Developing Motivation of Adolescent Mathematics Students Through Instructional Choice

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Abstract

Maintaining student motivation in mathematics increases the likelihood of long-term academic success. A key component to building motivation is having perceived control over a task. Students who maintain perceived control exhibit greater task engagement, motivation, and exhibit lower levels of stress and anxiety in that task (Bandura, 1989; Schunk, 2012; Skinner, 1990). This six-week study investigated the relationship between student choice and motivation in mathematics instruction, by affording students an individual choice of their instructor in their mathematics course. A quasi-experimental pretest-posttest two group design was implemented using a sample of Integrated Mathematics II high school students. Student motivation to study mathematics was measured by The Motivation for Mathematics Abbreviated Instrument (MMAI; Butler, 2016), a psychometric motivational scale for students in developmental Algebra courses. Students in the intervention group were presented an individual choice: to remain in the current class meeting and follow the lesson instruction with their math instructor, or choose to leave the meeting and join an alternative, yet identically paced class meeting taught using a pre-recorded video lesson of a different instructor. Independent and paired t-tests were conducted to determine the change in student motivation across and within groups. The intervention group exhibited a larger increase in mean scores compared to the control group; however, this change was not statistically significant. Further research should investigate other means of providing student autonomy in a mathematics classroom.

Keywords: motivation, student autonomy, perceived control, mathematics, high school

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Literature Review

Human thought and behavior are purposeful. Consequences are anticipated, and in turn, people initially motivate themselves to action by creating goals and estimating the effort required to accomplish those goals. The promise of fulfilling goals provides people with motivation. The promise of gratification from completing the task provides additional motivation to the individual (Bandura, 1989). A motivated student is able to set academic goals and persevere until those goals are attained. Motivation is a key component to academic success.

Self-determination refers to one's ability to make choices and feel in control of their own outcome, which has an effect on their motivation. Self-Determination Theory (SDT), a macro theory of motivation, posits that three core needs cause people to act: competence in one's behaviors, relatedness to other people, and autonomy of actions (Deci, 2008). Central to SDT are the two types of motivation that provide the impetus to act: autonomous (intrinsic) and controlled (extrinsic) motivation. According to SDT, autonomous and controlled motivation produce different results, with autonomous motivation leading to greater task performance and psychological health (Deci, 2008).

Teachers appeal to their students' extrinsic motivation through positive consequences such as offering praise and negative consequences such as threats or punishment. In education, grades are commonly used to extrinsically motivate students to achieve a certain academic level in a course of study. In reality, grades tend to fall short of their intended goal of promoting academic motivation; rather grades can have the unintended effect of producing anxiety and avoidance in the student (Chamberlin, 2018). Thus, the type of extrinsic motivation used by the teacher can affect the development of intrinsic motivation in the student. Positive feedback such as a teacher's praise, and narrative evaluations backed with actionable feedback, enhances intrinsic motivation. Tangible results, such as trophies, monetary prizes, or grades tend to undermine student motivation (Chamberlin, 2018; Sansone, 2000).

Intrinsic motivation however, is not dependent on an external reward, rather intrinsic motivation comes from working a task in which completing the task is the reward itself. Intrinsic motivation allows the learner to feel pride, competence, and satisfaction in the work they have done (Schunk, 2012). Teachers attempt to foster intrinsic motivation in their students by initially providing extrinsic rewards that are gradually withdrawn as the student's intrinsic motivation grows. Increasing extrinsic motivation should not be seen as a goal, but rather a tool to further the development of a student's intrinsic motivation (Schunk, 2012).

Intrinsic motivation has a positive effect on a student's cognitive engagement and interest in a task. This increased interest may in turn sustain or even increase the student's engagement. Ultimately, increased cognitive engagement leads to increased knowledge and academic achievement (Blumenfeld, 2006).

Motivation and Academic Achievement

According to Bandura (1989), self-efficacy, the belief that one has the ability to perform in such a way to achieve goals, manifests itself within motivational, affective, and cognitive processes. One's self-efficacy and motivational level are positively correlated, the greater the belief in one's ability, the more motivation that person will have for that task, and the more likely they will persevere in that activity.

For educators, the reward for developing student motivation is high. Students with increased motivation exhibit higher levels of engagement (Blumenfeld, 2006), which in turn leads to an increase in content understanding. The combination of increased motivation, engagement, and content understanding work in a synergistic method that improves all three attributes. By maintaining a student's motivation towards studying mathematics, a student may exhibit increased long-term academic success in mathematics. To test this, Murayama (2012) conducted a study with fifth to seventh grade students and found a positive relationship exists between a students' intrinsic motivation in mathematics and their long-term academic achievement. The same study also failed to demonstrate any relationship between a student's long-term achievement and their intelligence. This leads to a notable conclusion for mathematics instructors; student motivation is likely to be a larger factor in student success than student ability for long-term success in mathematics.

