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Abstract

The work presented here aims to address a critical knowledge gap in the engineering education literature through a preliminary study meant to determine if active learning is more effective when students with learning disabilities are first front-loaded with information. These preliminary findings aimed at not only determining if the work should be continued in the future, but also at evaluating if frontloading resulted in: (1) increased student engagement and (2) increased learning effectiveness. Preliminary findings conclude that students with documented, and undocumented, learning disabilities did have an increased understanding of the course content as a result of combining frontloading and active learning.

Introduction

The benefits of active learning, one of the latest trends and research foci in engineering education, to the average student are well-understood, supported by research, and endorsed by numerous agencies [1]. However, active learning can be a challenge for students with learning disabilities (dyslexia, dyscalculia, dysgraphia, visual and auditory processing deficits, ADHD, nonverbal learning disabilities, and many others), and there is little supporting evidence that it is inclusive to these individuals [2].

Learning disabilities affect a person's executive functioning skills and their ability to receive, store, and process information, as well as retrieving and communicating information [3]. A common characteristic found in students with learning disabilities is that they require extra time to assimilate information from a lecture. Consequently, an active learning activity can present additional challenges when it requires immediate recall of new information.

As the demand for engineers in the U.S. workforce consistently outpaces the number of engineering graduates across the nation, there has been concerted effort to attract more students to the fields of engineering. As the search for engineering students expands, the number of students with learning disabilities in engineering programs, documented and undocumented, increases [3]. Yet, within these programs students with learning disabilities are often a forgotten and underserved group, even though they are the third largest minority behind those of Latino origin and African Americans [4]. Therefore, there is an immediate need to understand the potentially damaging effects active learning can have on this group of students who already face challenges in the classroom [5, 6] and are underrepresented in STEM education.

Strong evidence exists in post-secondary education research that active learning is a beneficial teaching method for the average student. Strong evidence exists in primary and secondary education research that frontloading students with learning disabilities aids in the learning process [7, 8, 9]. While literature of frontloading in post-secondary education is deficient, it is hypothesized that by combining these methods, frontloading and active learning, the resulting hybrid will become a more beneficial teaching method for students with learning disabilities.

A preliminary study was conducted in Fundamentals of Engineering (MCET 101) to determine if active learning is more effective when students with learning disabilities are first front-loaded with information. Fundamentals of Engineering is a core course in the Manufacturing and Mechanical Engineering Technology program at the Rochester Institute of Technology (RIT). To increase student engagement and retention, active learning has been a key component of the Fundamentals of Engineering course, a course typically taken by first semester freshman. Since the course is very much hands-on, and the first year can be difficult for students, it was selected to be restructured to include frontloading.

What is Frontloading?

Frontloading, also known as pre-teaching, is a Universal Design for Learning (UDL) strategy. Frontloading is intended to move away from lecture styled teaching and incorporate other, more authentic and engaging strategies to introduce and scaffold the material for students [10, 6, 9]. During this process, students are intentionally exposed to vocabulary, concepts, and skills that they will learn later in the lesson. Previous work has shown frontloading assignments to be critical for students with certain learning disabilities because it allows them to be exposed to the context of the lesson ahead of time, and therefore building student motivation and confidence during the later lesson [11]. In addition to using frontloading activities as a framework to support and organize student use of new concepts and strategies, frontloading can also be used to assess student conceptual, procedural, or general knowledge that may be necessary for success on subsequent tasks [12].

Research has found that student comprehension is higher when an instructor consistently utilizes a minimum of two front-loading strategies for each lesson: (1) one to connect to prior knowledge and form predictions; (2) the other to pre-teach the essential vocabulary for the lesson [11]. When used properly, frontloading material helps to build student motivation and interest in a new topic, activates or builds necessary knowledge for dealing with said new topic, and serves as a template to assist students through learning of the new topic [12].

When working with students with learning disabilities, research recommends accommodations such as, using multiple senses, participating in hands-on and lab experiences, and using more demonstrations by the instructor [5]. All of which fit perfectly with frontloading activities. Numerous examples of how to frontload information exist in primary and secondary education research and will be adapted in this post-secondary study. Some examples of frontloading techniques are: vocabulary study charts, anticipation guides, concept organizers, KWL charts, group discussions, brainstorming, aligning themes, opinionaire, surveys, and real-life examples [11, 10, 12].

