative measures, as 7th grade students completed a biology unit. Blended learning may not work equally well for all students. Therefore, we also studied how the following student variables were related to the learning of the content: Affective characteristics (self-efficacy and self-regulation skills) and cognitive characteristics (prior knowledge and reading proficiency). The outcomes of interest were how much the students learned about the topic (cognitive outcome) and how much they enjoyed and were interested in the topic (affective outcome).

Although adolescents may be skilled at using digital media, they tend to use it for communication purposes and those skills may provide limited transfer to academic learning (Castek & Coiro, 2015; Jang & Ryoo, 2018). In addition, although access to information and communication technologies is becoming widespread there is still a digital divide. Adolescents show inequality in digital skills as a function of their socioeconomic backgrounds (Li, et al., 2015; Linne, 2014; Zhong, 2011). For example, in a study with low-SES adolescents in Argentina, Linne (2014) discovered that adolescents used technology mainly for communicative and recreational purposes and it was difficult for them to use it effectively or academic purposes.

Learning about complex topics, such as science and math is challenging for many students. The complexity of science concepts and scientific texts may result in failure or difficulty in the early years of education. Because of those difficulties, students may develop high levels of anxiety and low levels of motivation towards learning science subjects and eventually, low interest in pursuing relevant careers (Raes & Schellens, 2015; Osborne, Simon, & Collins, 2003). Therefore, it is crucial to examine factors relevant to successful science learning in blended learning.

In blended learning, students are asked to read the required material, watch assigned videos, and take required quizzes on their own at their own pace. However, such autonomous learning requires students to have certain cognitive and affective strengths (Castek & Coiro, 2015). For some students, the difficulties of scientific learning may be exacerbated by the demands placed on them in blended learning contexts (Morgan, 2015). The autonomous part of blended learning requires students to possess cognitive skills such as adequate reading proficiency. Blended learning also requires students to have certain affective strengths such as self-efficacy and regulation (Azevedo, 2007; Moos & Azevedo, 2008). Hence, it is important to understand how students perform in blended environments as a function of their existing strengths and challenges, because students who have low self-efficacy and/or low reading proficiency may be at risk of falling behind.

Cognitive Variables: Prior Knowledge and Reading Proficiency

For many years, educators have known that prior knowledge is a good predictor of student achievement. As cognitive psychologist Ausubel said, "The most important single factor influencing learning is what the learner already knows" (Ausubel, 1968, p. vi). Recent research also supports the importance of prior knowledge in learning. In Yenilmez et al.,'s study (2006) with 8th grade students, prior knowledge in science was a statistically significant predictor of students' learning photosynthesis concepts. Similarly, in Chen et al.,'s study (2014) with middle school students, participants with higher prior knowledge showed significantly better performance in learning chemical formulas via a 3D role-playing game than those with lower levels of prior knowledge.

In science education, students need to read and understand their textbooks and other reading material independently. Therefore, reading proficiency is expected to be strongly related to science proficiency. According to widely accepted models of knowledge-building theories, such as construction-integration model of comprehension (Kintsch, 1998), knowledge integration framework for science learning (Linn & Eylon, 2006), constructionist model of inference in reading comprehension (Graesser, et al., 1994), and landscape model of reading comprehension (van den Broek, et al., 2005), learners gain knowledge by creating interconnected mental representations. This process is effortful and through this process learners connect what they already know with what is presented in text. These models of knowledge building theories can show us clearly, reading proficiency and science proficiency are interconnected.

Despite having these theoretical explanations on the connection between reading proficiency and science proficiency, studies looking at this relationship are scant. In O'Reilly and McNamara's study with high school students, reading comprehension was a significant predictor science proficiency (2007). Medina and Mishra (1994) also found a significant correlation between reading comprehension and science proficiency with their sample of second- to eighth-grade students. Data sets obtained from Programme on International Student Assessment (PISA), with 174,896 fifteen-year-old students from 43 countries across the world, showed strong correlations between reading scores and science scores, r=.840, p<.001, with a range across the 43 countries from .675 to .916 (Cromley, 2009). By adding reading proficiency as a predictor, we wanted to contribute the research examining the relationship between reading proficiency and science proficiency.