Whereas student motivation is key for long-term mathematics success, there is also a tendency for intrinsic motivation to gradually decline as students age. While developing a self-report tool to measure a child's intrinsic versus extrinsic motivation, Harter's (1981) participant data tangentially revealed a gradual decline in intrinsic motivation among students in grades three through nine, specifically in regards to their capacity to engage with challenging content, their curiosity, and their independent mastery of topics. Building upon this finding in Harter's research, Lepper (2005) used a sample of third through eighth grade students to specifically research the correlation of intrinsic motivation and a students' age. Leper's research confirmed the annual decline of intrinsic motivation in grade school students that emerged in Harter's research. Furthermore, Leper found only a moderate correlation between intrinsic and extrinsic motivation, the later exhibiting almost no change among age groups. Lepper (2005) posits the decline of intrinsic motivation may be attributed to schools limiting the options available to students, just as a student's need for autonomy increases.

Motivation from Perceived Control

For long-term academic success, students need to maintain high levels of motivation (Blumenfeld, 2006). Unfortunately, mathematics students also experience a similar annual decline in intrinsic motivation with a decline of approximately 20% each year from middle through high school (Gottfried, 2007). Gottfried's study confirmed a prevailing theory that student motivation in mathematics is related to academic ability in mathematics. But there are other factors beyond academic achievement that build motivation in a task.

In a general sense, motivation to complete a task is tied to a student's self-regulatory processes. If a student maintains a greater interest in a topic, they exhibit higher levels of motivation (Cleary, 2009). High levels of motivation lead students to use features of self-regulated learning such as strategic planning, how the task is performed, and spending time after the task for self-reflection on their work (Schunk, 2012). Students who employ such self-regulated learning strategies will have a stronger sense of ownership in their task. Students who perceive control over a task feel less threatened and exhibit lower levels of stress and anxiety in that task (Bandura, 1989). Conversely, students who lack self-efficacy are likely to avoid the task in order to avoid a displeasing outcome or failure. This avoidance is a natural reaction when faced with a situation that feels beyond the person's coping ability. High achieving mathematics students use more of these self-regulated processes and are shown to also have a higher level of interest and enjoyment in mathematics (Cleary, 2009). All of these self-regulation strategies heavily rely on the student's task motivation.

Loss of control can lead to a loss of intrinsic motivation. Parents or guardians typically control the degree of autonomy given to their children. As the child grows older, more autonomy is afforded, with a steep increase in individual autonomy after the age of 15 (Wray-Lake, 2010).

Adolescents are thus given more freedom than children, but are still restricted in the choices they are allowed to make. Society does not provide adolescents a choice in education, mandating education through 12^{th} grade or until the student turns 18. Adolescent youth may lack perceived control, which is to say they lack the belief that they have the power or ability to alter their personal behavior, internal state, or environment (Pagnini, 2016). Students who maintain perceived control exhibit both greater engagement and motivation towards a task, which is fundamental to the development of intrinsic motivation (Schunk, 2012; Skinner, 1990).

Conventionally, mathematics teachers held control of nearly all aspects within their classroom, allowing little room for student autonomy within the classroom environment. In these environments the teacher does not trust the self-efficacy of the student, nor does the student trust themselves (Simmons, 2010). Perhaps part of adolescents' loss of motivation towards mathematics can be prescribed to a loss of control in their classroom environment. Since perceived control over a task is fundamental in developing intrinsic motivation (Schunk, 2012), the remainder of this literature review will focus on methods to incorporate student choice into a mathematics classroom.

Methods of incorporating Student Choice into a Classroom

Example Choice

Example choice is a method of affording a student a personal choice in which example they wish to read about, or which problem/task that they choose to work on and solve. Example choice was found to improve students' interest and ability to stay on task (Høgheim, 2015). Example choice was also shown to have a large benefit among students with low interest in mathematics; however, conversely it was shown to have a slight negative effect among students with high interest in mathematics. Høgheim posits that high achieving mathematics students may view their choice as inconsequential, not connected to the task, or even irritating. Based on Høgheim's research, example choice may increase engagement of low achieving students at the expense of high achieving student engagement. Alternatively, instead of focusing on student choice through individual problems or examples within an assignment, a holistic approach may be taken by providing students a choice of assignment itself.

Assignment Choice

Student Choice can be used to establish terms of an assignment, project, or task. By providing a theme or topic for an assignment, the instructor allows the students to create their own project relating to that theme. In this type of scenario students will have autonomy to create and work on their own project, in so much as that it aligns with the intended theme.

