Facilitative Teaching Utilizing Active Learning Modules in Engineering Graphics: A Model for Promoting Success and Engagement in Technology and Engineering Education

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Abstract

Success in post-secondary engineering graphics courses in technology and engineering often relies on self-efficacy, academic success, and mental rotation abilities. Using a facilitative instructor model, the Improving Undergraduate STEM Education (IUSE) team applied active learning modules as supplemental material at two post-secondary institutions in the United States of America, then used a quasi-experimental design iterative study approach to investigate impacts in an introductory engineering graphics course. Active learning modules were composed of ten units that engaged students through relatable examples and practices of foundational principles and applications of engineering graphics that are heavily applicable to the Standards for Technological and Engineering Literacy. The modules were presented to students through an online learning management system that encouraged elements of self-regulated learning. Measurements of self-efficacy, mental rotation ability, and academic success were gathered. Differences in academic and non-academic indicators were examined in combination with students at risk of non-matriculation and students not at risk of non-matriculation subgroups. Results from paired t-tests supported previous findings that there are positive impacts of supplemental materials available to students. Students at risk of non-matriculation benefited from the combination of active learning modules and supplementary video tutorials resulting in greater self-efficacy and higher final exam scores than at-risk students whose modules did not include video tutorials. Students not at risk of non-matriculation had higher levels of self-efficacy and mental rotation ability when video tutorials were not included. With this information, engineering, engineering education, and other STEM programs can model elements of active learning modules to promote early student success in both subgroups. Furthermore, the IUSE team has published the material through open access for educators and students to utilize.

Keywords: self-efficacy, mental rotation ability, engineering graphics

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Introduction

In a transition away from the traditional delivery of technology and engineering courses where content is provided during course time, the Improving Undergraduate STEM Education (IUSE) team investigated the application of active learning modules through a facilitative instructor model of an introductory engineering graphics course at two post-secondary institutions located in the United States of America. Such a course includes content commonly taught and integrated into technological and engineering literacy development. A facilitative instructor model consists of instructors providing content material such as presentations, readings, and demonstrations, typically obtained through online lectures through a learning management system (LMS). Such practice enables students to go through the online content any time before or after class and allows course time to function as a period for students to experience collaborative, problem-based, active learning, field trips, guest speakers, data analysis, and other engaging methods that technology and engineering educators present in learning environments.

A facilitative instructor model supports elements of adaptive self-regulated learning through scaffolding because student learning can be monitored and supplemented through engaged learning by the instructor during in-person course time (Nelson et al., 2014). Engaged learning during class time involves peer support and collaborative learning to achieve task-specific and domain-specific success and increase self-efficacy in 21st century skills (González-Pérez & Ramírez-Montoya, 2022). Collaborative, problem-based learning involving the use of the engineering design process to develop models of solutions can also enhance mental rotation ability (Busby et al., 2013; Marunic & Glazer, 2012; Ariffin et al., 2017). Students can access online content outside of class to use as reference material. Applied active learning modules through a facilitative instructor model is similar to the "flipped" method of course delivery where content is provided in online, digital formats available before course time; this opens in-person course time to be used for providing engaging learning experiences (Mason et al., 2013; Talley & Scherer, 2013). Flipped instruction has typically been restricted to smaller class sizes in which engaging learning activities are simpler to apply, whereas a facilitative instructor model applies to larger class sizes.

Technology and Engineering Education Standards and Practices

Although the current project focuses on an introductory engineering graphic communications course, it is imperative to highlight that graphic communications has become an integral component of technology and engineering education curricula as well as directly and indirectly related to the International Technology and Engineering Educators Association's (ITEEA, 2020) Standards for Technological and Engineering Literacy (STEL) through the application of computer-aided design (CAD) (Kelley, 2013; Grubbs et al., 2018). Investigating a model established for an engineering graphics course applies to current practices and standards in technology and engineering education because of the wide range of fields that utilize virtual and physical modeling. In several technology and engineering education systems, including manufacturing, transportation, construction, communication, and power and energy, students use CAD to communicate details of human-centered design projects (Kelley, 2013; Grubbs et al., 2018). A practical framework utilized and replicated throughout technology and engineering education has been supported by investigating a facilitative instructor model using active learning modules.

Active Learning Modules Structure

A set of active learning modules culminating into a single unit aligning with an introductory engineering graphics course curriculum was developed to engage students through more in-depth discussion and examples of real-world relevancy of course content (Ernst et al., 2018). The active learning modules were arranged into ten topics: sketching, engineering geometry, orthographic and pictorial projections, working drawings, dimensioning standards and annotations, assemblies, section views, and auxiliary views. They contained course content information, video tutorials, sample exercises, and self-check features that encouraged students to practice elements of self-regulated learning and relate content to real-world applications.