How is the Course Front-loaded?

Students with and without learning disabilities learn in many different ways (visual, hands-on, verbal, interpersonal, intrapersonal, etc.). When conducting research on frontloading, it is important to confirm students are being taught in a way that matches their specific learner profile. Therefore, to ensure students’ learner profiles were being met, students first completed a learning-style questionnaire. This information was used to develop frontloading materials and implementation strategies that best fit the students and their needs.

Research has shown the multi-model frontloading to be most beneficial for all students, which provides opportunities throughout the lesson to accommodate all types of learners, [9]. With this in mind, frontloading materials were developed, adapted, and refined by the Fundamentals of Engineering instructional team together with the Disability Services Office and a special education expert.

At the start of the Fundamentals of Engineering course, the concept of frontloading and the basics of this study were explained to all enrolled students. In addition, students were made aware of the frontloading experiences they participated in throughout the semester. General front-loading techniques were used throughout the course, such as incorporating three of the five senses in every lesson - students hear, see visually what is being said, and work/feel with what is being said; using large print on PowerPoint, with few words per slide and many visuals; having opportunities for students to work with peers in groups; brainstorming; KWL charts; and hands-on activities. Multiple frontloading techniques were used so that if students were bored in one context, they would be motivated in another. Detailed examples of some of the frontloading techniques used in the course are discussed next.

One of the most fundamental concepts taught in Fundamentals of Engineering is the engineering design process. The instructors agreed that the pumpkin chunkin' competition would be a great way to determine if students understood and could follow the engineering design process. It was also agreed that frontloading this concept would be critical in the students' success. Therefore the concepts associated with the engineering design process were frontloaded by scaffolding the material through the following steps:

- Class discussion on what goes into a design (drew from previous experiences);
- Lecture using visuals and real-world examples;
- Class activity on what denotes a "good" or "bad" engineering design;
- Class activity on how to complete a decision matrix, with corresponding HW;
- Class hands-on activity with the "Cards to the Sky" competition, reinforcing the engineering design process and understanding customer design specifications; and
- Marshmallow launcher build and competition.

The concepts associated with the engineering design process were intentionally frontloaded to better prepare students for the marshmallow launching project and the pumpkin chunkin' competition. Both projects, marshmallow and pumpkin launchers, were a form of frontloading in terms of doing a prototype model and then going to full-scale.

The concept of teamwork was frontloaded by having students experience the design process with the marshmallow launcher (first project) in a small team of three before receiving a formal lecture on teamwork. After a formal lecture and activity, the students were put into a much larger team of six for the pumpkin chunkin' project. Students had to essentially repeat the marshmallow project, except in a larger team with a full-scale launcher that was capable of firing a five pound pumpkin 100 yards.

The concept of technical writing was frontloaded in Fundamentals of Engineering by scaffolding the content, as described below.

- Project 1 required a one-page summary per team of three;

- Students received a lecture on technical writing;
- Project 2 required a full technical memo per team of six;
- Students completed a peer-review process on their individual Project 3 reports; and
- Project 3 required each individual to create a full technical memo.

The final concepts frontloaded in Fundamentals of Engineering were the software programs taught to the students – Excel, LabVIEW, and MATLAB. The instructors found development of frontloading material for these topics to be the most difficult. As previously mentioned, examples of frontloading are scarce at the post-secondary level. In fact, there are few examples in the literature at even the secondary level. The majority of the literature is focused on how to frontload primary school students. With little literature to serve as a basis, the instructors heavily relied on the experience of the special education expert. The materials used to frontload the software were online tutorials, step-by-step guides, and PPTs with demonstrations.

Assessment

An ideal assessment of the investigation would include an experimental group, students with learning disabilities who are frontloaded, and a control group, students with learning disabilities who are not frontloaded. However, since there is a variable number of students with learning disabilities enrolled each semester, a statistically meaningful sample size cannot be guaranteed. Instead, all enrolled students were frontloaded.

Originally, the authors had planned to gather data via a focus group of students with learning disabilities (historically 10 to 15% of the enrolled students were registered through the Disability Services Office). However, since only one student of the 133 enrolled in Fundamentals of Engineering was registered with the Disability Services Office, focus groups were not possible to use. Instead, the overall effectiveness of the investigation, i.e. impact to student learning and student experience, was assessed via a survey given to all students at the end of the semester.

