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Utilizing a Flipped Learning Model to Support Special Educators' Mathematical Knowledge for Teaching

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Flipped learning is a popular pedagogical approach in K-12 and in higher education (Graziano, 2017), however minimal research exists on the effectiveness of flipped learning in special education teacher preparation courses. Special education teacher candidates enrolled in five sections of a special education math methods course engaged with interactive, flipped "learning lessons" prior to class. During class, they participated in extension activities and lesson planning. The researchers utilized mixed methods to evaluate the impact of performance on and engagement with these learning lessons and found positive predictive relationships with student achievement on all individual summative assignments. Nearly all students agreed flipped learning was useful in helping them meet the course outcomes. Most students specifically credited the flipped lessons as a facilitator of their learning because they allowed them to interact with the content at their own pace and to utilize class time for more meaningful review and extension activities with the instructor's support.
Keywords: engagement; flipped learning; mathematics; multimedia learning; Scholarship of Teaching and Learning (SoTL); special education teacher preparation

For decades, students in higher education sectors have engaged in blended learning environments where they learn content outside the classroom (i.e., through reading text or watching videos) and reinforce or extend that content within the classroom through discussion or activities (Ent, 2016). This approach to teaching is also known as *flipped learning*, defined by the Flipped Learning Network (2014):

> Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guided students as they apply concepts and engage creatively in the subject matter.

Flipped learning includes four pillars: F (flexible environment); L (learning culture); I (intentional content); and P (professional educator), which guide the instructor. Throughout all of these pillars, the teacher must be reflective and flexible in their practice to support diverse learning needs. By moving direct instruction outside the classroom, the classroom becomes a more student-centered environment with rich opportunities for learning. While flipped learning does not require the use of technology, there are many tools on the market that can help facilitate this approach in the college classroom. In the present study, we explore how student engagement with flipped video content impacts the learning of pre-service special education teachers.

There is an emerging body of literature exploring the benefits of flipped learning in higher education. Much of this research is perceptions-based and/or focuses on different strategies to successfully implement flipped learning (DeLozier & Rhodes, 2016; Jenkins et al., 2017; Milman, 2012; Song, Jong, Chang, & Chen, 2017). In one study, student questionnaire responses indicated flipped learning promoted student involvement, self-efficacy, and self-directed learning (Chyr, Shen, Chiang, Lin, & Tsai, 2017). In a teacher preparation course, student-reported benefits of flipped learning included increased motivation and enthusiasm for content and more student-to-student interaction during the in-class activities (Graziano, 2017). Pedagogically, flipped learning allows instructors to differentiate instruction by providing self-paced lessons for mastery learning with immediate feedback and increased opportunities for discourse, collaboration, and cooperative learning (Altemueller & Lindquist, 2017).

Though perceptions of flipped learning are often positive, few researchers have actually measured academic achievement in a flipped learning environment (Altemueller & Lindquist, 2017). Gopalan and Klann (2017) compared a combination of flipped learning and modified team-based learning with more traditional lecture-based instruction. These researchers found the flipped learning group had higher exam scores. Similarly, Al-Zahrani (2015) conducted a quasi-experimental group design comparing a lecture-based class to a flipped classroom and found significant differences in measures of students' creative thinking on a final assessment in favor of the flipped classroom structure. In both of the aforementioned studies, the researchers' in-class activities for flipped learning involved high peer-peer interaction, whereas the in-class activities in the control groups were more lecture-based. It is difficult to determine whether the academic benefits were more related to the flipped content, the in-class activities, or to a combination of the two. DeLozier and Rhodes (2016) suggest learning outcomes in any teaching structure are most impacted by the cognitive processes of the learner. They make a compelling argument that research on flipped learning should focus on specific components of instruction (e.g., video lectures, quizzing games, student-led discussions) rather than on the flipped structure as a whole to better understand which practices lead to academic gains.

