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A Mentorship and Module-Based System to Ensure the Adequacy of Required Prerequisite Knowledge for Enhancing Student Success in Engineering

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WIP: A Mentorship and Module-Based System to Ensure the Adequacy of Required Prerequisite Knowledge for Enhancing Student Success in Engineering

Abstract

Attrition and retention are issues that have been the subject of ample pedagogical studies. For engineering, nationwide student retention rates fall anywhere in the range of 40% - 60%, with many students capable of completing an engineering degree switching to a different one. National studies consistently show that after junior year, the number of students either switching to non-STEM majors or dropping out from college is around 56%. This negatively impacts college retention and graduation rates and causes lasting negative consequences such as student loan debts for drop-out students. Statics and Dynamics are fundamental courses in the critical graduation path of almost every engineering major. A common complaint among Statics and Dynamics professors is the need for the basic math and physics (MAP) prerequisite knowledge in newly enrolled students that is required for the successful completion of these courses and advancement in their majors.

In this ongoing study, the researchers developed a two-prong approach to address the above and increase student success. The approach involves 1) Creation of a specific set of modules specifically targeting the MAP prerequisite knowledge needed by the students to be successful in Statics and Dynamics courses and 2) Mentoring of "at-risk" students by student mentors (SMs) starting from the second week of the semester. The developed modules include pretests and targeted interventions based on each student's knowledge needs. In addition, sets of videos, practice problems, and further assessments are provided to ensure that all students have the same baseline knowledge and the tools to be successful in these courses. In addition, assigning students to SMs also helps students with their social integration into the university environment. These close knits serve as a "Learning Community" providing opportunities for a deeper understanding of the material being learned and closer interaction with fellow participants as well as helping them navigate all the university facilities and opportunities. Faculty also motivates the students to keep attending remediation by periodically sending encouraging automated messages as they progress and improve their standing in the class. This paper describes the authors' efforts in developing and implementing the above approach, along with some preliminary results.

1. Introduction

Due to the well-documented success of first-year experience initiatives all around the country, there has been a good amount of effort to study and create programs specifically designed for first-year students [1]–[5]. However, less research has been dedicated to increasing retention in engineering majors during the second and third years. One possible reason that has been very well documented in extensive research is the students' lack of adequate previous knowledge. Students often struggle to balance their academic and social life. Social integration-related challenges, lack of motivation, and lack of a sense of "belonging" also play a significant role in the abandonment of STEM disciplines [6]–[11]. In such situations, a support system of peer mentoring students may help students overcome these challenges. A network of fellow students can actively help second- or third-year students struggling to cope with the academic pressures of the STEM fields and navigate through all the university facilities and existing help. Such peer support can motivate these struggling students in their academic pursuits and help them better understand course materials while sharing their personal insights and creating a learning community [11].

Engineering Statics and Dynamics professors usually complain that students enrolled in their courses do not have the adequate mathematical and physical (MAP) prerequisite knowledge they should have acquired in previous classes. They were previously tested and approved on those topics, now for no apparent reason they either do not remember or cannot make adequate connections between what they have studied and the new engineering application. This often results in the failure of the students, not because of new course concepts but due to the MAP they previously "learned." Ambrose et al. established that "a student's previous knowledge can help or hinder learning" [12]. If students' prior knowledge is good and they understand how to apply it to new situations, then their foundation is very strong. However, this happens only in a minority of cases. In most cases, the student's previous knowledge is completely forgotten, nonexistent, or even worse, they learned it wrong and advanced to future courses. The increase in transfer students accentuates the variability in the background knowledge and non-uniformity in the MAP prerequisite coverage, making this issue more pronounced.