Affective Variables: Self-Efficacy and Self-Regulation

Self-efficacy can be defined as students' belief in their ability to succeed in a task, an activity, or a course. Self-efficacy is a strong predictor of academic achievement, course selection, and career decisions (Britner &Pajares, 2006). Those who have high science self-efficacy are more likely to engage in science related activities, more likely to expend effort on those activities, and more likely to persevere when facing difficulty (Bandura, 1997; Britner & Pajares, 2001; Zeldin & Pajares, 2000).

Self-efficacy beliefs of students influence a few behavioral and psychological processes (Bandura, 1986, 1997). Students who have a strong belief that they can accomplish science tasks are more likely to select those activities, work diligently to accomplish them, persevere even when they struggle, and feel confident despite obstacles. On the other hand, students who do not believe that they can be successful in science activities are more likely to avoid those tasks when possible or put minimal effort. They are more likely to quit the task when facing challenges (Britner &Pajares, 2006). Because of its relationship to persistence and motivation, self-efficacy is an important variable in blended learning contexts, where students are asked to persist and complete some tasks on their own.

Even if students appear to have interacted with all parts of the curriculum, it is no guarantee of mastery of the content. Some students may not have yet developed adequate skills to comprehend the digital readings and video recordings. Also, some disadvantaged students may not have adequate self-regulation skills and the motivation to complete assigned readings on their own. For example, for adolescents learning about the circulatory system, externally regulated learning was more effective than self-regulated learning (Azevedo et al., 2005). In externally regulated learning, as students learned the hypermedia content on their own, human tutors prompted the students to activate their prior knowledge, use metacognitive strategies and monitor their goals. Self-regulated learning did not provide this guidance. In sum, some the self-efficacy and self-regulation strategies of learners may be predictive of success in a blended learning environment.

Hypotheses

In this study, we examined the effectiveness of blended learning with seventh graders learning about genetics. Our goal was to examine the relationship between the students' science learning outcomes and their cognitive (prior knowledge and reading proficiency) and affective (self-efficacy and self-regulation) characteristics.

H1: The cognitive outcome (science knowledge posttest), will be predicted by both cognitive and affective variables listed above.

H2: Similarly, the affective outcome (interest and enjoyment) will be predicted by both cognitive and affective variables

METHOD

Research Design

For this study, a quantitative prediction method, regression analysis, was used to predict the cognitive outcome and the affective outcome from the student characteristic variables. Regression analysis is a method to determine the linear relationship between two or more variables. Regression analysis is used for prediction, and it does not imply causation Montgomery, Peck, & Vining (2021). For the first hypothesis, the dependent variable was cognitive outcome, as measured by the posttest, and the predictor variables were pretest scores, reading proficiency and self-efficacy. For the second hypothesis, the dependent variable was affective outcome as measured by the exit survey and the predictors were prior knowledge, reading proficiency and self-efficacy.

Participants

Seventh-grade students in seven classrooms (taught by three teachers) in a middle school located in rural northern Minnesota were invited to participate in the study. Of the 198 students, 197 parental consents were obtained. There were 25 mainstreamed students with special needs, who were required to do the unit only partially. Their data are not included in the current analyses. In the school, overall, 41.8% of the students were eligible for free or reduced lunch and 12.6% were of Native American. The high percentage of students eligible to receive lunch aid as well as the percent of minority students are usually indicators of the low socioeconomic status of the students in a school.

The Teachers

Teacher A had 26 years' experience teaching seventh grade life science. She was teaching life science at this middle school for 20 years, before that she taught 8th grade earth and 9th grade physical science. She graduated from the University of MN Duluth with degrees in: Teaching Life Science (7 to 12 grades); Teaching Middle School Science (Grades 5-9) and Teaching Earth Science (7-12 grades). From UMD she received a Master of Education (M.Ed) and from the University of MN Twin Cities Campus an Educational Doctorate (EdD) in Educational Policy and Administration (EdPA).