The literature base for flipped learning in higher education shows promise, though more research is needed that links flipped learning to learning outcomes. This need is especially noted in classrooms for teacher preparation programs (Graziano, 2017). In our search, we did not find any studies examining the impact of flipped learning on achievement in special education teacher preparation courses in the United States (our research context). The purpose of this study is to explore how engagement with flipped video content impacts student learning. Our research extends the existing body of literature by connecting learner perceptions to academic outcomes associated with flipped learning within an unexplored area – special education teacher preparation. The following questions guided our research:

1. To what extent does engagement with flipped learning videos relate to special education teacher candidates' demonstration of mathematical knowledge for teaching?
2. What are special education teacher candidates' perceptions of the effectiveness of flipped learning in an undergraduate special education math methods course?

Methods

We have taken a pragmatic approach to this research, electing to utilize multiple methods for collecting, analyzing, and interpreting our data. Specifically, we utilized a partially-mixed parallel convergent design (Creswell & Plano Clark, 2017) with qualitative and quantitative results mixed during the interpretation stage of the research after conducting separate qualitative and quantitative analyses. A pragmatic approach allows the freedom to select methods that are the best fit for each research question (Felizer, 2010), acknowledging that the combination of qualitative and quantitative approaches mitigates some of the limitations and provides a better understanding of the problem than either approach alone.

Participants and Setting

Upon acquiring IRB approval, participants were recruited over two semesters from five sections of an undergraduate special education mathematics methods course at a large public university in the Midwestern United States. As this was a Scholarship of Teaching and Learning (SoTL; Boyer, 1990) study, the lead author was also the course instructor for all sections. Additional researchers helped with the recruitment and scoring of work samples to reduce coercion and bias in scoring and analysis. Of the 106 total students enrolled in these sections, 88 students (83%) agreed to participate. Typical of population demographics for special education majors at our institution, our participants were primarily female (89%) and Caucasian (95%). Most special education teacher candidates take this course in their junior year, the semester prior to their first practicum experience.

Theoretical and Practical Underpinnings of Flipped Learning Lessons

We utilized video "learning lessons" as part of a flipped learning structure – a pedagogical approach that includes the direct instruction of content outside of the classroom, to maximize in-class engagement with the content under the guidance of an expert (i.e., the instructor). We created the learning lessons as a replacement for the original course textbook. In earlier semesters, feedback collected from students indicated they either did not read the textbook, or had difficulty following the mathematical strategies presented in text form. Other reasons for flipping the course included the need for more time to apply content through lesson planning with the instructor's guidance, and to provide individualized support during group work to teach and reinforce collaborative work habits.

To manage the individual learning space, we utilized a free tool, *EDpuzzle* (EDpuzzle Inc., 2019), to post video learning lessons with embedded questions and prompts. The number of embedded prompts varied depending on the video content and length. The average number of multiple-choice questions per video was 2.5 (range = 0-10) and the average number of open answer responses per video was 4.4 (range = 0-9). Seven of the learning lessons that focused on math strategies also had a corresponding worksheet because the individual practice required the student to show their calculations or draw a mathematical representation. We used the comments feature in *EDpuzzle* to embed prompts that would pause the video and direct students to a specific question on the worksheet. *EDpuzzle* has built in accountability features; it allows the instructor to view which students watched the video, see their responses to questions/prompts, and count how many times they re-watched any segments of the video. Another affordance of this tool is how it facilitates engagement because students cannot fast forward through the video and the platform pauses the video if a student tries to click off the webpage. Student accuracy on the embedded questions and prompts were not used for summative assessment in the course, though completion of the learning lessons accounted for 15% of their final course grade as an additional measure of accountability.

We designed learning lessons utilizing principles of Mayer's (2009) cognitive theory of multimedia learning, which builds off existing cognitive theories for learning to address how people learn with a combination of words, text, and narration. Researchers have found videos created using these principles, known as Content Acquisition Podcasts (CAPs), to be effective in developing foundational knowledge of special education teacher candidates in areas such as early literacy (Carlisle, Newman Thomas, & McCathren, 2016) and positive behavior supports (Kennedy & Newman Thomas, 2012). Similar to CAPs, the 25 video learning lessons used in this study followed multimedia learning principles, except they have more content breadth and are therefore longer (median = 12 min; range = 5-26 min). They also included embedded questions and prompts to guide students in the individual learning process. Multiple choice questions embedded into the video were graded automatically and provided immediate feedback to the students as they watched. Embedded open-answer questions were not graded automatically; however, the instructors added qualitative feedback that displayed to students once they submitted a response.