Modules included technical knowledge from the course and real-world examples that reinforced classroom content, such as demonstrating how engineers use section views of models to show function and using everyday objects to help define technical terms, such as various section views cut out of fruit (Figure 1). Video tutorials provided step-by-step guides on how students can apply content knowledge in both software and technical practice, such as in a video demonstrating how to properly sketch lines or operate CAD software tools (Figures 2 & 3). Engaged learning experiences are promoted when the student can control the pace at which they follow a demonstration, as was the case with online video tutorials. Sample exercises in the modules provided further interactions by enabling students to complete activities where, after finishing their work, they could click to reveal the correct result allowing them to check for accuracy of understanding (Figure 4). Students experienced pop-up reflection questions throughout the modules that encouraged them to identify real-world relations to content knowledge based on their lived experiences (Figure 5).

Application of Visualization Skills in Technology and Engineering

Engineering graphics courses are a vital source of development of spatial visualization ability that is significantly related to success in the development of future technology and engineering teachers and the courses they teach. ITEEA's (2021) Engineering byDesign™ courses—Invention and Innovation as well as

Technological Design—have CAD-specific objectives that will influence the future Science, Technology, Engineering, and Mathematics (STEM) workforce (ITEEA, 2021; Sorby & Baartmans, 2000; Busby et al., 2013). The ability to mentally rotate objects is a critical skill in effective engineering (Sorby, 2007). The Accrediting Board for Engineering and Technology (ABET) has established requirements that students pursuing engineering/engineering technology programs take either an engineering graphics course or demonstrate proficiency in visualization and mental rotation abilities (ABET, 2019; 2021). In engineering graphics courses, students learn how graphics and visualization are applied in the various stages of the engineering design process (Utschig & Pucha, 2012; Turns et al., 2007). Additionally, these courses allow students to enhance their visualization and mental rotation abilities (Marunic & Glazer, 2012), promoting success in technology and engineering programs (Sorby, 2007).