When implementing assignment choice, instructors should avoid assignments that are too open-ended; otherwise students may have difficulty in selecting a project (Simmons, 2010). To assist student choice, the teacher may provide examples to the students. This type of project could be unfamiliar to students, who may struggle with making a choice. Grouping students together can be beneficial for projects that are extremely open-ended, so the students rely on their peers for help, instead of the natural inclination of a student to ask their teacher for assistance (Simmons, 2010). This type of student choice project is more readily applied to English language arts (ELA), or the social sciences. Mathematics uses indisputable axioms, which for the most part are not subject to individual interpretation. The difficulty of implementing assignment choice within a mathematics classroom leads us examine if homework would be a more suitable conduit for student choice.

Homework Choice

Instructors may offer student choice in their homework assignments. The educational world has traditionally viewed homework as an integral part of student achievement as it aims to improve a student's mastery and recall of the topic. In addition, homework may have a positive, long-term effect on a student's achievement motivation (Bempechat, 2004). Homework not only provides the student time to practice and develop their academic skill, but also time to develop coping strategies to deal with inevitable setbacks from mistakes and difficult assignments. Among primary school students homework has little to no effect on achievement, instead the primary benefit of homework is to develop the student's study skills (Bempechat, 2004). However, among secondary school students a strong positive correlation exists between the amount of homework completed and their academic achievement (Cooper, 1998).

Academic researchers are divided on the effectiveness of homework. Some researchers, such as Jo Boaler, see little and possible negative benefits to homework; suggesting mathematics teachers reduce, or completely forgo assignment of homework. Boaler views mathematics homework as inequitable, as children in low socio-economic families usually do not have a quiet place to study, allowing the students in privileged backgrounds to having higher levels of achievement than their peers (Boaler, 2016). Furthermore, homework can cause students to resent mathematics and may lower a student's intrinsic motivation in mathematics. Boaler (2016) instead suggests providing students with more reflective homework assignments, as opposed to assigning a list of problems to complete in a rote manner, which may lead to a decrease in student motivation. If homework is to be assigned, it should be done in such a manner as to either build the student's motivation, or at least stymie the potential loss of motivation caused by the assignment.

In a study of 207 high school students in a southeastern US state, students were offered choice in their homework assignments between two similar options (Patall, 2010). Patall (2010) found that homework choice correlated to both student interest and enjoyment of the assignment, the students' perceived ability in the task, increased exam scores, and a slight predictor of homework completion. Of note, the study was not able to show a correlation between homework choice and the amount of effort invested in completing the assignment. Relying on homework as a means of providing student choice will have minimal effect on students who do not normally complete homework. By instead incorporating an in-class instructional choice, all students in the class would be afforded a measure of autonomy.

Mode of Instruction Choice

Increases and development of technology may provide students with alternative methods of instruction. The advent of this technology has brought upon various modes of instruction, and has created new educational approaches such as online learning, virtual learning, e-learning, and web-based instruction. At the core of each of these modes of instruction is access to some form of technology, such as a computer or tablet, and access to the internet.

Enrollment in online learning courses has become more commonplace. According to the National Center for Education Statistics (2019), in Fall 2018, 6.9 million out of 19.6 million college students were taking some form of distance learning or online course. Students are able to choose online learning courses as alternative modes of instruction in place of a traditional in-person class. These choices may be due to a conflicting class, work schedule, or may simply be a personal preference.

The efficacy of online learning has been largely researched at the post-secondary level. While secondary students are not at the same developmental levels of post-secondary students, there will still be commonalities, and analogous trends in the research that are worth consideration. A study involving 146 students enrolled in a management information business course was able to show that a web-based virtual learning environment was a viable alternative to a traditional classroom environment in regards to learner outcomes at the post-secondary level (Piccoli, 2001). While the virtual learner outcomes in Piccoli's study were comparable, the students did report lower satisfaction with the learning experience. In another comparable study 205 medical students were presented either a live four hour lesson, or an equivalent video lesson (Brockfeld, 2018). At the end of the treatment, a summative assessment revealed nearly identical outcomes with an average score of 78.3% in the live group versus an average score of 78.6% in the video group. However, user satisfaction echoes Piccoli's study, with students preferring live lessons nearly two to one.

Due to the COVID-19 pandemic, instruction rapidly shifted to an online setting, and by Fall 2020 93% of United States households with school age children reported some form of distance learning (McElrath, 2020). As a result of the pandemic, students may have no choice in distance learning, but could still be provided a choice in their method of instruction: choosing between a live or pre-recorded lesson. The unique nature of distance learning and availability of pre-recorded video lessons allows a unique experimental design that effectively allows students to make a choice in not only their method of instruction, but also their instructor.