Data Sources and Analysis

With our first research question, we explored how engagement with flipped learning videos relates to special education teacher candidates' demonstration of mathematical knowledge for teaching. We utilized quantitative data sources to run a series of simultaneous multiple regression analyses within SPSS to determine if engagement habits with the flipped videos predicted student achievement as measured by performance on five different summative assessments aligned with the course outcomes.

Independent variables. The following variables were measured by copying data gathered within the *EDpuzzle* platform into a spreadsheet.

- **Word count** - a summative total number of words written on open-answer questions embedded across all 25 learning lessons. These questions were generally reflective in nature or required an explanation of mathematical thinking. We used this measure as an approximation of engagement duration – students who wrote more, theoretically would have spent more time with the content in the video.
- **Accuracy** - a cumulative accuracy of multiple-choice questions across learning lessons (total correct divided by total attempted). The answers to these questions came directly from the video, so we used this measure as an approximation of engagement quality – students who better attended to the video, should have higher accuracy on the questions that come directly from the video.

These two variables were first entered as a group in the multiple regression analysis for each outcome variable. If either variable was not significantly contributing to the model, it was removed, and a simple regression was run with the one contributing variable.

Dependent variables. In the mathematics methods course, there were five individual summative assignments aligned to the course outcomes. For consistency, all assessments were graded with detailed rubrics. Following the semester, 10% of each of the following five assignments were regraded and checked for reliability. We discussed any minor discrepancies within the sub-scores and had a 100% agreement on the overall scores.

- **Explicit Instruction Video Reflection -** Teacher candidates designed an explicit instruction lesson and taught it within a virtual learning classroom, which was video recorded for them to reflect upon. They utilized video tagging software (given reflective prompts aligned to course outcomes) to identify strengths and areas of improvement related to their instruction.
- **Midterm Application Exam –** Teacher candidates completed an open-answer take-home exam that included application questions related to the domains of math knowledge and pedagogical knowledge.
- **Lesson Observation Reflective Report –** Teacher candidates observed a math lesson in a K-12 classroom containing at least one student with an IEP. Given a graphic organizer for note taking, they submitted a written reflective report about what they saw and how it does/does not align with the mathematical knowledge for teaching they learned throughout the course.
- **Co-Teaching Video Reflection --** Teacher candidates designed a co-taught lesson on a mathematical topic of their choice and were video recorded when they taught it to their peers during class. They utilized video tagging software (given reflective prompts aligned to course outcomes) to identify

strengths and areas of improvement related to their instruction.

- **Final Application Exam –** Teacher candidates completed an open-answer take-home exam that included application problems focused on math strategies and pedagogy.

Due to the sample size and the exploratory nature of this study, we ran separate multiple regression analyses rather than using a single multivariate regression analysis. This also allowed us to examine which individual summative assignments, if any, were most impacted by engagement with the learning lessons.

To answer the second research question – *What are special education teacher candidates' perceptions of the effectiveness of flipped learning in an undergraduate special education math methods course?* – we analyzed two anonymous sources of teacher candidate feedback. One source was a midterm feedback survey that asked teacher candidates the following open-answer questions: (a) *What specific aspects of the course/instruction have FACILITATED the development of your knowledge and skills in providing math instruction to students with disabilities?*; and (b) *What specific aspects of the course/instruction have been a BARRIER to the development of your knowledge and skills in providing math instruction to students with disabilities?* On this survey, we did not explicitly ask about the flipped learning structure or videos because we wanted to see if any teacher candidates would bring this up on their own. A second feedback source was an end of course survey asking candidates to rate the helpfulness of the flipped "learning lesson" videos on a Likert-scale of 1-5 (1 = not helpful; 5 - extremely helpful) followed by an open answer prompt asking students to describe the most effective aspects of the learning lessons and add any additional feedback about the flipped learning structure. We summarized descriptive results from the Likert-scale ratings and utilized open coding and axial coding (Strauss & Corbin, 1999) to identify themes and sub-themes from the open answer responses.

Results

Our analyses revealed a generally positive impact of a flipped structure on teacher candidates' learning and demonstration of mathematical knowledge of teaching. Descriptive and qualitative data provided by teacher candidates provided insights to better understand the implications of our regression analyses.