The preliminary study used a survey where questions were written in the form of statements or questions and students were asked their level of agreement on a 5 point Likert scale from 1 (definitely not) to 5 (definitely yes). The survey also contained free response questions that allowed students to comment on experiences, as well as things they liked or could be improved. It is noted that as this is a preliminary assessment the questions were not peer reviewed. Future work will include an expert review of survey questions. The survey was administered once at the end of the fall 2017 semester. The surveys were approved by the Institutional Review Board (IRB) at the RIT prior to their use. All data was compiled by a neutral party, with instructors receiving a summary report containing no identifiers after the end of the semester.

The given survey asked for general background information about the students, such as name, major, year at RIT, if they're a transfer, and what grade they think they will earn in the course. Students were also asked if they received any accommodations at RIT or in the past (i.e. high school) from the Disabilities Service Office. Additional general questions asked of the students were about their learning style, resources used on campus (tutoring, office hours, etc.), and what their instructors could have done to make them feel more comfortable on campus. These general questions were asked to establish a background of the students. The names were collected to compare responses with actual performance in the Fundamentals of Engineering course. Due to the low number of students registered with the Disability Service Office, part of the study will look at a comparison of student responses regarding the impact of frontloading and how well they did in the course, plus how well they thought they would do in the course. This was followed with questions regarding specific instances frontloading occurred in the course, such as during the design process or technical writing. Another important question asked of the students in the survey was if students saw any of the course material in high school. This is important because this would also be a form of frontloading.

Results and Discussion

The goal of the survey was to determine if the students' learning experience benefited from front-loading course content, and if students found combining frontloading and active learning to be effective. Of the 133 students enrolled in the Fundamentals of Engineering course, 76 survey responses were usable – students responded with their name and gave a response in at least one other field. The demographic of responses were 56 Mechanical, 2 Manufacturing, and 16 Electrical/Mechanical Engineering Technology students, and 4 students from other departments on campus.

Of the respondents, 70 of 76 students were in their first year, first semester at RIT. The remaining 6 students transferred from other departments on campus (Game Design, University Exploration, and Biomed Engineering), or a 2-year university, or were taking the course late in the curriculum (2nd year).

When asked about current or past accommodations through the Disability Services Office, one student of the 76 was enrolled to receive accommodations at RIT. However, 7 students said they received accommodations while in high school.

To ensure the developed frontloaded materials met the students' learning profiles, students were given a learning-style questionnaire. The resulting data, 57 kinesthetic learners, 1 auditory learner, and 19 visual learners, further supported the need for a hands-on and visual approach to frontloading.

The first set of questions, shown in Figure 1, focused on how well frontloading aided the learning process throughout the course of the semester. When asked about the effectiveness of frontloading the design process, more than 75% of students responded with "probably yes" or "definitely yes." When asked about how well frontloading improved the learning of the software programs and technical writing, more than 70% of students responded with "probably yes" or "definitely yes." However, almost 80% of students said they felt more confident in their ability to deliver quality written technical documents. Finally, when asked about how well frontloading in general aided in the learning process, 80% of students responded positively.