Consequently, it has become even more important to start the Statics and Dynamic courses from a common ground regarding the students' MAP required prior knowledge. Several researchers have investigated how to address these deficiencies. Shryock et al. prepared an instrument based on the required prerequisite calculus knowledge for the Statics and Dynamics courses [13]. This assessment was applied to the incoming students to inform the instructors what was the baseline of their students and where they had to dedicate more time to review previous knowledge. In addition, the researchers posed a question for future research to link the results of the pre-assessment and their performance in the course material. Laman and Brannon investigated the need to integrate prerequisite materials in a structural design of foundations course utilizing electronic media [14]. Velegol et al. provided online modules for prerequisite topics for online or flipped courses. Their results showed an improvement in the students' knowledge of these prerequisites after watching the videos [15]. Weiss and Sanders created a Review Video Library (or RVL) to help students review the prerequisite topics for several courses in the mechanical engineering curriculum. Survey results showed that undergraduates who watched the review videos felt that they improved their knowledge in that subject [16]. In another study, researchers opted to remove any prerequisite review from the course through an online series of videos and assessments and compared it with previous in-class reviews. Their results showed that the effectiveness for both (online and in-class) was similar, but students preferred the online review [17]. In another study, Chauda and Recktenwald introduced concept review quizzes to identify students' prerequisite knowledge deficiencies and measured improvement after a concept review intervention for several Mechanical Engineering Courses. The method showed a slight improvement in the course for some students. However, the authors could not identify the cause for the grade distribution on the prerequisite quizzes [18]. Similarly, Goold studied and linked physics and mathematics background with the success of engineering students [19].

More recently, Zaurin et al. investigated the impact of incorporating an Adaptive Learning Module in Statics to review the mathematical prerequisite knowledge the students need [20]. Two multivariate models were estimated: (a) pass/fail outcome and (b) grade outcome (classified in 5 levels) using a multivariate ordered logit model. In these models, the effects of adaptive learning methods and other factors on the student's final grade were captured. The model results offer several important findings. First, the pass/fail model clearly highlights the role of the modules in increasing pass rate while controlling for all other student attributes. Also, the adaptive learning module had a positive effect for White American and Hispanic students, but no correlation could be found with other groups due to very small sample sizes. In addition to the model results generated, the students' perception was that reviewing the prerequisites helped them to better perform in the class.

In this paper, the authors show their attempt to develop and implement a plan to decrease the attrition rates of second- or third-year STEM engineering students and to increase the graduation rates through a planned set of interventions in the two most critical fundamental sophomore courses; Engineering Analysis Statics and Engineering Analysis Dynamics Both these courses are critical in the graduation path of almost every engineering major and are important prerequisite classes as they lay the foundation concepts for advanced courses higher up in the curriculum such as Solid Mechanics, Mechanics of Materials, Structural Analysis, Mechanical Vibrations, Feedback Controls and Intermediate System Dynamics. Student failure rate (DFW) in both courses is typically high at the University of Central Florida, 27% to 37% for Statics (causing approximately 450 students to fail per year) and around 21 to 37% for Dynamics (Approximately 250 to 300 students fail per year). High failure rates have adverse consequences such as delay in many students' graduation timeline, dropping from engineering majors and thus reducing retention, progression, graduation rates. The causes for these high failure rates are diverse. One of the fastest to address refers to the much needed and required previous knowledge. To address these issues, in this study, the authors introduced a module and mentoring-based intervention on required prerequisite math and physics knowledge in the fundamental engineering courses of statics and dynamics. The goal is to assess the effect of these interventions on student performance and retention in these two fundamental engineering courses.

2. Methods

At the time of this ongoing study, two faculty members (one for Statics and one for Dynamics) applied the procedure described below each in one course during the Fall 2022 semester. The researchers created an introductory learning module (Figure 1A) in Canvas (Webcourses) to be completed by students within the four weeks of classes. This learning module started with a pre-baseline assessment quiz that was administered to the entire class in the first week to check all students' background math and physics knowledge. Low-performing students in the baseline quiz were "at risk" of failing the class and were placed in a group entitled Remediation Group (RG). For the next three weeks, the RG students were assigned to a Student Mentor (SM) and were encouraged to attend a weekly two-hour Remediation Session (RS) conducted by the SM (Figure 1B) for those three weeks. Even though the remediation was not mandatory due to internal university policies, the researchers repeatedly described the benefits of attending via class announcements and automated messages to the targeted students. The SMs not only helped the