Teacher B had 18 years' experience teaching middle and high school science. He graduated from the University of MN Duluth with a degree in: Teaching Earth Science (7 to 12 grades); Teaching Middle School Science (Grades 5-9) a concentration in Outdoor and Environmental Education and a geology minor. From Hamline University, he received a Master of Arts in Education for teaching natural science and environmental education.

Teacher C recently retired from teaching secondary science after 30 years in the classroom, 24 of them in this middle school teaching 7th grade Life and 8th grade Earth Science. She also supervised student teachers for UMD for 3 years. She graduated from the University of Maine, Orono with a degree in Wildlife Biology and minors in Natural History Interpretation and Education. She had a Master of Science degree from Stephen F. Austin State University (Nacogdoches, Texas) with a focus on the Natural Sciences.

MATERIALS

An online curriculum in Genetics for 7th grade students was created in Schoology, the LMS used in the school in which the study was conducted. The researchers and teachers created the learning unit collaboratively, using the Minnesota Academic Standards as a guide. The topics included heredity, genes, DNA, chromosomes, alleles, dominant and recessive traits, Punnett squares, Mendel's work with peas, incomplete dominance, polygenetic heritance, and genetic engineering. Besides doing hands-on activities, such as building a DNA model with licorice and marshmallows, teachers also provided students with explicit vocabulary instruction, such as the examination of root words and suffixes. Students watched visually rich videos showing how these topics are related (e.g., DNA, chromosome, gene), and these activities were followed by class discussions.

Two years ago, the school had an iPad roll out. The staff was trained on how to use a LMS to grade, organize and deliver curriculum. The trainings enabled the science teachers to implement the unit in a consistent manner, allowing instruction to be relatively standard across students and classrooms. The LMS provided a way to structure the online content and to apply work completion rules. This way content was covered in a sequence, and students could work at their own pace.

Each module in the unit was centered on different heredity concepts, with its accompanying vocabulary. In each module, on their own, students read the materials, viewed the videos, took notes and then submitted images of their notes. After learning the material in this manner, the students practiced the new vocabulary with online Quizlets. The students practiced the words until they received at least 85% in the test mode (initially the passing percentage was 100% which was frustrating for students and was reduced to 85%). This preparatory work was done individually in the classroom, with the teachers providing support and guidance as needed. After this self-study, the students were placed in groups for application activities such as constructing a DNA molecule, creating their own genetic baby and a dog, and determining prevalence of traits among their classmates. More detailed description of each module in the unit is presented below:

1. During the first module of the unit, students answered the pretest questions on heredity, completed a self-efficacy and self-regulation survey and took the reading test (described in the Methods section) on their iPads. The assignment was to complete a survey of their own

traits that includes items such as "I am right-handed," and "I have dimples." The next day, with the teachers' help, they created a graph documenting the number of traits they observed across the students in the classroom and discussed these individual differences.

2. During the second module, teachers reviewed some vocabulary words such as "traits", "genetics" and "heredity". Students watched a short YouTube video on inheritance on their individual iPads.
3. In the third module the biological foundations of heredity were covered. Vocabulary included "DNA", "chromosome" and "gene". Students watched a YouTube video about genes, DNA, and chromosomes. Using an illustration, teachers discussed where the nucleus, chromosomes, and genes were located, and how they were related to each other. Students then created and labeled the parts of a DNA model using licorice, marshmallow, and toothpicks.
4. During the fourth module the students reviewed an illustration explaining how genes are part of a chromosome, and how in humans, each nucleus includes 23 pairs of 46 total chromosomes. Then with illustrations, they learned about meiosis and how children receive one part from each parent. The vocabulary included word roots of pheno-(showing), gen- (being born), homo-(-same), hetero-(different), and zygote (joined). Students learned how each allele is represented with one letter and how letter combinations indicate different phenotypes depending on whether the trait is dominant or recessive. Following that, they created Punnett squares using the dimple and eye color phenotypes and decided what phenotype would be observed in each combination of alleles.
5. During the fifth module, the students reviewed the relationship between chromosomes, DNA and genes and the vocabulary words of "allele", "dominant", "recessive", "phenotype" and "genotype". Following that, they watched a short YouTube video that introduced Mendel and his work with pea plants. They practiced with Punnett squares to determine the probability of peas' offspring having green seeds depending on parents' homozygotic or heterozygotic alleles.
6. During the sixth module, class discussions included the topics of incomplete dominance, multiple alleles, sex linked disorders and polygenetic inheritance, the role of environment and genetic engineering. The unit was completed with the heredity posttest and the interest and enjoyment survey.