Figure 1
Content Module Utilizing Real-World Examples

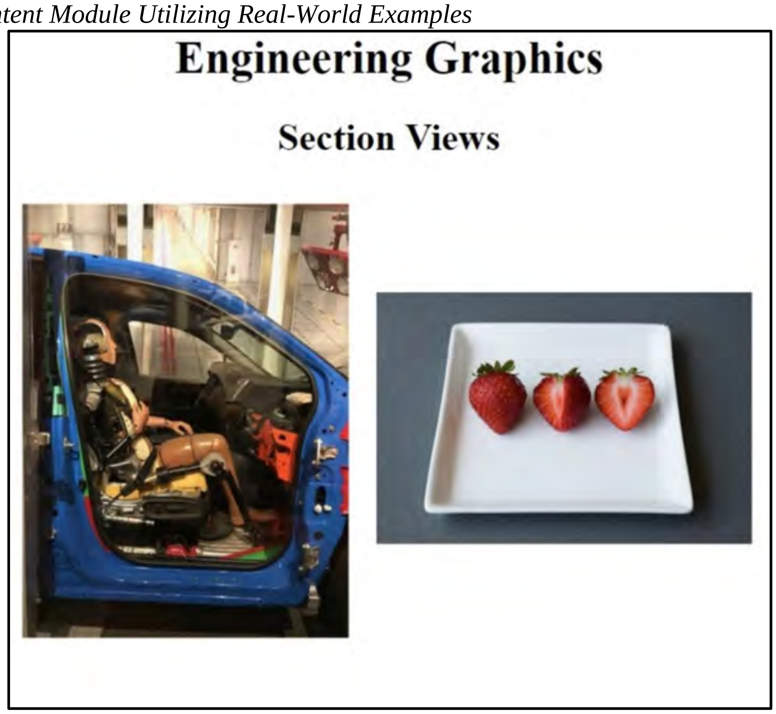


Figure 2

Screenshot of Step-by-Step Tutorial Video for Sketching Lines

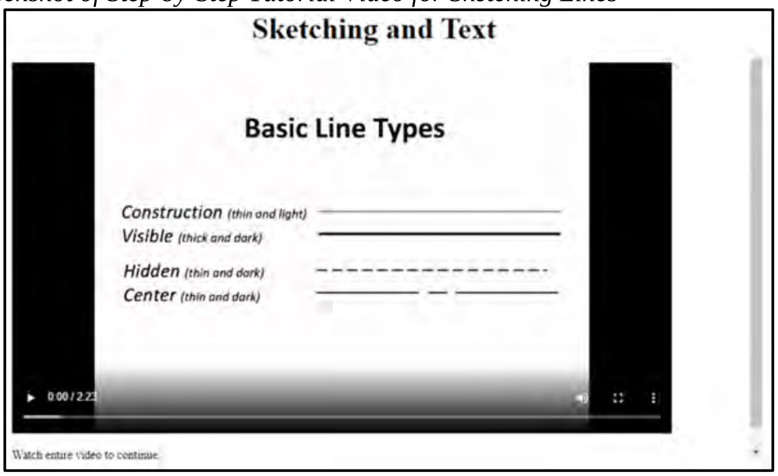


Figure 3

Example of CAD Tutorial Video

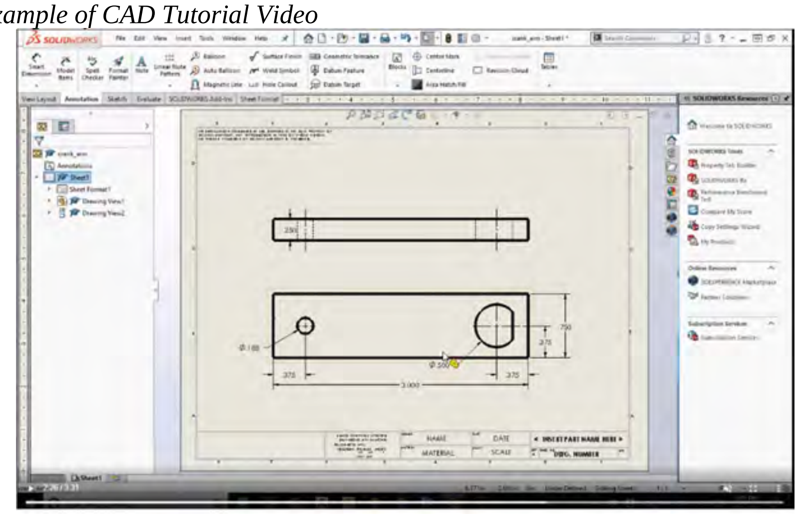


Figure 4
Example of Activity along with Presented Solution

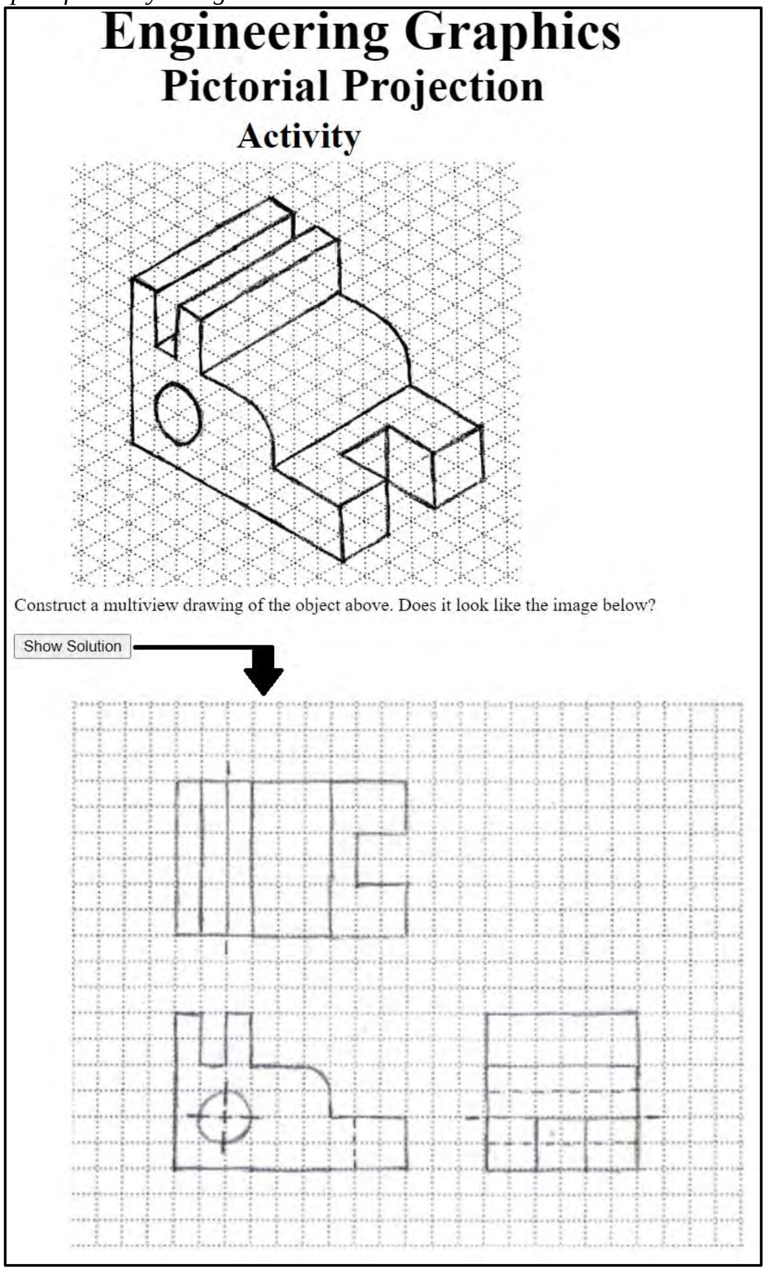
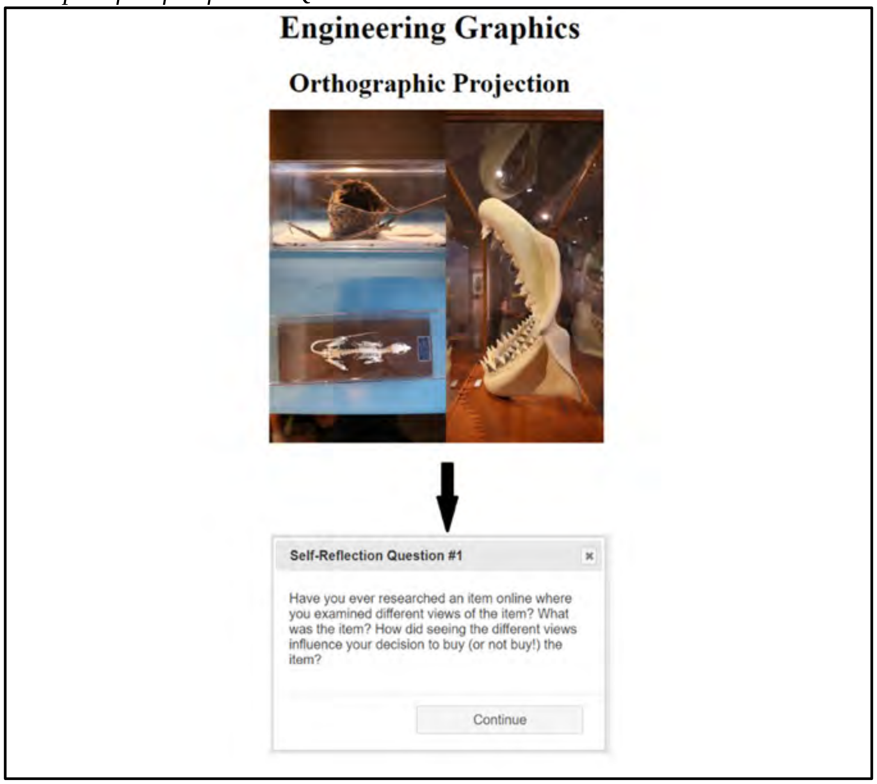