Methods

Purpose and Research Question

Much of the research into developing student autonomy and intrinsic motivation through student choice was conducted in subject areas other than mathematics. Mathematics, by its very nature leaves little to individual interpretation. However according to Schunk (2012), perceived control is fundamental to developing intrinsic motivation. This study investigated if a positive relationship exists between student autonomy and student motivation in the domain of mathematics instruction. Therefore, the research question for this study is: will affording adolescent mathematics students more individual choice within their class increase their motivation to study mathematics, as measured by The Motivation for Mathematics Abbreviated Instrument (MMAI)?

Hypothesis

According to Self-Determination Theory, a key component to increasing motivation is the need for autonomy, or perceived control (Deci, 2008). This research investigated whether increased student choice has an effect on a students' motivation towards mathematics. The researcher hypothesized that allowing students to make fundamental choices in their daily mathematics routine would have an effect on the student's motivation to learn mathematics.

H_0:

Student activity choice in their mathematics lesson has no effect on their motivation to learn mathematics.

H_1:

Student activity choice in their mathematics lesson has an effect on their motivation to learn mathematics.

Research Design

The educational setting of the participants limited a true experimental design, as the participating students could not be randomly assigned into the two experimental groups, instead the participants were required to remain within their pre-existing groups (i.e., classes). In addition, all students in the study were from a single instructor, opposed to the larger pool of all Integrated Math II students at the school site. Therefore, a quasi-experimental pretest-posttest two-group design was implemented. Two of the four classes were randomly assigned as the treatment group, and the other two classes became the control group. Both treatment and control groups took the pretest and posttest survey, however only the treatment group received the intervention. Data was analyzed after the study to determine if there was significant change in motivation both within and across groups.

Independent variable

The independent variable was student-choice for method of mathematical instruction. Each student in the intervention group was able to choose their method of instruction for each mathematics class meeting. According to Deci (2008), the ability to self-determine and control our environment is one of the core needs that promote intrinsic motivation. The students in the intervention group were able to choose between a live instructor led lesson, or join an alternative class that played a prerecorded video of the same lesson by a different instructor.

Dependent variable

The dependent variable was the student's self-reported level of motivation to study mathematics. Motivation is defined in this research study as the tendency of a student to engage in mathematics when the opportunity presents itself (Butler, 2016). Students' motivational levels were measured before and after the experiment using the Motivation for Mathematics Abbreviated Instrument (MMAI; Butler, 2016; Appendix C).

Setting & Participants

The setting for this study was a Title I high school (grades 9 through 12) with 1,149 students located in central California. According to California School Dashboard (caschooldashboard.org) in the 2020-2021 school year 1,017 students (88.5%) were Hispanic, 85 students were white (7.4%), 15 (1.3%) students were American Indian/Alaska Native, 8 (0.7%) students were two or more races, 5 (0.4%) students were Asian, and 4 (0.3%) students were black. 81.3% of students come from homes designated as socioeconomically disadvantaged. According to Public School Review (2020), 21% of students achieve proficiency in Mathematics, compared to the state average of 39%. The school placed in the bottom half for math proficiency in California.

Participants in this study represented a convenience sample, as they were enrolled in four separate classes taught by the researcher. However, the sample was also purposeful in that all participants in this study were enrolled in the same mathematics course: Integrated Mathematics II. Integrated Mathematics II is a college preparatory math course, typically taught to sophomores. As part of the Integrated Mathematics pathway, the first semester primarily covers quadratic equations, while the second covers select Geometry topics.

Ages and grade level varied somewhat among the participants. The majority of students (91 total) were in 10^{th} grade, taking the course for the first time. Those in 11^{th} grade (45 total) and 12^{th} grade (3 total), were either repeating the course or had their mathematics progression delayed previously.

Due to the COVID-19 pandemic of 2020-2021, all classes were taught remotely using Microsoft Teams as the educational platform. The mathematics curriculum used was a modified version of “All Things Algebra” (Davis, 2016). This curriculum was chosen by the school’s mathematics department to be used during distance learning, due to being a more traditional lecture style mathematics curriculum, as each lesson employs several guided practice problems, followed by independent student work.

Treatment group

The treatment group initially consisted of 71 students enrolled in two Integrated Mathematics II courses, randomly selected, and taught by the researcher. There were 34 males and 37 females in this group. The treatment group was ethnically homogenous, and representative of the general school population, with 63 Hispanic students, 4 white students, 2 black students, and 2 Filipino/Asian students. Of the 71 students in the initial treatment group, 10 did not, or were otherwise unable to take the post-intervention MMAI assessment survey. As a result, their survey responses were removed prior to the data analysis, resulting in a de facto treatment size of 61 students.