Measures and Variables

Prior Knowledge (Heredity pretest). Initially, an 18-item multiple choice test on general genetics concepts was given to assess students' prior knowledge. The questions were developed using the science standards as a guide and using the publishers' materials as a starting point.

Reading proficiency. Students were asked to read a two-page expository text on a different biological topic (beneficial insects), and answer reading comprehension questions. The text was created by modifying an article that was published on National Wildlife Federation Webpage. Fifteen multiple choice questions that were created by researchers were intended to measure various reading comprehension components such as vocabulary learning from the text, making cause and effect inferences, and figuring out the main idea. The validity of this experimenter-developed test was determined by correlating this measure with the Star Reading Proficiency Test (SRPT, Renaissance Learning, 2017) used by the school district. SRPT assesses components of word knowledge and skills, comprehension monitoring and constructing meaning, understanding author's craft, analyzing literary text, analyzing argument and evaluating text. There was a significant correlation ($r = .49$, $p < .001$) between our proficiency measure and the district's proficiency test.

Cognitive outcome (posttest). The same test was given as a post-test, after the students completed the Genetics Unit.

Self-Efficacy and Regulation Scale. Within the first module, students took a survey rating their confidence and interest in learning different subjects, their comfort level in asking for help when they were learning new material, their self-efficacy in meeting requirements of different subjects. The items were adopted from Children's Self Efficacy Scale (Bandura, 2005). This test had 15 items and the students could rate each item from 0 to 100, with 0 referring to "Cannot do at all," 50 referring to "moderately can do," and 100 referring to "highly certain can do." This scale had a reliability of .94 (Cronbach's α, N=154).

Factor analysis with principal component analysis and Varimax rotation with Kaiser Normalization revealed that the survey had three components (see Table 1). The first component, as indicated by the bolded numbers, was about effective study and self-regulation strategies that were used during learning. The second component reflected self-efficacy beliefs and interest regarding science and math. The third component was about asking for help when needed. In the following analyses, to have more power, we used the total score on the survey rather than examining the three components separately. Hence, it is referred to as the "self-efficacy and regulation" scale.

Affective outcome. Upon completion of the whole unit, students were asked to fill out a 7-item online survey using a Likert scale. The scale had four alternatives, *Strongly Disagree, Disagree, Agree and Strongly Agree*. Survey items asked the students to report their perceptions about their understanding of the unit, interest in the topic, adequacy of the learning material, usefulness of the information provided in the unit, adequacy of the time to complete the required tasks, effectiveness of assessments and whether

Table 1. Factorial analysis of self-efficacy and regulation scale Component 1 (self- regulation), 2 (self-efficacy) and 3 (willingness to ask for help)

Scale items	Component		
	1	2	3
1. I can learn mathematics	.466	.741	.098
2. I can learn science	.443	.726	.232
3. I can read and understand my science textbook	.342	.728	.319
4. I can read and understand my math textbook	.372	.757	.177
5. I find the topic of genetics interesting	.322	.641	.225
6. I understand genetics concepts well	-.096	.728	.261
7. I can ask my teacher to help me when I get stuck on schoolwork related to science	.465	.150	.679
8. I can ask my teacher to help me when I get stuck on schoolwork related to mathematics	.433	.269	.654
9. I can ask my classmate to help me when I get stuck on schoolwork related to science	.206	.293	.836
10. I can ask my classmate to help me when I get stuck on schoolwork related to mathematics	.263	.270	.836
11. I can finish my math homework assignments by deadlines	.771	.339	.234
12. I can finish my science homework assignments by deadlines	.776	.277	.341
13. I can get myself to study when there are other interesting things to do	.770	.140	.302
14. I can always concentrate on school subjects during class	.729	.312	.264
15. I can take good notes during class instruction	.605	.368	.403

Notes. Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a.Rotation converged in 7 iterations.

the unit was organized well. The reliability of these 7 items was good (Cronbach's α=.79, N=114). There were also three open-ended questions asking students to list which of the topics they enjoyed, which topics they struggled with, and which other topics should have been included.