RG students learn the required prerequisite knowledge for the course, but also informed, helped, and guided the RG students to navigate through the university facilities and opportunities, thus easing their social integration into the university environment. Each SM was responsible for approximately fifteen students per session (75 per SM). In addition to this, the RG students were required to review several math and physics videos (Figure 1C) in the learning module created by the instructors that included explanations and step-by-step solved examples on prerequisite topics. At the end of the learning module, after watching the prerequisite math and physics videos and attending the RS for three weeks, the RG students completed a second post baseline assessment quiz to check their score improvement. Based on the post quiz score improvement, the RG students had the option to continue or leave the RS, while the low-performing students continued with the sessions. For the remainder of the semester, the sessions focused on course-specific content learning. All RG students along with other students were closely monitored for class assessment performances throughout the semester.

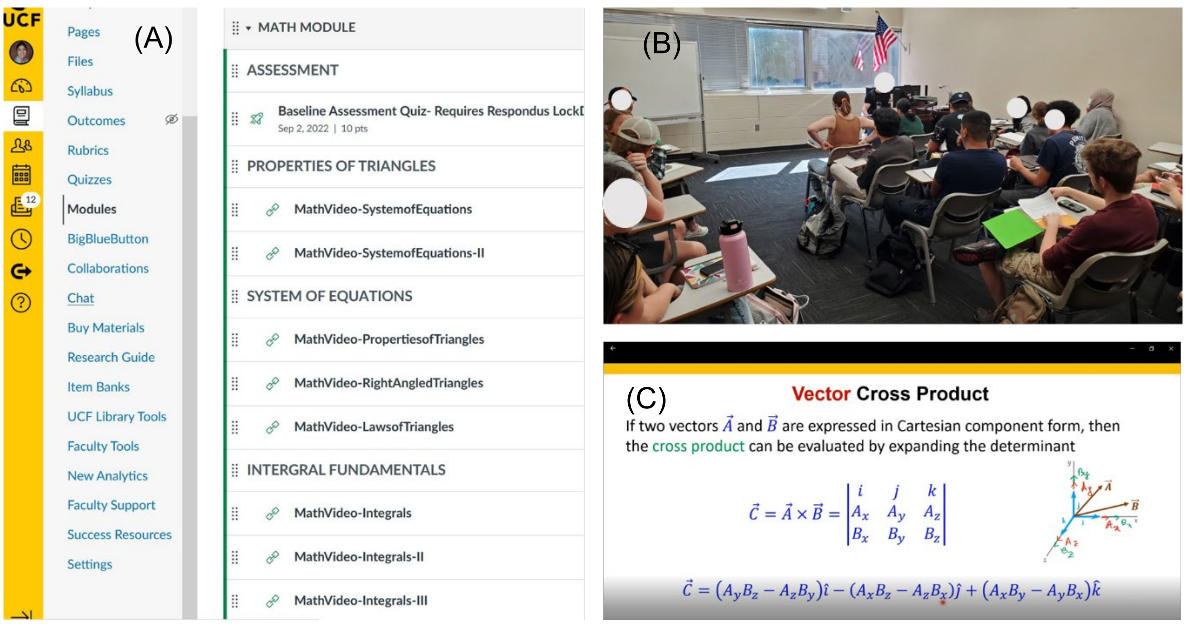

Figure 1: Images of interventions (A) the learning module, (B) remediation sessions conducted by SMs and (C) instructor created math video used in this study.

Figure 2 shows a flow chart of the sequence of activities in the module and mentorship-based intervention used. The specific research questions that are being investigated in this study are the following:

1. What effect does a Webcourses module and mentorship-based system have on student confidence on success in the Statics and Dynamics courses?
2. Does the above intervention influence student success and student retention in the Statics and Dynamics courses?

To investigate the first research question on student confidence and student satisfaction, an IRB approved ungraded end-of-course survey was given out to all RG students who participated in the module and mentorship-based learning in both Statics and Dynamics courses. To evaluate the effect of the module and mentorship-based system on student success and retention, the performances of the RG students in Statics and Dynamics were compared to that of the regular students in these courses.