Figure 5
Example of Self-Reflection Questions



Engineering graphics courses are typically provided in the first two years of post-secondary technology and engineering teacher educator programs, engineering, or engineering technology programs because success in the engineering graphics course, in addition to the development of spatial abilities, is closely related to success in such degree programs (Sorby & Baartmans, 2000; Min et al., 2011). Early success is an asset for the positive experiences of underrepresented minorities, females, and first-generation college students. *Underrepresented minorities* refers here to individuals identifying as Hispanic, Black/African American, and American Indian/Alaska Native (Roy et al., 2020, p. 74). *First-generation college students* is defined as those coming from a household where neither of their parents nor guardians completed a baccalaureate degree. First-generation college students are more likely to come from a lower socioeconomic status, to be non-White, to be older and have dependents, and to enroll in two-year rather than four-year institutions (Bui, 2002).

Sixty-one percent of students graduating from U.S. institutions in 2019 with engineering bachelor's degrees were White (Roy et al., 2020, p. 9). Of the underrepresented minorities earning engineering bachelor's degrees in 2019, four percent were Black, 12% were Hispanic, and 15% were Asian American. Of all U.S. engineering bachelor's degrees that year, 23% were earned by female students. When looking at race and gender, gaps exist in engineering degree programs. By identifying factors related to the success of underrepresented students, it is possible to develop curriculum materials addressing these factors that act as resources to gain an increased understanding of content and skills practice (Talley & Scherer, 2013).

Components of Success in Technology and Engineering

Success in technology and engineering education courses may correlate to self-efficacy, academic success, and engagement. A student's self-efficacy is their confidence in their ability to complete specific tasks (Stajkovic & Luthans, 1998). Self-efficacy acts as a predictor of success in engineering, as well as a predictor of GPA in an engineering degree program, and GPA can act as a measurement of success (Ernst, Bowen, & Williams, 2016; Mamaril et al., 2016).

Accompanying self-efficacy in predicting success in engineering are both academic success and three-dimensional spatial visualization skills. A good measure of academic success includes GPA scores calculated from course grades consisting of assessments measuring student proficiency in course learning objectives (Vogt et al., 2007; Ernst, Williams, Clark et al., 2016). Increased knowledge and quality of performance in the course due to the use of the active learning modules acting as a resource can increase student performance in the course and other related courses leading to an increase in GPA (Freeman et al., 2014). Three-dimensional spatial visualization is a significant predictor of academic success in engineering (Ernst, Williams, Clark et al., 2016). Spatial visualization is “the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimuli” (Mcgee, 1979, p. 893). Spatial visualization skill is vital among engineers as they experience higher-level thinking, reasoning, and creative processes (Sorby, 2007) and is malleable through training (Sorby & Baartmans, 2000; Sorby et al., 2013). Incorporating enhanced resources for students can improve their spatial visualization ability and, therefore, their performance in technology and engineering education courses. If a student’s performance increases, their GPA likely increases, leading to improved academic success (Sorby & Baartmans, 2000).

Additionally, because spatial visualization ability is so deeply ingrained in science and math as well as technology and engineering education, then an increase in spatial visualization ability through technology and engineering courses can lead to an improved understanding and engagement in other topics such as science and math, furthering academic success (Sorby et al., 2013).