Control group

The control group initially consisted of 68 students enrolled in two Integrated Mathematics II courses, randomly selected, and taught by the researcher. There were 31 males and 37 females in this group. The control group was ethnically homogenous, and representative of the general school population, with 62 Hispanic students, 6 white students, 0 black students, and 0 Filipino/Asian students. Of the 68 students in the initial control group, 4 did not, or were otherwise unable to take the post-intervention MMAI assessment survey. As a result, their survey responses were removed prior to the data analysis, resulting in a de facto control size of 64 students.

Measures

To measure student's motivation to study mathematics, students answered all 16 questions from the MMAI (Butler, 2016; Appendix C). The MMAI is a psychometric scale for students in developmental Algebra courses that measures motivation holistically by the four dominant factors of motivation: intrinsic, mastery orientation, performance orientation, and expectancy. The MMAI has 16 questions total, with four questions from each of the four dominant factors of motivation. Sample items included: "I would describe mathematics as very interesting," or "It's important to me that I thoroughly understand mathematics" aim to elicit a student's motivational level towards mathematics. The students answered each question using a 5-point Likert-Scale, ranging from 1 point (*Not at all true*), 2 points, 3 points (*Somewhat true*), 4, or 5 points (*Very true*). The total value of the Likert-Scale responses provides an aggregate score for that student; the higher their score, the more that student is motivated towards studying mathematics (Bulter, 2016). Students were given the MMAI recommended time of 15 minutes to complete the motivational survey. Student participants in both the experimental and control groups completed the MMAI both prior to and post intervention.

Validity

Through expert surveys and interviews, Butler (2016) determined questions involving extrinsic motivation, self-efficacy, and task-value could not be generalized to a mathematics domain, and questions were limited to the four factors: intrinsic, mastery orientation, performance orientation, and expectancy. For construct validity, all questions from the MMAI came from previously published and validated surveys, and were selected by survey respondents from the Motivation in Education Special Interest Group (SIG) of the American Education Research Association (AERA) as being valid representations of their intended motivational construct (Butler, 2016).

Reliability

Cronbach's alpha was used to measure internal consistency of each of the four factors of the MMAI: intrinsic motivation (.90), mastery orientation (.88), performance orientation (.85), and expectancy (.89). As each alpha value was close to one, each subscale could be included in the measure without hesitation. Using a confirmatory factor analysis, Butler (2016) reported that not only did strong discrimination (i.e., ability to distinguish separately) exist between each of the four motivational factors, but also convergence within each factor: RMSEA = .06 90% C.I. (.046, .078), TLI = .951, SRMR = .045.

Intervention

This research study took place during one learning segment of an Integrated Mathematics II course. The learning segment consisted of 10 individual lessons and took 6 weeks to complete. Students took classes in a block schedule, and met for two 95-minute synchronous lessons, and one 48-minute asynchronous lesson each week. The asynchronous class meeting each week was unaffected by the research study, and was used for student office hours, homework help, and quizzes.

The pacing and instructional style of each lesson within the control group was consistent with a traditional, instructor-led discussion, as well as being consistent to the style of instruction the students had become accustomed to. The instructional goal was to provide several worked examples for the students, as well as individual time for student practice, followed by explanations. This process repeated throughout the lesson. During the last 5 minutes, the instructor posed an exit style question in which to assess student learning.

The initial 10-15 minutes of each intervention class was the same as the control group. This block of time was used to welcome the class and conduct any administrative tasks, such as answering homework questions, reminding students upcoming quizzes, exams, and assignment due dates. In addition, the instructor also used this block of time to describe the purpose and goal of the day’s lesson, which included discussions on required prior knowledge and example problems. When the administrative tasks were complete, the instructor presented each student an individual choice: to remain in the current class meeting and follow the lesson instruction led by their current math instructor, or choose to leave the meeting and join an alternative class meeting.

Intervention group students were provided a choice in their method of instruction. Student choice was the mechanism to increase the student’s perceived control in the task.

Students maintaining perceived control exhibit both greater engagement and task motivation, both of which are crucial to the development of intrinsic motivation (Schunk, 2012; Skinner, 1990). In turn, higher levels of motivation lead students to use more self-regulated learning processes such as planning, task performance, and self-reflection (Schunk, 2012). These self-regulated processes not only give the student a greater sense of ownership, but also increases their level of interest, enjoyment, and ultimately intrinsic motivation in mathematics (Cleary, 2019).