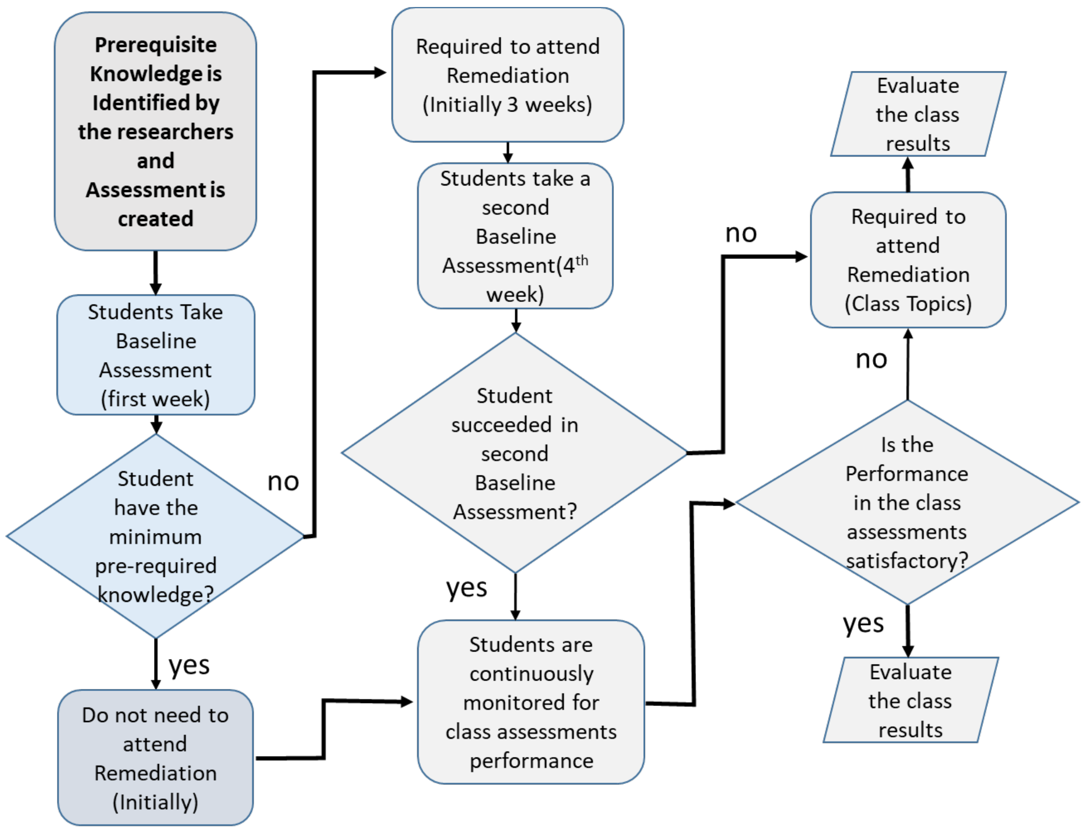

Figure 2: Flow chart of the sequence of activities implemented for both the Statics and Dynamics courses.

3. Results

3a. Student Success and Retention

The effect of the module and mentorship-based learning system on student success and retention was evaluated by comparing the cumulative performances of students in both Statics and Dynamics courses. In the Statics class, a total of 94 students did not require or attend remediation while 53 of them did. Figure 3A compares the grade distribution of the students attending the remediation sessions (RG) with that of the regular students (non-RG) in the Statics class. As observed in Figure 3A, the percentage of A's was higher for the students that didn't need remediation; however, the RG students scored a higher number of B's (%) and C's (%). In addition, there was a remarked reduction in the D's & F's in the remediation group compared to the non-RG students.

In the Dynamics class, a total of 200 students passed the initial baseline quiz and did not require remediation, while 60 students needed remediation. Of the 60 students that needed remediation, only 75% of the students joined the remediation group and attended sessions, while 25% did not attend sessions. Figure 3B shows the comparison of grade distribution between the students attending the remediation sessions (RG) and all non-remediation students (regular) in the Dynamics class. From figure 3B, an improvement in the performance of the students in the remediation group is evident (similar to the Statics class). The number of students scoring B's or C's is 5% - 7% higher for the RG students compared to the regular students. Additionally, the percentage of students scoring D's or F's is nearly similar for the RG and non-RG students, with only a 1% difference in terms of the total number of students registered in class.