Student engagement is a critical component also related to success in engineering which consists of numerous aspects, including behavior, emotional, and cognitive process that involve such concepts as self-regulation, interest, and enjoyment (Wang & Eccles, 2013). Behavioral engagement consists of student actions toward learning and can involve behaviors such as following rules or being disruptive, as well as participating or not participating in lessons (Wang & Eccles, 2013). Emotional engagement refers to a student's enjoyment, interest, and feelings of acceptance or vice versa (Wang & Eccles, 2013). This includes a student's excitement toward a lesson, a feeling of being included in the activity, or interest in the topic (Wang & Eccles, 2013). When looking at the cognitive engagement of students, the concepts of self-regulated learning, self-monitoring, and self-evaluation come into play because each of those elements utilizes a student's mental efforts invested in one's learning and work (Wang & Eccles, 2013).

Elements of Self-Regulated Learning

With the increased incorporation of online learning environments, such as in technology and engineering education, there is a need to promote self-regulated learning to prepare students for function in such digital environments they are likely to see in future degree programs. (Stephen & Rockinson-Szapkiw, 2021). Students who lack the associated cognitive engagement skills or have "maladaptive self-regulated learning behaviors" may need supplemental material (Nelson et al., 2014). Additionally, classroom interactions have changed to encourage further multiple avenues of student engagement (Stephen & Rockinson-Szapkiw, 2021). When addressing teacher methodology, *how* students are taught is just as important as *what* students are taught when incorporating student engagement. The diverse populations of students making up our classrooms will not respond the same way to the same treatment (Ohland et al., 2011).

A student's self-regulation is facilitated by a teacher's autonomy support in the classroom (Zheng et al., 2020, p. 54). Autonomy support in an educational setting is promoted when the teacher establishes an environment that "(1) takes the student's perspective, (2) allows opportunities for choice and self-initiation, (3) provides a meaningful rationale for the requirement, (4) acknowledges student's feelings and (5) minimizes the use of pressures and demands" (Deci et al., 1994, as cited in Zheng et al., 2020 p. 44). When autonomy support is provided to students, such as through active learning modules in a facilitative instructor model, academic stress can be reduced, and self-regulation can increase (Zheng et al., 2020).

Incorporating Components of Success in Active Learning Modules

Traditionally taught courses delivered in a lecture format can be a disservice to students due to the inability to replay live lectures, large course sizes where they may feel lost among the crowd, and the need to complete assignments while away from instructors' guidance or tools available during the course time (Ernst et al., 2018). Such a traditional format puts students who are at risk of non-matriculation at a disadvantage, possibly resulting in lower self-efficacy (Ernst, Bowen, & Williams, 2016). Students at risk of non-matriculation in engineering degree programs include students with a GPA less than 3.0, students who identify as underrepresented minorities, or first-generation college students. (Ernst et al., 2018).

Using active learning modules as a resource for reducing struggles related to self-efficacy and academic success can enable students to be more engaged with technology and engineering course content. This increased engagement occurs in the form of behavioral engagement, such as participating in lessons, or through emotional engagement, such as a student's enjoyment or interest in a lesson due to increased understanding (Wang & Eccles, 2013). Since active learning modules can be presented to students as a resource for tasks outside of formal class time, the modules incorporate students' cognitive engagement through their self-regulated learning, self-monitoring, and self-evaluation (Wang & Eccles, 2013).

The flexible availability of the active learning modules establishes a foundation of autonomy for students by reducing time and distance barriers to content, enabling students to manage better their time and learning process (Rosero-Zambrano et al., 2017). While Zheng et al. (2020) provide insight into how teachers can establish support for autonomy, Rosero-Zambrano et al. summarized the literature on learning autonomy:

> According to Zimmerman (2002), Snodin (2013), and Lim and Chai (2004), learning autonomy has five dimensions which can be assessed through how students:
> (1) manage their learning,
> (2) manage their time,
> (3) design strategies to achieve learning goals,
> (4) make decisions and take action with respect to the learning process, and
> (5) evaluate and monitor their results (Theoretical Framework section, para. 3).

Incorporating such dimensions of learning autonomy encourages further responsibility for one's learning.

Research Questions

The research team intended to apply the facilitative instructor model in conjunction with active learning modules to answer five research questions:

RQ1. How does the facilitative instructor model affect three-dimensional modeling self-efficacy?

RQ2. How does the facilitative instructor model affect mental rotation skills?

RQ3. How does the facilitative instructor model affect academic success?

RQ4. How does the facilitative instructor model affect self-regulated learning?

RQ5. How do the sub-groups of at-risk students and not-at-risk students differ regarding measures of self-efficacy, self-regulation, mental rotation, and academic success at the end of the course?

Method

Data associated with self-efficacy, mental rotation ability, self-regulation, and academic success was collected for a quasi-experimental design iterative study conducted in introductory engineering graphics courses at two universities in the United States. Participants in the study were students enrolled in introductory engineering graphics courses. The first institution employed a large course section approach of up to 60 students per section. The course comprised students in engineering degree programs, a technology and engineering education degree program, and science, math, or other STEM degree programs. The second institution consisted of smaller course sizes consisting of 20 students restricted to engineering technology and technology and engineering education degree program areas. Efforts for ethical considerations were present in that Institutional Review Board approval was granted, participants provided consent, all questions were optional, and students were allowed to quit the study at any point. All collected data were deidentified following ethical requirements for data where information was kept secure and confidential through alphanumeric scheming.