For quantitative analyses, a composite score was obtained by coding students' responses to each survey item [Strongly disagree =1, Disagree =2 Agree =3, and Strongly Agree =4] and adding up the scores. This score was used as the affective outcome measure. Students' comments to open ended questions were analyzed separately.

We also obtained some qualitative data by observing classrooms in session at random times and by interviewing the teachers.

Preliminary Data Analysis

Case processing in SPSS revealed that in each measure there were some missing data: the largest missing data was on the Interest and enjoyment survey (30.9%). This was followed by science posttest with 13.3% and the self-efficacy and regulation survey with 10.9%, Reading proficiency test and prior knowledge (pretest) had very few missing data, 0.6%, and 0%, respectively. As in other studies, missing data are common in real-world educational settings, as students may miss school days for various reasons. However, as can be seen from the percentages for the tasks above, the proportions of students who were not able to complete the tasks increased as the unit progressed. Tasks given during the first module of the unit had low missing data rates. Although all students finished the unit, some students required additional time and hence they did not complete the posttest and the survey by time the study ended. This missing data patterns indicate that in a blended learning environment, there can be wide disparities in the time it takes for students to complete a unit, despite a well-structured curriculum.

Teachers who taught the unit were interviewed to understand why some students were not able to complete their work in a timely manner. Teachers mentioned that the majority of students were coming from low SES families. When students were not able to complete the work in the classroom, they were asked to complete it at home. However, some students could not do that as they lacked adult support because of limited resources, and some were even homeless. We were not able to obtain information about the prevalence of homelessness due to FERPA regulations. However, the high percentage (41.8%) of students who qualify for reduced or free lunch can be seen as an indication of the low socioeconomic level of this group.

There were also some logistical glitches. For example, some students showed up at school with their iPads not charged. There were not many charging stations in classrooms. As a result, some students had to wait to work on their iPads until they were charged. Another issue, possibly again affected by low SES levels, was the low vocabulary levels of some students, as reported by teachers. For example, some students did not know the meaning of “alternate.” Teachers expressed that in the past they were not able to teach the genetics unit due to lack of time and they now noticed that some topics such as genetic engineering and incomplete dominance were difficult for the students. Also, it was observed by the researchers during visits to the class that some students struggled, as they did not know about the availability of electronic resources. For example, a student who did not know the meaning of a word waited for the teacher’s help, instead of using the online resources.

To further examine the reasons behind missing data, independent samples t-tests were conducted to investigate if and how characteristics of those who missed the posttest differed from than the rest. Those who had not completed the posttest had a slightly lower average score for reading proficiency (8.14, SD=2.2) as compared to those who completed the posttest (8.47, SD=2.7). Likewise, those who missed the posttest had slightly lower pretest scores than those who completed the posttest, 6.82 (SD=1.8) and 7.22 (SD=2. 7), respectively. These differences were not statistically significant.

The largest difference (marginally significant at $p<.06$) was observed with self-efficacy and regulation. The mean and standard deviations were 867.68 (SD=236.84) and 973.63 (SD=225.80) for students who missed the posttest and the students who completed the posttest, respectively. Overall, those who could not complete the work on time tended to have lower self-efficacy and regulation scores. This is the first pattern in the data signaling that students’ performance in a blended learning are related to their existing strengths and challenges, as will be discussed below.

RESULTS

Table 2 summarizes the means and standard deviations of heredity pretest (prior knowledge), posttest (cognitive outcome), self-efficacy and regulation, reading proficiency and Interest and enjoyment survey (affective outcome) scores. On a positive note, students overall made significant gains in their learning of genetics, as there was about five points increase from average pretest to posttest scores, $t(142)=15.73$, $p<.0001$.

Although the students overall showed significant gains in understanding the heredity concepts after studying the prepared modules, the main question is if student outcomes are predicted by student characteristics. For that reason, a regression analysis was conducted to predict post-test performances from (a) prior knowledge, (b) reading proficiency and (c) self-efficacy and regulation scores.