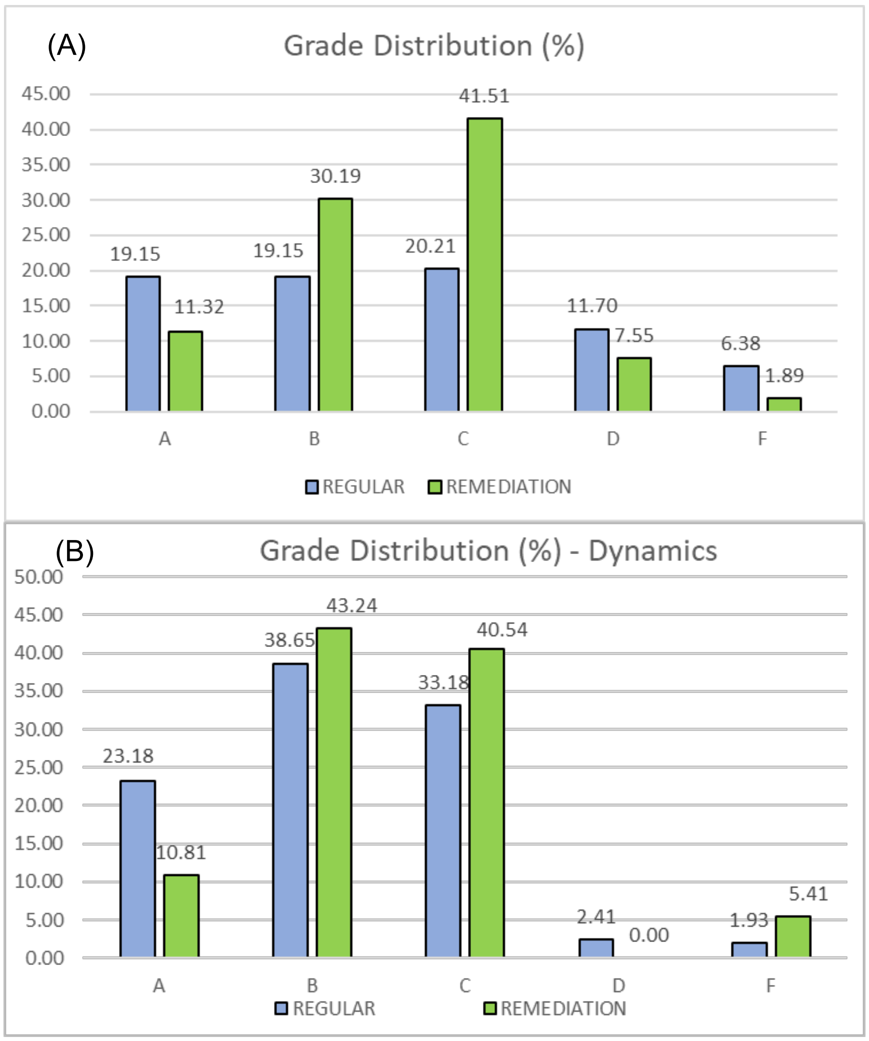

Figure 3: Comparison of grade distribution for RG and regular students in (A) Statics and (B) Dynamics class

Figures 4A and 4B show another comparison of the success rates of the students in the Statics and Dynamics classes to assess the effect of the module and mentorship-based learning intervention. Three groups are shown in both figures: students that needed and attended remediation, regular students that didn't need remediation, and students that needed remediation but didn't attend. For the Statics class (Figure 4A), the effect of the remediation session was the most significant, where the first group showed the biggest success rate (83.02% success) and the last the lowest (54.44%), but very comparable with the second (58.51%). Figure 4B shows the results of the three groups in the Dynamics class. In the Dynamics class, the success rate of the regular group was slightly higher (88.39%) than the remediation group (81.41%) but were still comparable. However, the success rate of the students in the third group, which is students who needed remediation but did not attend, was much lower (68.75%) than the first two. These results are a positive indicator of the effect of the mentorship-based learning intervention on student success.