In addition to the active learning modules, the course LMS contained optional tutorial videos to supplement in-class lectures and demonstrations for students who needed additional review. During this study, significant changes occurred in the software used in course instruction rendering the supplemental videos obsolete and no longer appropriate for continued use. Due to the timing of these changes and the in-depth nature of the videos, there was not enough time to recreate videos to match the updated software. This presented an opportunity for investigators to examine the effect of active learning modules with and without supplemental videos.

At the beginning of the semester, students took pre-tests and were assigned active learning modules to be completed outside of regularly scheduled class time. The assigned active learning modules were provided in an online learning management system along with the developed course curriculum. Students received a certificate of completion submitted to the instructor for credit by the end of the semester, which acted as evidence of completion and autonomy.

Students were given post-tests at the end of the semester; their final project grade, final exam grade, and final course grade scores from the semester were recorded. To evaluate impacts among sub-groups, data on study participants, including major, age, gender, and self-identified race, were collected. Participants were also asked to identify whether they were first-generation college students and to report their current GPA.

Self-efficacy was measured using a 3D Modeling Self-Efficacy instrument (Ernst, Bowen, & Williams, 2016). To measure spatial visualization and mental rotation skills, students completed the Purdue Spatial Visualization Test: Rotations (PSVT:R), following the methods of Sorby and Baartmans (2000). Psychometric analysis of the 3D Modeling Self-Efficacy and the PSVT:R instruments used in this study were previously conducted and found to have evidence of reliability and validity among similar populations (Ernst, Williams, Clark et al., 2016; Ernst et al., 2018). Limited evidence of reliability and validity in the contemporary literature exists for this population related to the instrument used for assessing self-regulation; however, it is a subset of the Motivated Strategies for Learning Questionnaire (Pintrich, 1991; Pintrich et al., 1993), which is an established instrument in motivational research.

Academic success was measured using a combination of the Purdue Spatial Visualization Test: Rotations Instrument, grades by the course's learning objectives, and final course grade (Sorby & Baartmans, 2000; Busby et al., 2013; Vogt et al., 2007; Ernst, Williams, Clark et al., 2016). These metrics of academic success, combined with scores on the mental rotation skills test, allowed the team to triangulate among data sources (Sorby & Baartmans, 2000; Sorby, 2007) and to quantify relationships among metrics of academic success.

Student engagement was measured through the Self-Regulated Learning subscale of the Motivated Strategies for Learning Questionnaire available through the fair use act using pre-and post-assessment (Pintrich, 1991; Pintrich et al., 1993; Ohland et al., 2011; Bjork et al., 2013; Nelson et al., 2014).

To examine the effects of the facilitative instructor model on cognitive and affective constructs, the team compared baseline pretest data with posttest data for self-efficacy, mental rotation skills, self-regulated learning, and academic success metrics. Analyses were conducted for students at risk of non-matriculation, students not at risk of non-matriculation, and all students combined. Students at risk of non-matriculation were those who had a GPA less than 3.0. For all analyses, two-tailed significance was determined at the $p < .05$ level.

Results

Pilot tests of the facilitative instructor model occurred over three semesters between 2017 and 2019 at both institutions, with field tests conducted during the 2019 and 2020 academic year. University one had a total of 904 students agree to allow their data to be used in the research described in this study. Participation was spread across three semesters with one pilot and two field tests that included 284, 318, and 302 participants, respectively. University two included 98 participants over two field tests that included 44 and 54 participants in two semesters. It should be noted that although 1,002 students agreed to participate, the tabled values do not add up to this amount due to incomplete or missing data from some students.

Data from pilot and field tests were combined for this analysis. Differences in academic and non-academic indicators were examined in combination with students identified as at risk of non-matriculation and not at risk of non-matriculation subgroups. The analysis tables are organized to demonstrate academic and non-academic outcomes through pre-test/post-test progressions. The paired t-test results show a significant ($p \le .05$, two-tailed) positive impact that active learning modules had on increasing self-efficacy and mental rotation abilities (Table 1). There was also a small but significant decrease in self-regulation among all students between the pre- and post-tests.

The results of subgroup analysis show that students at risk of non-matriculation had significantly higher final exam grades and self-efficacy when tutorial videos were combined with active learning modules than with modules alone (Table 2). Conversely, students not at risk of non-matriculation demonstrated significantly greater self-efficacy and mental rotation ability when the active learning modules were not accompanied by tutorial videos than when they were (Table 3). Comparing subgroups in terms of academic success, self-efficacy, self-regulation, and mental rotation ability shows no significant differences in the level of impact from facilitative instructor modeling using active learning modules (Tables 4 and 5).