Impact of Engagement with Flipped Videos on Student Learning

We ran simultaneous multiple linear regressions to predict academic performance on each of the five summative course assignments based on cumulative accuracy and word count (measures of engagement) for the learning lesson videos. Prior to conducting regressions, we examined our data to: (a) remove any outliers (data points greater than 1.5 times the interquartile range from the mean); (b) confirm our residuals were normally distributed; and (c) check there was no multicollinearity among the two independent variables. Descriptive statistics for all variables are presented in Table 1.

Table 1
Descriptive Statistics for Independent and Dependent Variables

Variable	*N*	Min	Max	*M*	*SD*
Word count	88	624	4681	2315.45	735.74
Accuracy	88	72.92	97.48	89.63	4.16
Explicit Instruction Video Reflection*	86	22.50	30.00	27.97	1.75
Midterm*	83	14.50	25.00	20.85	2.45
Lesson Observation Report*	87	33.00	40.00	37.09	1.75
Co-Teaching Video Reflection*	86	22.50	30.00	27.49	1.78
Final Exam*	86	34.00	49.50	43.60	3.97

* dependent variables with outliers removed

For the outcome variable, *Explicit Instruction Reflection*, results of the multiple regression indicated only accuracy was a significant predictor of performance, so we conducted a simple linear regression to determine the extent to which learning lesson accuracy predicted achievement on this summative assignment (Table 2). The regression results were significant, $F_{(1, 84)}$ = 18.58, $p < .001$, with an R^2 of .181. On average, for every percentage point increase in overall accuracy on the learning lessons, there was an increase of .18 points (out of 30) on this assignment. Accuracy accounted for about 18% of the score variance. Similar to the first assignment, results of the multiple regression indicated only accuracy was a significant predictor for two other summative assignments. Accuracy predicted performance on the *Observation Report*, $F_{(1, 85)}$ = 16.50, $p < .001$, with an R^2 of .163 (explaining about 16% of the variance). A one percent increase in accuracy generally produced an increase of .17 points (out of 40) on this assignment. Accuracy was also a significant predictor for performance on the *Final Exam*, $F_{(1, 84)}$ = 12.10, $p = .001$, with an R^2 of .126 (explaining about 13% of the variance). For this assignment, an increase of one percent on accuracy resulted in an increase of .34 points (out of 50) on average.

For the other two assignments, multiple regression results indicate the combination of word count and accuracy positively predicted performance. For the outcome variable, *Midterm*, both accuracy and word count significantly predicted performance on the assessment, $F_{(2, 80)}$ = 21.85, $p < .001$, with an R^2 of .353. On average, for every percentage point increase in overall accuracy on the learning lessons, there was an increase of .24 points (out of 25) on the midterm, and for every additional word written, there was an increase of .001 points. Accuracy and Word Count together accounted for about 35% of the score variance on this assignment. The combination of accuracy and word count predicted achievement on the final summative assessment, *Co-teaching Lesson Reflection*, as well, $F_{(2, 83)}$ = 10.05, $p < .001$, with an R^2 of .195. On average, a one-point increase in overall accuracy resulted in a .10-point increase (out of 30) on the assignment, and for every additional word written there was a .001-point increase. These variables together account for approximately 20% of the variance on this assignment.

Table 2
Results of the Simple and Multiple Regression Analyses by Dependent Variable

Models by Variable	*F*	*Df*	*p*	R^2	*t*	*p*	*B*
EI Video Reflection							
Overall model	18.58	1, 84	<.001	.181			
Accuracy					4.31	<.001	.179
Midterm							
Overall model	21.85	2, 80	<.001	.353			
Word count					2.60	.011	.001
Accuracy					3.89	<.001	.236
Lesson Observation Report							
Overall model	16.50	1, 85	<.001	.163			
Accuracy					4.06	<.001	.169
Co-Teaching Video Reflection							
Overall model	10.05	2, 83	<.001	.195			
Word count					2.45	.016	.001
Accuracy					1.99	.050	.098
Final Exam							
Overall model	12.10	1, 84	.001	.126			
Accuracy					3.48	.001	.339