After presenting the class a choice in their method of instruction, the instructor allowed a three-minute break for the students. This three-minute break gave all students in the class the opportunity to leave the regular class meeting in order to join the alternative meeting or remain in the regular meeting. At the conclusion of the break, a pre-recorded video of a different, yet fully qualified instructor was played to the students who chose to join the alternative meeting. The literature has shown that virtual learning with an equivalent video lesson to be a viable alternative to a traditional classroom learning environment in regards to student learning outcomes (Brockfeld, 2018; Piccoli, 2001). The pre-recorded video lessons varied in length, from 30 to 45 minutes. Each alternative video was pre-edited by the instructor to include real-time pauses for the students to independently practice when prompted by the alternative instructor. The pauses also included problem scaffolding in the form of time-delayed supports, such as the initial problem setup, followed by time-delayed incremental steps taken to solve the problem. These scaffolds assisted students by allowing them to work effectively within their own Zone of Proximal Development (Vygotsky, 1978). The scaffolds ultimately provided all the necessary work, allowing students to check their work. The supports provided by the scaffolding were analogous to help the live class received from the instructor.

At the conclusion of the pre-recorded video, students in the alternative meeting were prompted to rejoin the main class in session. After the recombination of both student groups into the live meeting channel, all students were afforded additional problems to practice on, as well ask any questions they may have had with topics from the video lesson, and time to start working on their independent homework assignment if applicable.

The pacing of the instructor-led class and the video lesson were as similar as possible. The instructor reviewed the pre-recorded video lesson in advance to determine pacing, and which, if any problems were omitted from the lesson. Omitted problems in the video lesson were also omitted in the live lesson, to provide parity between the alternatives. Problems omitted in this way were sometimes assigned as student practice after the recombination of the classes.

Procedures

For student accountability, the instructor downloaded an attendance log for students in both the live class and video class. Students who left the live class, but did not join the video class were marked absent. Students who did not return to the live meeting at the conclusion of the video lesson were marked tardy. The classwork policy for each class was unaffected by this study. All students, whether in the live or video class, were required to submit photographic evidence of completed classwork at the end of each week. All live and video classes were recorded. Students had access to these recordings after class for review, primarily used by students who missed a class meeting. For this experiment, there were two independent raters to ensure fidelity. The independent raters had full access to all classes, as well as the ability to review the video recordings to ensure fidelity.

Data collection

All students in this study took the MMAI psychometric scale (Butler, 2016; Appendix B) prior to, and after the completion of the last math lesson of this study. The MMAI was converted into a Microsoft Form available to the students as a Microsoft Teams assignment in their class. Prior to taking the MMAI, students were made aware that their answers were completely confidential, and had no effect on their grade. The students were asked to take their time, both in reading and choosing the most appropriate answer to each question. Students were informed they had 15 minutes to complete the survey but were able to take additional time if needed.

Fidelity

To ensure fidelity during this experiment, two additional math teachers at the school site acted as independent raters. Both independent raters followed a fidelity checklist (Appendix A). The raters were included as Microsoft Team members for each class participating in this study. In doing so, the independent raters were able to independently audit each class meeting, and could join and leave class meetings at their own discretion, with no disturbance to the meeting. In addition, all control and intervention group meetings were recorded. The raters had access to all of these recordings to review when conducting their audits. At the conclusion of the intervention both independent raters reported 100% fidelity to the intervention.

Ethical Considerations

As a quasi-experimental pretest-posttest two-group design, only the treatment group of students received the intervention. If the experiment was able to reject the null hypothesis, and having choice increases a student's motivation towards mathematics, then student choice would be extended to the control group as well.

Conversely, if student choice was found to not have an effect on student motivation, students who repeatedly chose the alternative task, but did not actively work or participate while in the video lesson may experience a learning loss compared to students in the control group, or students who chose to remain in the instructor-led meeting. To mitigate this potential learning loss, the alternative video lessons were limited to 30 to 45 minutes in length. Participant confidentiality in survey results was maintained by replacing student names with a research identification code for each participant.

Validity threats

Due to the COVID-19 pandemic, all classes were taught remotely, decreasing the likelihood of intra-student conversation between members of the control and intervention groups, limiting the extent of treatment diffusion. Furthermore, students in the control group were not subjected to a change in class routine, and were not told of the experiment in progress.

Participants (students) in the intervention group were aware of the change in routine, but were not told of the significance or intent of the research design. When pressed by students on the intent, the researcher told the students that such questions could be addressed in six weeks (following the conclusion of the experiment).

Students in the intervention group were required to attend one of the two instructional class choices presented. Students were advised that attendance rosters would be taken, and students who left the main class, but did not attend either meeting, or students who attended the alternative video class but do not return to the main class meeting following the conclusion of the video would be marked tardy.