Table 1
Impact of Active Learning Modules on Self-Efficacy, Self-Regulation, and Mental Rotation Ability at Both Universities

		Pre-Test		Post-Test					
	n	**Mean**	**SD**	**Mean**	**SD**	**Diff**	***t***	**df**	***p***
Self-Efficacy	633	51.89	20.21	**74.67**	26.65	22.78	20.61	632	**< .001†**
Self-Regulation	638	**4.36**	0.64	4.25	0.72	-0.11	3.43	637	**< .001†**
Mental Rotation	641	5.73	2.18	**6.21**	2.38	0.48	4.76	640	**< .001†**

† $p < .001$.

Table 2
Comparison Between Modules Only Versus Videos and Modules for Students At Risk of Non-Matriculation

	Modules Only			Videos & Modules						
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**Diff**	***t***	**df**	***p***
Self-Efficacy[a]	110	68.27	22.48	129	**74.39**	19.17	6.16	2.29	237	**.023***
Self-Regulation[a]	110	4.29	0.72	129	4.16	0.70	-0.13	1.47	237	.144
Mental Rotation[a]	111	6.12	2.51	129	6.39	2.27	0.27	0.88	238	.382
Final Course Gr.	193	86.44	14.66	207	88.83	10.64	2.39	1.88	398	.062
Final Exam Gr.	190	82.05	13.72	206	**85.33**	9.47	3.27	2.78	394	**.006****
Final Project Gr.	193	87.00	21.48	207	89.83	17.15	2.83	1.46	398	.146

[a] Values are from the posttest.
* $p < .05$, ** $p < .01$.

Table 3
Comparison Between Modules Only Versus Videos and Modules for Students Not At Risk of Non-Matriculation

	Modules Only			Modules & Videos						
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**Diff**	***t***	**df**	***p***
Self-Efficacy[a]	144	**79.08**	18.5	162	72.8	19.7	-6.27	2.86	304	**.005****
Self-Regulation[a]	145	4.30	0.73	162	4.21	0.68	-0.09	1.06	305	.291
Mental Rotation[a]	146	**6.87**	2.22	162	6.26	2.29	-0.61	2.37	306	**.019***
Final Course Gr.	243	90.41	10.03	234	89.31	9.21	-1.10	1.24	475	.215
Final Exam Gr.	241	85.97	12.17	234	85.11	11.75	-0.86	0.78	473	.434
Final Project Gr.	243	90.77	15.93	234	90.32	12.07	-0.46	0.35	475	.724

[a] Values are from the posttest.
* $p < .05$, ** $p < .01$.

Table 4
Comparison of Not At-Risk and At-Risk Subgroups in Terms of Academic Success

	Not At-Risk (n = 234)			At-Risk (n = 207)						
	Mean	**Grade %**	**SD**	**Mean**	**Grade %**	**SD**	**Diff**	***t***	**df**	***p***
Final Course Gr.	2.37	90.89	9.95	2.20	90.72	13.05	-0.2	0.16	439	.438
Final Exam Gr.	0.26	85.31	11.54	0.36	85.41	11.09	0.1	0.09	439	.536
Final Project Gr.	2.36	91.68	12.22	0.49	89.81	16.28	-1.9	1.37	439	.085

Table 5
Subgroup Posttest Analysis of Self-Efficacy, Self-Regulation, and Mental Rotation

	Not At-Risk (n = 162)		At-Risk (n = 129)					
	Mean	**SD**	**Mean**	**SD**	**Diff**	***t***	**df**	***p***
Self-Efficacy	72.80	19.70	74.39	19.17	1.59	0.69	289	0.49
Self-Regulation	4.21	0.68	4.16	0.70	0.05	0.65	289	0.52
Mental Rotation	6.26	2.29	6.39	2.27	0.13	0.48	289	0.63

Discussion

Within an introductory engineering graphics course, facilitative instructor modeling through the use of active learning modules had a positive impact on self-efficacy, academic success, and mental rotation ability. When broken down into the sub-groups of students at risk of non-matriculation and those not at risk of non-matriculation, evidence shows that both groups progressed; however, there was no significant difference in progressions between the groups when receiving supplemental material available outside of in-person course time.

The results provide evidence that supplemental material in the form of active learning modules and additional videos positively impacted the self-efficacy and indicators of academic success (Final Course Grades, Final Exam Grades, and Final Project Grades), including the mental rotation abilities of students in an introductory engineering course. Therefore, active learning modules contribute to elements of student success in engineering since these elements are identifiers of success and cognitive engagement of students in engineering and other STEM fields.

Results of mental rotation scores support that spatial visualization, which is a valuable skill in technology and engineering education, is a skill that can be enhanced through active learning modules. By identifying supplemental materials which include real-world applications of classroom content and provide additional practice available to students outside of in-person course time, student 3D modeling self-efficacy increased, and engineering-related skills advanced. The modules also offer a mode of autonomy for students due to their flexible availability through an accessible online learning management system. Such aspects of demonstrated real-world applicability and student autonomy in the learning process can be incorporated into technology and engineering education courses to promote an increase in self-efficacy and academic success. An instructor providing supplemental materials and support of autonomy within self-regulation, as in Zheng et al. (2020), demonstrates that active learning modules can reduce the stress of students and enable deeper engagement with course content.