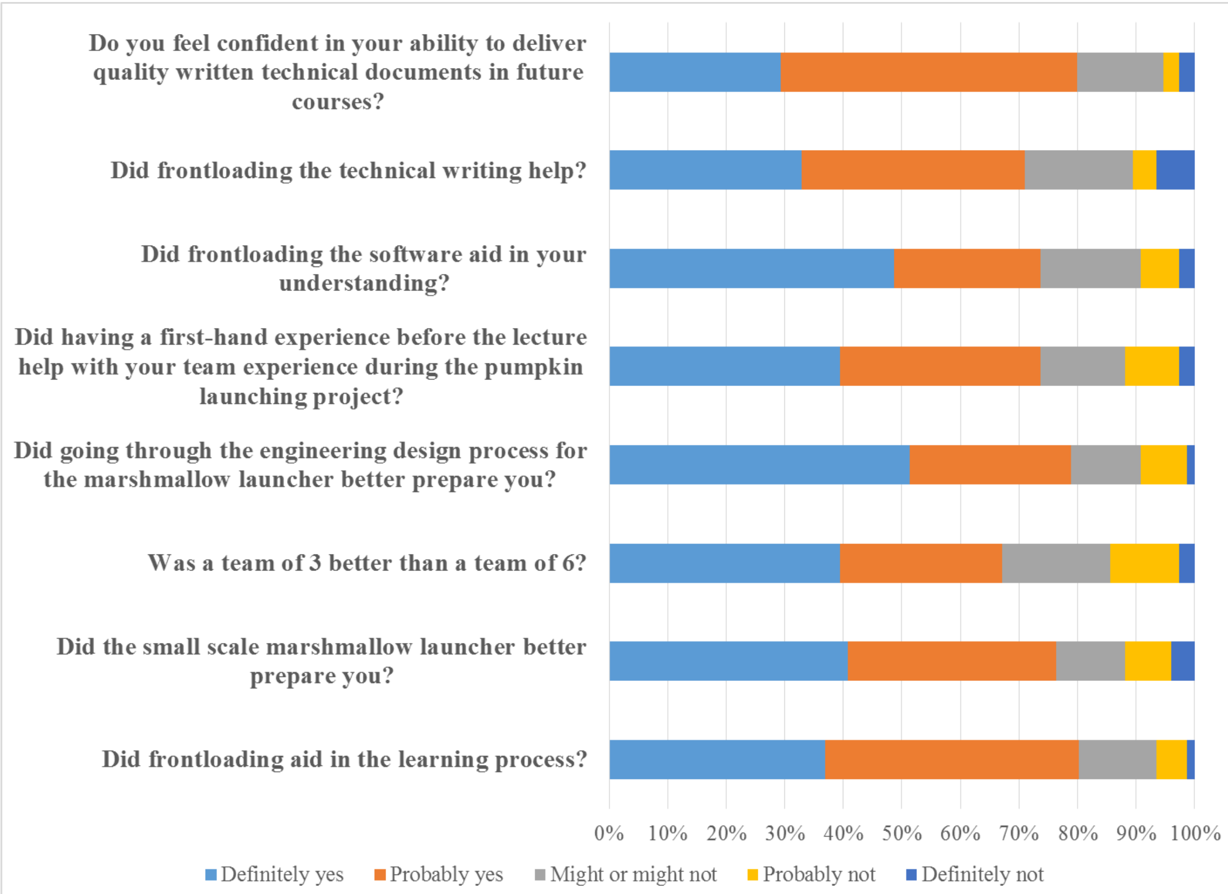

Figure 1: Student responses to how well frontloading aided the learning process.

Of the 76 students who responded to the survey, 31 identified as facing issues or problems academically during the fall 2017 semester. Of these 31 students, 10 did not seek help. Those who sought help used a variety of resources, as shown in Figure 2. The most commonly used resource was one-on-one help from the instructor during office hours. Surprisingly, few students listed seeking out peers or study groups for additional help. A few interesting follow-up questions would be: (1) if these results are true for all students, or a result of the study being focused on first-semester freshmen; (2) if students have ideas on how to encourage study groups for when they have an issue or for frontloading activities; (3) how to better address student academic problems; and (4) if more could be done in the classroom to assist students who may be struggling. Future work should also include identifying students who did not seek help and why.