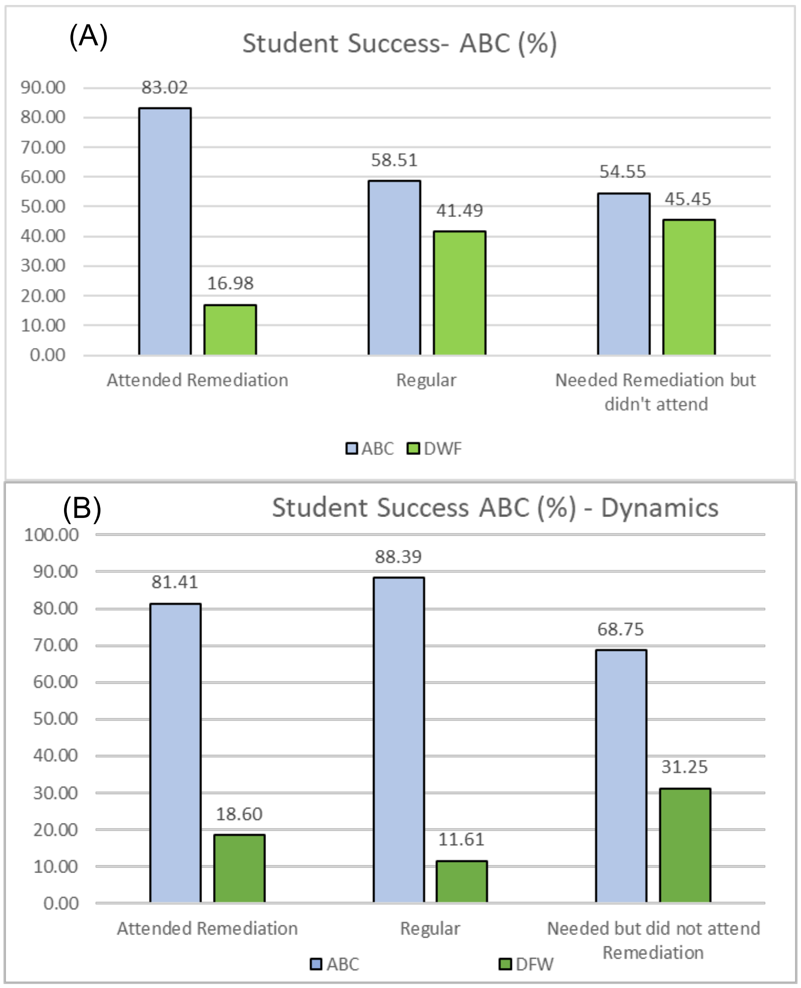

Figure 4: Comparison of student success for RG and regular students in (A) Statics and (B) Dynamics courses.

3b. Student Satisfaction

Student satisfaction with the module and mentorship-based intervention was gauged through an IRB-approved ungraded survey administered in both courses. The survey responses were positive for the remediation-based intervention and are detailed in Figure 5. In addition, 63 -

68% of the students felt that the baseline assessment quiz helped them gauge the prerequisite knowledge necessary for these classes.