Many institutions and technology and engineering education programs aim to encourage and foster students' success within their programs. To promote students' success in engineering or other STEM fields, programs can model the use of active learning modules through a facilitative instructor model and other supplemental materials in curriculum development and student support resources. Supplemental materials can be developed in the form of self-paced active learning modules that enhance student learning of how content from the classroom applies to real-world scenarios.

Encouraging student success through the use of effective supplemental material can better prepare students to function in 21st century society in addition to STEM and non-STEM careers. Students who are least likely to succeed or at risk of non-matriculation in technology and engineering education or other STEM fields can benefit from the application of supplemental learning materials. Providing resources to encourage autonomy as well as the improvement of self-efficacy, academic success, and mental rotation ability can lead to the success of students at risk of non-matriculation.

Improving the performance of students at risk of non-matriculation benefits the STEM industry by establishing a larger prepared workforce. Additionally, since many students at risk of non-matriculation are traditionally in underrepresented groups, including students of color and those who identify as female, enhancing performance through active learning modules and other supplemental materials can lead to not only their success but also a more diversified STEM field. Similarly, studies have demonstrated that incorporating active learning within curricula can level the playing field by enhancing the performance of underrepresented students and the inclusivity of courses (Miller et al., 2021; Theobald et al., 2020). While the study in this article highlights improving academic success and providing support for autonomy, other studies have identified how active learning can enhance the community aspect of courses, enhancing the learning experience for participants (Ricks et al., 2014). According to Ricks et al. (2014) and Theobald et al. (2020), active learning modules provide a flexible avenue for accessing content and using course time as a collaborative time to practice the application of course content. Active learning can increase students' final course grades in classes aside from engineering, such as in Calculus courses (Miller et al., 2021) and can also narrow achievement gaps in passing rates of underrepresented students (Theobald et al., 2020). Utilizing active learning can support students' interaction with course content while also providing a social system through collaboration, therefore allowing for an increase in retention as discussed by Xu (2016).

The model also encourages students' autonomy because it opens the opportunity for students to complete the active learning modules on their schedule in a location of their choosing. This flexibility can reduce stress, as identified by Zheng et al. (2020), and therefore increase success. Since the active learning modules are provided through a facilitative instructor model that provides elements of support in autonomy, the actions of student autonomy and self-regulated learning are promoted even though there is no identifiable progression of self-regulation. Applying active learning modules enables students to practice elements of self-regulated learning while also establishing content knowledge, self-efficacy, and academic success in introductory engineering graphics or related technology and engineering education courses.

Although the present study shows that a facilitative instructor model supports the advancement of 3D modeling self-efficacy beliefs, mental rotation skills, and academic success, there was a decrease in self-regulation demonstrated in this study. It is possible that as the semester progressed, external variables played a role in students' lives that their self-regulation decreased. Due to self-regulation being a self-directed process as described by Pintrich (1999) involving "planning, monitoring, and regulating," it is possible that curated materials can reduce opportunities for students to plan (e.g., setting their own goals and analyzing the task), monitoring (e.g. questioning areas of improvements, and regulation (e.g., self-correcting their thinking or behavior based upon performance and feedback). Further explanations for a decrease in self-regulation are supported by Zheng and Zhang (2020, p. 7) where it is stated that "self-regulation is dynamic, thus changeable while working on a task."

Limitations of this study include the content area in which this study is applied. While engineering graphics is a vital source of technology and engineering skill development, it will be beneficial to evaluate how a facilitative instructor model utilizing active learning modules can impact other areas of technology and engineering education. An additional limitation is that not all metrics possess an equal number of responses which can enable a balanced comparison of results. Further limitations include the characteristics of the institutions at which the study was applied. Technology and engineering education communities vary across the nations. The way students react at these two universities may differ from how students at other institutions react to the same model.

Conclusion

Whether a student is at risk or not at risk of non-matriculation, evidence shows a significant impact on self-efficacy and mental rotation skills when using a facilitative instructor model of applying active learning modules in an introductory graphics engineering course. When instructors use a facilitative instructor model in providing content material through active learning modules in an online learning management system, course time can be used for enhanced learning opportunities in engaging with the Standards for Technological and Engineering Literacy. This information can be enveloped in the development and refinement of technology and engineering and other STEM education program areas to support student success further.

Additionally, active learning modules support the increase of self-efficacy and academic success, including the mental rotation abilities of students at risk of non-matriculation. Establishing firmer support for student success can lead to increased diversity of engineering and STEM graduates leading to a more diverse engineering or STEM workforce. Future studies might investigate the impact of active learning modules in other engineering or STEM fields, identifying other areas impacted by active learning modules and a facilitative learning model. Through active student learning in engineering and other STEM disciplines, students can increase their engagement in the learning process and further develop their self-efficacy and ability in STEM skills to increase success in their education programs.

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