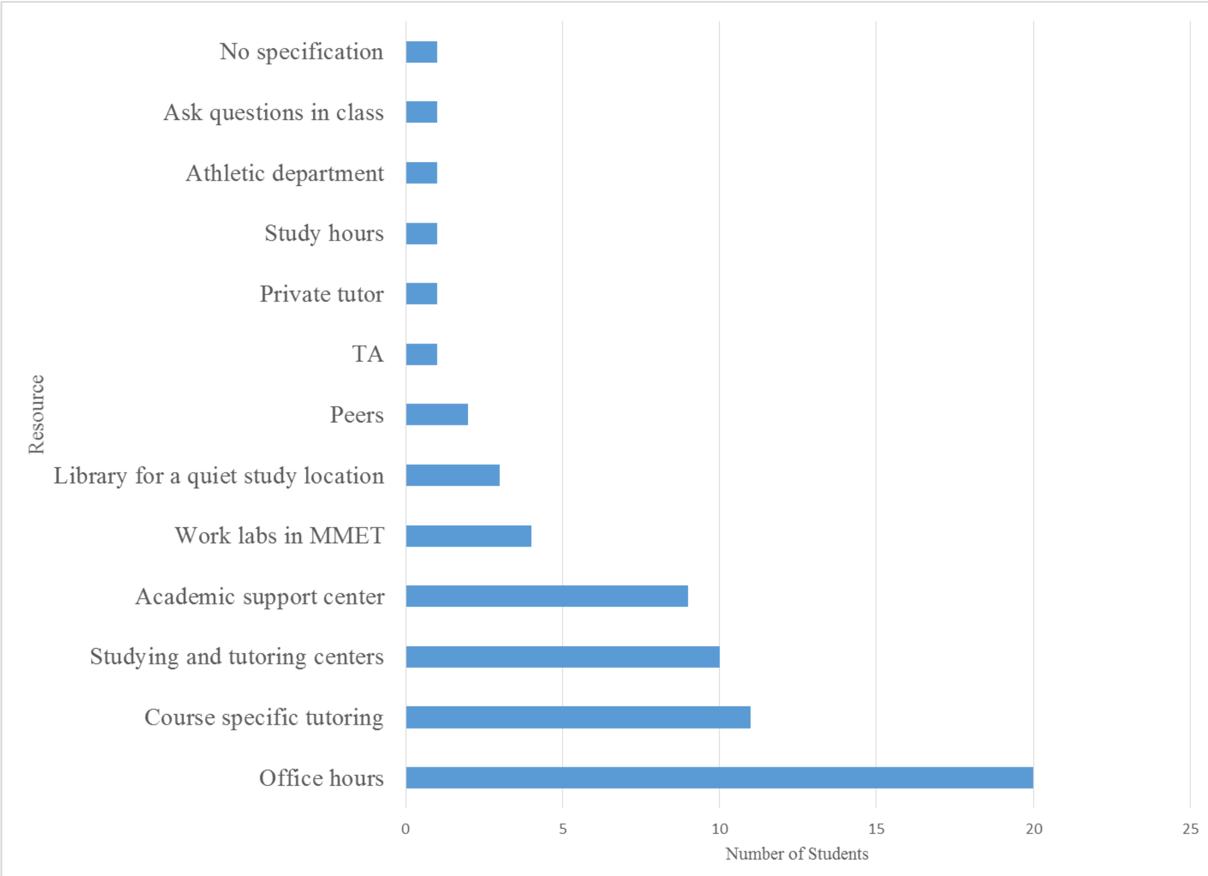

Figure 2: Resources used by students facing academic problems.

When asked about the most effective teaching strategy, shown in Figure 3, 57% of student responses were regarding hands-on activities, projects, and demonstrations. This directly correlates with the results of the student learning-style questionnaire and supports the decision to make active learning a component of the course. However, 36% of students responded with additional strategies ranging from one-on-one instruction to practice and teaching others. This supports the need for diverse methods of engaging students in the learning process, which can be done through a combination of frontloading and active learning.