The motivational survey (MMAI) used in this study was developed by Butler using college students enrolled in developmental and intermediate algebra courses at the University of South Florida (Butler, 2016). Butler mentions some of the motivational survey questions originated from surveys administered to elementary students through high school students, therefore the survey might not be valid for students outside of developmental algebra courses (Butler, 2016). The study population for this research were students enrolled in Integrated Mathematics II, which is considered both a developmental and intermediate algebra course. Therefore, the students in this study, while younger than the students used in the development of the MMAI, are aligned in their mathematics coursework. Butler mentions that a study with high school students enrolled in similar coursework would be valuable to help generalize the use of the MMAI for high school students.

Data Analyses

All data was entered into the Statistical Package for the Social Sciences® (SPSS®) for Windows, version 25.0.0 (SPSS, 2017). No names or identifying information were included in the data analysis. Before analyses were conducted all data was cleaned to ensure no outliers were present (Dimitrov, 2012). After cleaning the data, Independent samples t-tests (control and treatment groups) and dependent samples t-tests (pretest and posttest) were conducted to determine the significant difference in the students' self-reported level of motivation to study mathematics between the two means scores on the (Butler, 2016; Appendix C). Further, before interpreting the analytical output, Levene's Homogeneity of Variance was examined to see if the assumption of equivalence had been violated (Levene, 1960). If Levene's Homogeneity of Variance was not violated (i.e., the variances were equal across groups), data would be interpreted for the assumption of equivalence; however, if the variances were not equal across groups the corrected output would be used for interpretation.

Results

Two independent samples t-test were conducted on the whole sample (n = 125) for both the pre and post assessment scores. Results for the pre-test were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed and the t-test showed non-significant differences between the mean scores on the pre-tests between the two groups $t(123) = .22$, $p > .05$. This means there was not a significant difference found in the pre-intervention data of the control and treatment groups. Thus the two groups were homogenous at the start of the study, allowing comparisons between the two groups without hesitation (see Table 1). Results for the post-test were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed and the t-test showed non-significant differences between the mean scores on the post-tests between the two groups $t(123) = -.36$, $p > .05$. While there was a slight increase (.08) in the mean score of the treatment group, the increase was not statistically significant (see Table 1). This provides partial support of the intervention.

Table 1

Results of Independent Samples T-Tests

	Mean	SD
Pre Test		
Treatment	2.79	.68
Control	2.81	.63
Post Test		
Treatment	2.87	.76
Control	2.83	.64

Note. SD = Standard Deviation.

After determining the differences between pre and post assessment scores between groups, two paired t-tests were conducted for both groups (i.e., treatment and control) to determine if participants mean scores from pre to post were significantly different within each group (See Table 2). Results for each group were as follows: treatment group, $t(60) = -1.19$, $p > .05$; control group, $t(63) = -.23$, $p > .05$. Therefore, the change in mean values for both groups (pre to post-test) were not statistically significant. Additionally, the negative t-values from both groups represent an increase in mean value; therefore, both groups did have larger means on the post-test compared to the pre-test. While not considered statistically significant, the treatment group did exhibit a larger increase in mean value compared to the control group. This provides some support for the effectiveness of the intervention.

Table 2

Results of Paired T-Tests

	Mean	SD
Treatment Group		
Pre	2.79	.68
Post	2.87	.76
Control Group		
Pre	2.81	.63
Post	2.83	.64

Note. SD = Standard Deviation.

Discussion

Maintaining high levels of motivation increases long-term academic success in students. Unfortunately, student motivation towards mathematics tends to decline annually (Blumenfeld, 2006; Gottfried, 2007). A possible way to address this decline is to provide the student a sense of autonomy or perceived control. A main pillar of SDT is autonomy of actions, with autonomous motivation leading to greater task performance and psychological health (Deci, 2008). Since having perceived control encourages the development of intrinsic motivation (Schunk, 2012), this study investigated the relationship between student autonomy in a mathematics classroom and the students' motivation towards studying mathematics.

Participants were provided a choice in their method of instruction, between a live lesson taught by their existing instructor or a pre-recorded lesson taught by an alternative instructor. The unique nature of distance learning allowed for pre-recorded video lessons to be an academically effective substitute to the live lesson (Brockfeld, 2018; Piccoli, 2001). The motivation levels of the participants were measured pre and post-intervention by the MMAI (Butler, 2016).

The researcher hypothesized that allowing students to make a fundamental choice in their daily method of mathematics instruction would have a positive effect on the student's motivation to learn mathematics. The data analysis of the paired t-tests (pre to post) for the treatment group, exhibited an increase in motivation score of .083, compared to the paired t-tests (pre to post) for the control which exhibited an increase score of .013. While the increase in motivation was larger for the treatment group, the significance level was .238, which was larger than the significance level of .05 required for a 95% confidence level. Therefore, the researcher was unable to reject the null hypothesis (H_0: Student activity choice in their mathematics lesson has no effect on their motivation to learn mathematics). This result is unexpected as the need for autonomy is an innate psychological need, and a cornerstone of Self-Determination Theory (Deci, 2008). The researcher feels that further experimental research should be conducted that adequately addresses the limitations of this study.