Student Perceptions of Flipped Learning

For the second research question, we sought to better understand what aspects of the flipped videos, or any other elements of the course, may have facilitated development in mathematical knowledge for teaching, so we analyzed student feedback on the optional midterm and final course surveys. Fifty students responded to the first open-ended question on the midterm feedback about facilitators of their learning in the course. Though we did not mention flipped learning in the wording of the question, all 50 responses mentioned flipped learning as a facilitator. One student stated:

> *The structure of the class has facilitated the development of my knowledge and skills because before class I am able to learn the content, then at the beginning of class with the entrance tickets I get immediate feedback of what I know and what I don't know and then in class we review and that helps me to understand more deeply and gives me the opportunity to ask questions.*

Another wrote:

> *The learning lessons are incredibly helpful. I love how there are questions embedded so it is really easy to pick out the important information. If I don't understand, I have the ability to go back and listen to that part again, and that is super helpful. Also, in class discussions are great, because they seem to be a big debriefing time. The learning lessons bring a lot of information but then your lecture in class mixed with activities and discussion really helps everything come together.*

Students responses about flipped learning tended to acknowledge both the videos and the in-class activities as facilitators of their learning.

On the Likert-scale survey at the end of the semester, 73 of the 77 responders

(95%) rated the videos as *helpful* (*n* = 14) or *extremely helpful* (*n* = 59). Two students (3%) rated the videos as *neutral*, and two students rated them as *somewhat not helpful*. No students rated the learning lessons as *not helpful*. Student responses on the open answer questions on the midterm and final surveys gave some insight into which aspects of flipped instruction they perceived as most effective in facilitating their learning of course outcomes. Of the 108 total comments across survey questions that mentioned flipped learning, 25 responses (23%) mentioned out of class activities that went along with the learning lesson videos. Most of these (19%) mentioned the worksheets that went with the math strategy videos. Four responses also mentioned the PDF notes pages (slide images from the video with lines to take notes), which were posted for all 25 videos. Additionally, 26% of responses to open answer questions mentioned specific features of *EDpuzzle* as a facilitator of their learning. Embedded questions as checks for understanding (11%) and the ability to pause and re-watch sections of the video to work at their own pace (11%) were the most commonly liked features. Students also mentioned how the platform was easy to use and that they liked how there were mechanisms built into the program that would pause the video if they tried to multi-task with another internet tab.

Teacher candidates also commented on the in-class aspect of flipped learning on the surveys. Most of these students (40%) described the combination of the videos with the in-class activities (i.e., the entire flipped learning structure) as a facilitator of their learning. One student wrote, “I believe that I get more out of this class because the class time is spent discussing and collaborating with my peers.” Another student commented on the benefits of multiple perspectives during class:

> *I think being able to discuss the concepts with our group members at our table is also very helpful because we get to hear another person’s perspective if we are not understanding the "teacher language" - they might have it understood in simpler terms.*

The most common in-class activities students described included class discussion, group work during class, review games and activities, and content clarifications from the instructor.

Though primarily positive, students did present some feedback critical of flipped learning. Of the seven responses to the midterm question about barriers to learning, six described some aspect of flipped learning as a barrier (the other barrier was the difficulty and amount of course content). Additionally, seven responses to the end of semester question about the helpfulness of learning lessons gave some suggestions or considerations to improve the flipped learning experience. Three teacher candidates mentioned that they just do not like the idea of a flipped learning structure without giving any rationale other than preference. The most useful responses criticizing flipped learning in the course were the ones that provided rationales for any barriers presented. Two such responses indicated some frustration for having to wait to have questions answered until class time, two indicated some of the learning lessons were too long, and one mentioned there were not enough examples in the videos. The last comment is contrary to what many other teacher candidates described. It is also important to note, most students who described barriers to the flipped videos or structure, noted facilitators as well. Solely critical feedback represented less than 5% of the total responses.