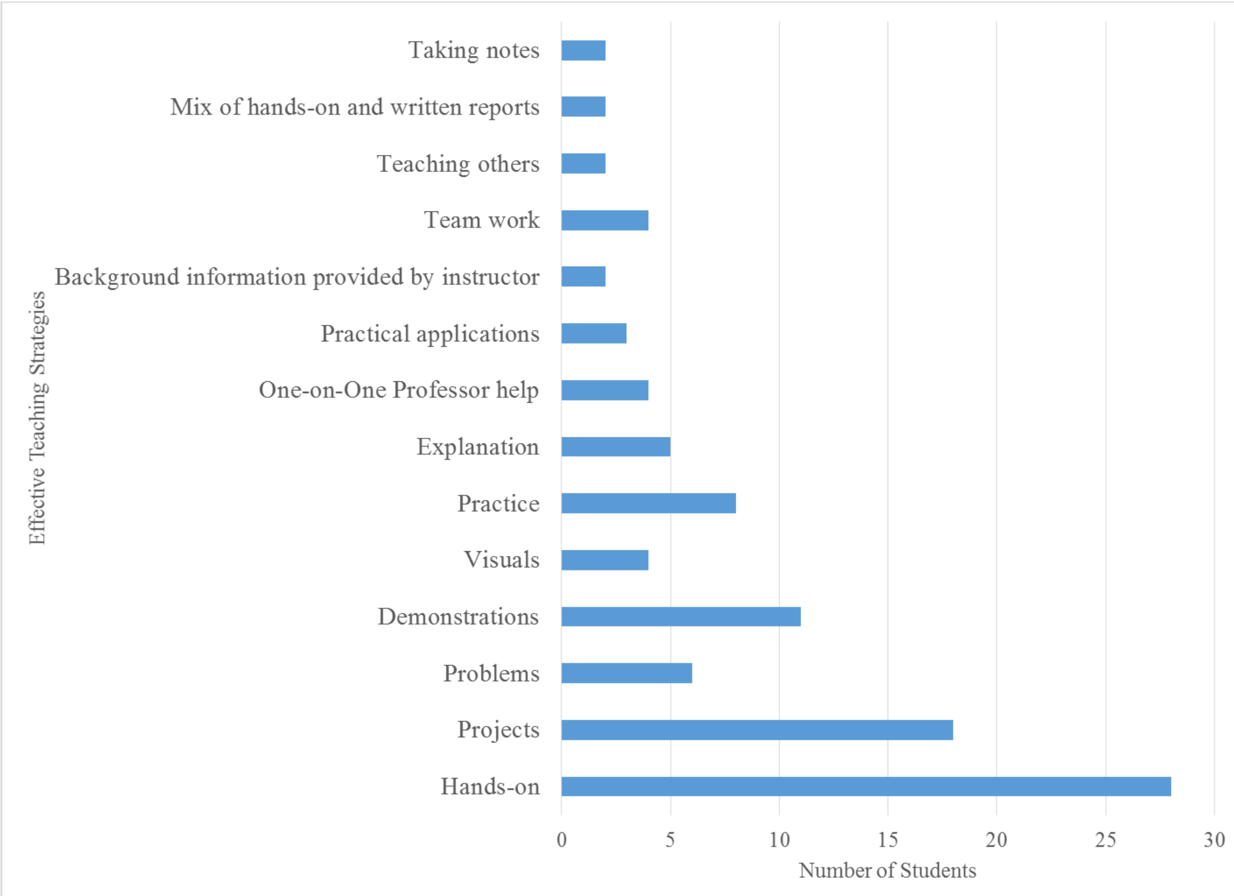

Figure 3: Student responses when asked about the most effective teaching strategy

When students were asked if they had seen any of the topics covered in Fundamentals of Engineering previously (i.e. high school or previous course), over 80% responded that they had, with almost 90% responding that this previous knowledge gave them a deeper understanding of the content when encountered again. The most common topics previously seen were engineering ethics, forces, MATLAB, LabVIEW, and circuits. These resulting topics were surprising to the authors since the majority of the students were first-semester freshmen. A follow-up question would be when, and to what extent, these topics were covered. As part of future frontloading studies, pre-tests could be given at the start of each new topic to determine the students' background knowledge.

Students were asked to consider what factors were most important in designing the course, if they were to design their own Fundamentals of Engineering course. Some of these factors included time of day, class duration and frequency, teaching style, and course content. These free responses, in conjunction with the free responses regarding recommendations to what the instructors could have done differently, could be used to improve delivery of course content in the future.

In response to class duration and frequency, 63% of students specified late morning to late afternoon as an optimal time period for classes. 62% of students responded that meeting for short durations (i.e. 50 minutes) more frequently during the week better suited them then meeting for longer periods less often. In terms of course content, most of the student responses, such as the samples below, pertained to teaching the various software programs.

"Spend more time on the software programs."
"Keep the course hands-on."
"Group the software (Excel, MATLAB, and LabVIEW) together."
"Keep the software programs a part of the course."
"Need a more in-depth understanding of MATLAB."

This was expected as there were few resources on how to frontload content related to software programs. For example, it was determined from the students' free responses that the tutorials were not helpful to all students. A few follow-up questions would be: (1) do the students read the textbook prior to lecture and what could be done to encourage this activity; and (2) what about the tutorials were not helpful in learning the software. Future work could include instructor-led demonstration videos, or step-by-step content for varying skill levels. A future frontloading activity could also include having students make videos of example problems or demonstrations and then asking if this helped in the learning process.

Conclusions

A preliminary study was conducted during the fall 2017 semester in Fundamentals of Engineering to determine if active learning is more effective when students with learning disabilities are first front-loaded with information. Fundamentals of Engineering is a core course in the Manufacturing and Mechanical Engineering Technology program at RIT. Since the results were promising, despite the low number of students registered with the Disabilities Services Office, the frontloaded content will be modified to address student concerns and delivered again during the 2018-2019 academic year.

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