Cognitive outcome: As presented in Table 3, the largest variance in post-test scores could be explained by prior knowledge (19.6%). Reading proficiency could explain about an additional 11% of variance in posttest scores. Self-efficacy and regulation explained an additional 3.5% variance, which was statistically significant. Together all three predictor variables explained 34% of variance in posttest scores. These data indicate that just like in face-to-face contexts, blended environments also display the “Matthew effect,” or the rich getting richer (Stanovich, 2009). Those with stronger reading skills and richer prior knowledge benefit the most from blended learning. The regression data supported the first hypothesis, that both cognitive and affective variables predicted science learning (cognitive outcome).

Affective outcome: Next, we conducted a regression analysis with the same predictors for the dependent variable of affective outcome (Interest and Enjoyment survey). While self-efficacy and reading proficiency were significant

Table 2. Means and standard deviations of the pretest, posttest, self-efficacy and regulation, and reading proficiency scores

Measures	Max	Mean	Std. Deviation	N
Prior Knowledge (Pretest)	18	7.17	2.58	165
Cognitive outcome (Posttest)	18	11.91	3.74	143
Reading proficiency	15	8.43	2.60	164
Self-efficacy and regulation scale	1500	959.93	229.21	147
Affective outcome (Exit survey)	28	19.83	3.41	114

Table 3. Predictors of post-test performance in the regression analysis.

	Predictors	Standardized coefficients	R square change	F change	P
Step1	Pretest	.386	.196	30.43	<.0001
Step2	Reading proficiency	.283	.109	19.49	<.0001
Step3	Efficacy/Regulation	.194	.035	6.49	.012
Total variance explained		34%			

predictors of the affective outcome, science pretest was not (see Table 4). Self-efficacy and regulation and reading proficiency together could explain about 28% of variance in exit scores, while by themselves each explained about 24% and 4% percent of variance in exit scores, respectively. This provided some support for the second hypothesis. Affective outcome was predicted by self-efficacy and regulation, and by existing reading proficiency. However, prior knowledge did not predict how much students enjoyed and were interested in the topic.

Qualitative analyses of the students' answers to the open-ended Interest and Enjoyment survey questions revealed that they enjoyed learning the unit with this blended type of instruction. Specifically, they mentioned that they enjoyed watching the videos and they thought it was a fun way to learn the topic of genetics. Furthermore, they found the unit interesting and mentioned that they enjoyed doing required tasks independently at their own pace, while still being able to ask for the help of the teacher when needed. They also mentioned that they enjoyed doing hands-on activities such as creating a DNA with marshmallow and licorice. Some students indicated that they found the reading material long and challenging, and that they struggled with the vocabulary words. A basic pattern emerging from student comments was that those who were interested in the topic of genetics believed that they did not struggle because of their high interest levels.

Out of the 57 students who provided responses, 39% reported enjoying specific topics (e.g., Punnett square), and 24.5% reported enjoying certain activities (e.g., creating a DNA model from marshmallows). Some students expressed a global view: 30% said they liked everything, and only 6.5% said they liked nothing. When they were asked to report difficult or uninteresting aspects, 30% listed specific topics (e.g., alleles), 11% reported studying vocabulary in general, 4% textbook readings, 15% assignments and tests and 10% activities. In addition, some students had global reactions: 14% found everything to be challenging, whereas 17% found nothing to be challenging.

DISCUSSION

In this study we examined how student characteristics were related to our cognitive outcome and affective outcome. Results showed full support for the prediction of the cognitive outcome and partial support for the affective outcome.

Successful science learning in a blended context were predicted by prior knowledge, reading proficiency, self-efficacy, and regulation, like what is found in face-to-face contexts. This indicates that the presence of technologically rich materials does not always lead to overall student success. As in traditional teaching, student characteristics are important and should be taken into consideration while planning and teaching. We found that reading proficiency was a significant predictor of posttest scores, replicating previous research showing large correlations between reading comprehension and science proficiency (Cromley, 2009; O'Reilly & McNamara, 2007). The basic components of comprehension, such as inferring the meaning of unfamiliar vocabulary, creating a mental model as new information is acquired and continuously monitoring progress, are essential for all types of knowledge acquisition regardless of modality. These components become even more salient while reading scientific texts, with their conceptual complexity and heavier vocabulary demands (Mayer, et al., 2002).