Discussion

Flipping some aspect of a higher education course is not a new idea (Ent, 2016). Many professors assign readings, videos, or other activities for students to prepare for class. The course in the present study is unique in that all of the direct instruction is flipped and the video learning lessons use a research-based framework (i.e., Multimedia Learning; Mayer, 2009) to carefully craft the lectures in a way that enhances the cognitive aspects of learning. Our quantitative analysis focused on the impact of the out-of-class learning lessons on demonstration of course outcomes. The student feedback indicates a convergence of our quantitative and qualitative data sources – students noted the academic benefit of the learning lessons and their engagement on those learning lessons predicted achievement. Our regression models indicate teacher candidate engagement with learning lessons only accounted for between 15-35% of performance on summative assignments though, so clearly additional factors contributed to their learning.

Flipped Learning: Beyond Video Engagement

The score distributions for all course assignments were negatively skewed, as students generally scored well on assignments in this course, so we were unsure if we would find a significantly predictive relationship between video engagement and achievement. For two of the assignments, word count and accuracy significantly predicted achievement and for three, only accuracy predicted achievement. Though the R^2 values were fairly small, our results indicate increased engagement with the video learning lessons did impact student learning. This is somewhat contrary to the supposition of DeLozier and Rhodes (2016) who suggest video instruction is not responsible for student learning. Nonetheless, engagement with the videos is likely not the only factor that contributes to achievement. Qualitative information gathered from the experiences of special education teacher candidates provides us with insights about other instructional factors that may have contributed to their learning.

Intentional, quality flipped content. One of the pillars of flipped learning (Flipped Learning Network, 2014) is *intentional content* – the instructor must decide what content should be taught directly and what content students should explore on their own. Once decided, the instructor either needs to find or create that content. As DeLozier and Rhodes (2016) suggest, flipped learning involves more than assigning videos to view outside of class; we must also consider the way in which content is presented and the learner’s cognitive engagement with the task. The learning lessons used for our course leverage multimedia learning principles (e.g., energetic and conversational narration, signaling and image builds to illustrate mathematical strategies; Mayer, 2009) and elements of explicit instruction (e.g., modeling, scaffolding, visual representations, opportunities to respond with immediate feedback; Archer & Hughes, 2011) to engage learners’ cognitive processes as they are prompted to reflect and think deeply about the content. In their open-answer responses, students specifically commented on the quality of presentation of the content and the incorporated explicit instruction elements as a facilitator of their learning. Though our learning lessons were effective in their current form, we recommend instructors review flipped content periodically to catch errors, reduce length, evaluate for inclusion of new research, or to include clearer examples.

Accountability and formative assessment. Before we flipped this course, students read the textbook for background knowledge before coming to class to do the practice activities. These activities are now embedded within our learning lessons. Our original (i.e., non-flipped) approach reduced the time allotted for collaborative work during class and it also lacked an element of accountability and formative assessment because instructors had no way of monitoring individual student work outside of classroom. There are a variety of tools on the market to implement flipped content that address the barriers of more traditional structures. We selected *EDpuzzle* specifically because of features that allow us to easily skim through student responses to gauge their understanding to help guide and differentiate our in-class activities. We used the gradebook feature in the platform as an additional accountability measure to verify teacher candidates watched and responded to embedded questions in the video on time. Regardless of the tool selected, instructors should ensure students have sufficient understanding of their expectations and of the tool functionality.

In-class activities. Given the students' feedback on the midterm and final course surveys, engagement within the in-class extension activities is likely another factor that contributed to academic gains on the course outcomes. Teacher candidates specifically mentioned review games, discussions, group work, hands-on activities, and the ability to have questions answered in class as helping solidify their understanding of the content from the flipped videos. In-class engagement is also likely to be related to out-of-class engagement because the extension activities are planned so they build off the explicit instruction from the video. This type of engagement is harder to measure, particularly for collaborative activities, however, our qualitative data collected from students in our course suggest these activities may contribute to the learning process as well. We are currently brainstorming ways to collect data about performance on specific in-class extension activities to include measures of in-class engagement as in independent variable in a future regression model.

Within-student factors. Other factors that likely contribute to performance on course assignments may have more to do with skills and characteristics of the learner than with the teacher's instruction. Self-regulated learning plays a significant role in how students attend to both in and out of class activities for flipped learning (Sun, Xie, & Anderman, 2017). This type of learning requires self-motivation and good work habits. In a study by Fisher, Ross, LaFerriere, and Maritz (2017), students themselves recognized the need for a self-directed approach to learning so they did not fall behind on the content. Finally, given the well-established impact of math knowledge, confidence, and self-efficacy on achievement (Pajares & Kranzler, 1995), these individual student factors are also likely to impact teacher candidate performance on these summative assignments, regardless of the quality of the instruction. Individual factors such as these should also be considered in a future regression model.