Limitations and Future Directions

As a quasi-experimental design, a potential concern was if the data adequately satisfied the requirements of a paired sample t-test, namely if the sample itself can be viewed as truly random. All the student participants in the sample were from the same instructor's class, therefore a statistical bias may have been introduced which would affect the p-value to some degree. Furthermore, all classes were taught through distance learning as a result of the COVID-19 pandemic, resulting in a non-standard learning environment. Student fatigue with remote learning led to markedly lower than normal student engagement compared to a typical year with in-person instruction. When the study commenced in February 2021, student participants had already been learning remotely for nearly a year.

The intervention group exhibited low overall participation in students selecting the alternative video lesson. Student participation in the video classes ranged from a high of seven to a low of one student. The researcher was hopeful that even though individual students declined to attend the alternative class, they would nevertheless feel empowered that they were by default, making a choice to stay in their existing class environment. The researcher posits the low alternative class participation may be attributed to factors such as apathy due to distance learning fatigue or hesitancy to make fundamental changes in routine.

The researcher believes the relationship between student autonomy and motivation warrants further research. Further experiments into this topic would ideally be run during a standard school year, in which confounding factors such as distance learning and lower than normal student engagement are not present. An in-person experimental model using instructor-choice could allow students to choose between in-person instructors using a pre-determined time frame (e.g. daily, weekly, or monthly).

Alternatively, the mode of student choice could also be changed for the experiment. As a result of mandated distance learning from COVID-19, electronic devices have become ubiquitous in the classroom enabling an instructor to use an analogous electronic lesson the students can choose to complete. Online learning platforms such as Khan Academy, Math 180, or IXL, provide complete mathematics curriculums allowing the instructor to find alternative lessons for their students to choose. These online learning platforms provide guided practice, allowing the student to work independently without the aid of an instructor. The electronic lessons could be used independently, or in combination with intra-lesson student choice in which students could be provided further autonomy in choosing examples, assignments, or even homework assignments to complete. The researcher is hopeful that further investigation into student autonomy and its effect upon mathematics motivation can be conducted.

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Appendix A

Implementation Fidelity Checklist

Observer:

Date:

Class/Period:

Intervention Steps	Completed	
	Yes	No
1. Teacher provides a brief (5-10 minutes) overview of the daily topic and goals.		
2. Students are offered a choice for their daily instruction, in a clear manner, immediately following the daily overview.		
3. The alternative video class is open for students to join and students are provided adequate time of at least 3 minutes to transition to the video class.		
4. Video is played for students in the alternative video class with acceptable audio/video playback.		
4. Following conclusion of video, students rejoin the instructor-led class.		

Appendix B

The Motivation for Mathematics Abbreviated Instrument

I would describe mathematics as very interesting.
1 2 3 4 5
Not at all true Somewhat true Very true

I do mathematics for the excitement I feel when I am really involved in the activity.
1 2 3 4 5
Not at all true Somewhat true Very true

I think mathematics is enjoyable.
1 2 3 4 5
Not at all true Somewhat true Very true

Mathematics is fun to do.
1 2 3 4 5
Not at all true Somewhat true Very true

It’s important to me that I learn a lot of new math concepts this year.
1 2 3 4 5
Not at all true Somewhat true Very true

One of my goals is to master a lot of new mathematics this year.
1 2 3 4 5
Not at all true Somewhat true Very true

It’s important to me that I thoroughly understand mathematics.
1 2 3 4 5
Not at all true Somewhat true Very true

One of my goals in my math courses has been to learn as much as I can.
1 2 3 4 5
Not at all true Somewhat true Very true

I have liked showing math teachers that I’m smarter than the other students.
1 2 3 4 5
Not at all true Somewhat true Very true

I have felt successful in my math courses when I did better than the other students.
1 2 3 4 5
Not at all true Somewhat true Very true

In math courses, I have wanted to do better than other students.

1	2	3	4	5
Not at all true		Somewhat true		Very true

Doing better than other students in my math courses has been important to me.

1	2	3	4	5
Not at all true		Somewhat true		Very true

I'm confident I can understand the basic concepts taught in this math class.

1	2	3	4	5
Not at all true		Somewhat true		Very true

I believe I will receive excellent grades in this math class.

1	2	3	4	5
Not at all true		Somewhat true		Very true

I'm certain I can master the skills being taught in this math class.

1	2	3	4	5
Not at all true		Somewhat true		Very true

I expect to do well in this math class.

1	2	3	4	5
Not at all true		Somewhat true		Very true