We also found that prior knowledge, as measured by pretest, was a significant predictor of the posttest. Students come to school with environmental stimulation and home experiences of varying richness, which is usually tied to socioeconomic status. Therefore, it is especially important to build the relevant prior knowledge of students before they tackle complex learning material. In addition to explicitly teaching relevant background material in the classroom, students should be encouraged to do free reading (in different modalities), watching educational programs, and most of all feeding their natural curiosity and exploring on their own. Teachers can also provide students with low skills strategies that can help with comprehension of expository texts (Cromley, et al., 2010). Of course, developing prior knowledge is also deeply connected to motivation and interest.

The qualitative data that we obtained from several open-ended Interest and Enjoyment survey questions reveal that students enjoyed the self-paced nature of blended learning. They also enjoyed watching YouTube videos for learning. However, at the same time they expressed their struggle with the reading materials and vocabulary words. We suggest teachers to incorporate those fun videos into their curriculum and provide students with self-paced lecture materials. However, they should consider supporting students with low prior knowledge and reading difficulties with small group instructions. While students with high levels of knowledge and skills are engaging in individual

Table 4. Predictors of affective outcome in the regression analysis

	Predictors	Standardized coefficients	R square change	F change	p
Step1	Efficacy/Regulation	.450	.236	31.52	<.0001
Step2	Reading proficiency	.189	.040	5.612	.035
Step3	Pretest	.092	.008	1.136	.289
Total variance explained		28%			

learning, teachers can meet with those struggling students individually or in small groups.

Finally, self-efficacy and regulation was a good predictor of the posttest. Students with good self-regulation skills monitor their understanding of the text while reading, set goals and plan according to their current level of the understanding of the text (Azevedo, et al., 2012). While reading the text, if they encounter vocabulary or concepts that they do not know, they ask their teachers for help or searched for it electronically. They realize without prior knowledge or the meaning of that word, their understanding of the text would be limited. In a blended learning environment, such self-regulation is even more important, as students need to move through the content at their own pace.

Another aspect of the self-regulation is monitoring and planning the time that is spent for each activity. Spending too much time on an activity may result in not being able to complete some of the other required activities as they progressed through the modules, which was observed in this study. The students who were not included in the data analysis because of incomplete data were more likely to be the ones who did not have enough time to complete the activities to reach the posttest. This group tended to have lower self-efficacy and regulation scores. It is worth noting that even with a relatively more successful sample of children that were included in the analyses, self-efficacy and regulation was still a significant predictor of both cognitive and affective science learning outcomes. If students with even lower levels of self-efficacy and regulation had completed the tasks by the time the study ended and they were included in the analyses, the patterns are likely to have been even stronger.

The current results imply that it is important for teachers and family members to find ways to increase student self-efficacy related to the tasks that they need to accomplish. To do so, adults should provide children with activities that they can handle, and experience success with. Adults should avoid peer comparison and help students compare their current performances with their previous performances. Furthermore, teachers should deliver strategies to improve student self-efficacy, by helping them plan and divide the goals or tasks into smaller, manageable parts, celebrating success after each small component.

This study was conducted on the topic of heredity with seventh graders, which limits its generalizability. Hence, the same variables need to be assessed in other blended learning environments with different scientific topics and age groups. Despite this limitation, our findings illustrate that the blended learning unit we developed was effective in facilitating all students' understanding of heredity. However, reading proficiency, self-efficacy and regulation, and prior knowledge were all interrelated and were important predictors of science learning in a technologically rich context, just as in face-to-face learning environments.

For further exploration of how blended learning is related to student characteristics, future mixed-methods studies are recommended that include more classroom observations to test fidelity of application in each classroom. To examine, whether the student characteristics would exert similar or different effects on student learning, randomly assigned groups can be taught with blended learning or traditional learning and predictive value of each predictor in each context can be compared.

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