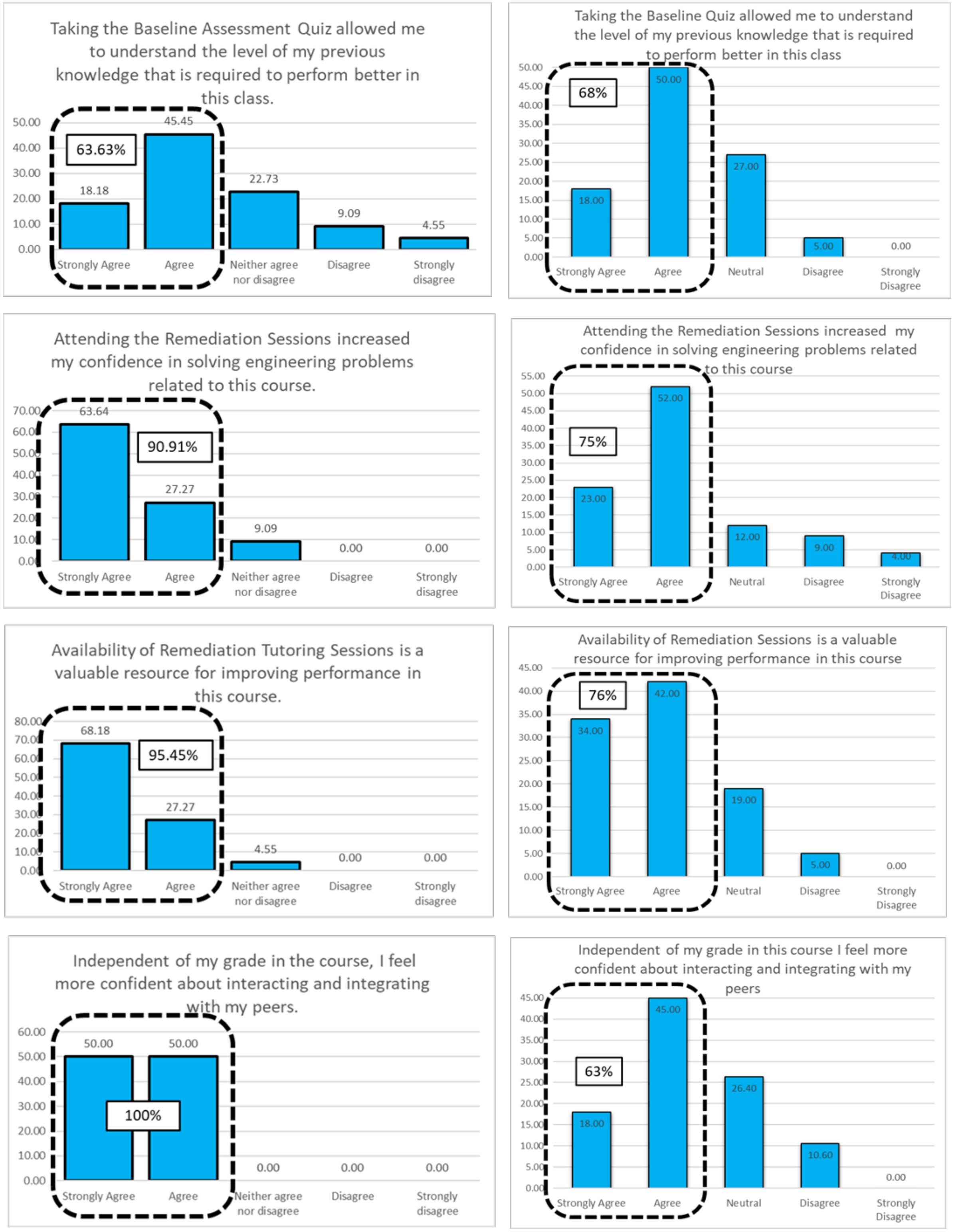

Figure 5: Student survey responses for the interventions used in this study for the Statics (left) and Dynamics (right) courses.

Additionally, the majority of the students (63-100%) agreed that the sessions improved their confidence in solving engineering problems related to the courses and integrating and interacting with their peers. Similarly, 75 -91% of the students in both Statics and Dynamics perceived the remediation sessions as valuable resources in improving their performance in these courses.

4. Conclusion and Future Work

In this study, the authors report their preliminary results of a mentorship and module-based system implemented in the undergraduate courses of Statics and Dynamics to enhance student success and retention in these courses while targeting the MAP prerequisite knowledge needed by the students to be successful in these courses. Data shows that students attending the remediation sessions as part of the mentorship-based intervention received better cumulative grades in both courses. Students attending the remediation sessions obtained a higher number of B's and C's (ranging from 12% to 30%) and lower D's and F's in both courses. Additionally, the performances of the students who needed and attended remediation in both classes were 14% to 29% higher than those of students who needed but did not attend remediation. Student survey responses for the interventions were also positive. Overall, the implementation of the mentorship and module-based system in Statics and Dynamics courses was successful. Future work will focus on improving the modules and remediation sessions to have higher success rates in these courses and on extending these interventions to other higher-level courses in the engineering curriculum.

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