Limitations and Future Research

Limitations for this study lead to multiple paths for future research. First, we collected data from one institution using one set of flipped videos from the same course. Future studies measuring effectiveness of flipped learning could explore the generalizability across institutions and content areas. Second, our measures of accuracy and word count on the learning lessons are only approximations of engagement. Increased writing, for example, does suggest the learner spent more time with the content, but it does not necessarily equate to increased accuracy or depth of understanding of the open answer questions. We are exploring additional options for measures of engagement in the future. Finally, the lead researcher served as the video creator and instructor of the course, so we acknowledge a potential bias in our interpretation of qualitative results. Despite the limitations of the quantitative analysis, triangulation with qualitative data suggests, the flipped learning lessons positively impacted student learning.

On average, our regression models explain less than a third of the variance on the summative assignments, so we acknowledge that other factors besides video engagement habits, such as the quality of instruction for in-class activities, may also have impacted achievement in mathematical knowledge for teaching. Additionally, teacher candidates start the semester with differing levels of math knowledge, self-efficacy, and anxiety, so those may be moderating or mediating factors in a more complex regression model. To explore this further, we plan to replicate this study in new sections of the course taught by different instructors with different levels of experience teaching the course. At the beginning of the semester, students will take a pre-course survey with questions related to their math self-efficacy and anxiety and these variables will be included in the regression model. For the replication study, all instructors will use the flipped videos and teacher candidates will complete the same summative assignments, however the in-class extension activities may differ. A predictive relationship between engagement on videos and course outcomes would be even stronger knowing the in-class activities differed.

Recommendations and Conclusion

The results of our study echo the benefits noted by other researchers of flipped learning in higher education coursework including increased motivation, engagement, and perceived learning (Altemueller & Lindquist, 2017) and increased opportunities for active learning (DeLozier & Rhodes, 2016). These benefits are particularly important in special education teacher preparation courses where students need class time to develop performance-based skills related to teaching with expert feedback while also acquiring content-specific knowledge. Based on our findings and experience, we outline several recommendations for implementation in other teacher preparation courses.

One recommendation for implementation of flipped learning is choosing technology tools for accountability and engagement. *EDpuzzle* is one example of a tool that worked for us. It allowed the professor to hold students accountable for learning outside of class by using responses to questions and documented completion of the videos as points towards their overall course grade. This tool facilitated student engagement by having them answering open-ended and multiple-choice questions and practicing with embedded links and worksheets within the learning modules. Additional recommendations for flipped learning include taking time to record quality videos that utilize elements of explicit instruction (Archer & Hughes, 2011) and research-supported multimedia principles (Mayer, 2009) to address the cognitive demands of learning. The video length is another important consideration. Students within our study mentioned longer videos were less engaging. We therefore recommend keeping videos as concise as possible, remembering that the longer the video, the more embedded questions and opportunities to reflect should be included to maintain the learners' attention. Finally, instructors should build a climate of self-directed learning. We started the semester by explaining a rationale for using flipped learning and provided multiple opportunities for self-monitoring and reflection on their learning throughout the semester.

Flipped learning benefited teacher candidates within our mathematics special education teacher preparation course. Students in this course differentiated foundational knowledge based on their own individual needs allowing the instructor to review, clarify, and expand upon concepts learned within the learning modules, which is the premise behind flipped learning (Ent, 2016). The instructor was able to address common misconceptions among the group during class time and any individual difficulties with the content could be addressed during office hours. This structure allowed class time to be used for lesson planning and opportunities to practice teaching with instructor and peer feedback. In teacher preparation programs, course content needs to be aligned with state standards for teacher licensure, so consistency across course sections is essential. Given our success with this model, in our department, flipped video learning lessons have become the curriculum that all instructors of this course share, which provides instructional consistency for the foundational content knowledge needed for student success in future semesters and in their teaching careers.

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