Minority Merit

Improving Retention with Cooperative Learning in a First-Year Electronics Course

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***Abstract*— Engaging underrepresented populations of women and minorities in engineering represents our greatest untapped resource for increasing the STEM workforce and its productivity. Guided by the research that shows that students' performance and experience in a first course in the discipline is predictive of retention of these students, we are adopting Merit workshops into our Introduction to Electronics course (one of our department's first-year courses). Merit workshops engage students in collaborative learning communities to improve students' sense of belonging in the department. In this work in progress paper, we will describe how we implemented our Merit workshops and provide some preliminary evaluations of the workshop.**

Keywords—women in engineering; underrepresented minorities; Merit; sense of belonging; collaborative learning

I. Introduction

Because engineers are seen as a critical source of economic growth, there are continuous calls to increase the Science, Technology, Engineering, and Mathematics (STEM) workforce [1]. Concurrently, research reveals that diverse workplaces increase creativity and innovation [2]. Consequently, engaging dramatically underrepresented populations of women and minorities in engineering represents our greatest untapped resource for increasing the STEM workforce and its productivity.

Mirroring the national landscape in engineering education, the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign enrolls fewer than 20% women and underrepresented minorities combined [1]. As part of broader efforts to improve the recruitment and retention of these students and to improve the overall learning experience of students in the department, we are adopting Merit workshops into our Introduction to Electronics course (ECE 110).

Merit workshops are a style of collaborative problem solving session that have been used on our campus for 20 years in chemistry, biology, and mathematics departments, but have never been used in engineering departments [3]. In these other departments, Merit workshops have doubled the retention rate of African-American students, almost completely eliminated the retention gap for women, and raised the overall graduation rate from STEM majors [3].

Based on these successes, we decided to adopt the Merit workshop for ECE 110. ECE 110 is a three-credit, large-enrollment (~400 students per semester) course that is required in the first year for electrical engineering and computer engineering majors. The course is also taken by more senior students from other departments and majors. Students attend two hours of lecture and one three-hour lab each week. In this work in progress paper, we describe how we implemented the Merit workshop, provide reflections from the instructors, and provide some preliminary assessments of the impact of the workshop on students' sense of belongingness in the department – an outcome that has not yet been directly assessed in prior research on Merit.

II. Background

Collaborative learning is a broad class of pedagogies that view learning as having a social and cultural component [4-7]. Learning happens in the interface between students as they co-construct knowledge and skills. Workshop-style pedagogies such as peer-led team learning (PLTL) [8, 9], supplemental instruction (SI) [10], and Merit are specific implementations of collaborative learning that have proven effective in STEM education. In workshop pedagogies, students are organized into small groups to collaboratively solve difficult problems. Merit workshops, based on the work of Uri Treisman [11], are specifically designed with the goal of providing traditionally underrepresented students (i.e., women, minorities, and first generation students) with a context in which they can build relationships and confidence that can increase their belief that they belong within a discipline. Critically, although the goal of Merit is to improve retention, the structure of the intervention is not remedial. Rather, emphasis is placed on the merit that students bring to the classroom. Consequently, students are generally solving problems that go beyond the standard content of the course. Merit grants students an extra hour of credit for attending additional instructional sessions that increase student interactions with course staff and peers.

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III. Administration of the Merit Section

The Merit workshop in ECE 110 was run for the first time in Fall 2015 semester and is in progress for the second time in Spring 2016 at the time of this writing. Our implementation drew heavily from the experiences of other departments on campus, but we made modifications according to specific needs of the course and its students. In this section, we describe the course structure, the selection and training of teaching assistants (TAs), the recruitment of students into the workshop, and grading policies.

In other departments, Merit workshop students register for extended discussion sections that replace the traditional discussion sections. In ECE 110, because there were no discussion sections in the standard offering of the course, we created a Merit workshop discussion section decoupled from the traditional course structures. This decoupling freed the instructors from student expectations about what the experience should be like. The section enrolled 20 students and met once a week for 2 hours. Students in the Merit workshop earned 1 credit hour of free elective credit, as is the practice in the other departments. Students were assigned to working groups of 3 or 4 students that were shuffled twice over the course of the semester. Groups were formed to not isolate female or minority students as a means to improve their sense of belonging.

Perhaps the most important administrative task was the selection of the Merit workshop teaching assistant (TA). Our ideal candidate combined thorough technical knowledge in ECE 110 material, sensitivity to the experiences of women and underrepresented minorities in the ECE department, and alignment with the instructors' vision for the Merit workshop. We were fortunate to have a TA in each semester who was an ECE graduate student specializing in engineering education research. One of our TAs had been heavily involved in course development for ECE 110 and the other had taken ECE 110 as a student. The instructors, both individually and collectively, provided technical and pedagogical guidance to the TAs on a weekly basis. The TAs also benefited from peer mentorship. The first TA was mentored by experienced TA from the chemistry department before becoming the mentor to the second TA.

We aimed to enroll students to create a demographically mixed group that served to improve recruitment and retention of women and underrepresented minority students in ECE. We used multiple means to reach out to potential students. The other departments that run Merit workshops already identified students incoming to the university that met the following criteria: ACT/SAT scores above some threshold, and either self-identification as an underrepresented minority student or attendance at a small (often rural) high school. For our Merit workshop, we invited students on this list who had been accepted as either ECE majors or were undeclared in the College of Engineering. This approach yielded more male students than female students, so we further invited all women ECE students who were likely to register for ECE 110. Finally, we invited several non-ECE students who had indicated interest in taking ECE 110 by signing up on a registration waitlist, focusing on women, underrepresented minority students and those from small high schools. The yield on invitations was about 50%.

We chose a grading policy that rewards student engagement rather than completion of tasks. The grading policy was based on attendance and participation. Each weekly meeting was worth 10 points, 5 for participation and 5 for attendance. The TA determined a student's participation points based on the whether the students worked actively on the designated activities, asked questions, helped fellow students, worked well with others, and used technology only for the designated Merit activities. Full attendance points were given for prompt attendance at the start of class; partial points were given on a sliding scale based on time of arrival. Students were also informed that absences could be excused by meeting with a course instructor who also holds the role of academic advisor in the ECE department. In the fall semester, this excuse policy was effective in identifying students who were struggling to adjust to university expectations. Those who visited the academic advisor were able to obtain help with both ECE 110 technical content and general academic matters (such as study habits and course registration choices).

IV. Design of Problems for Merit Activities

Workshop activities were structured around specially designed worksheets. Each worksheet focused on a single problem that was related to material previously covered in class and usually contained multiple questions or prompts. The worksheets contained blank space to show work and a line at the bottom to record when the consensus on the problem was reached. The activity was completed when all of the students in a given group agreed that they had satisfactorily answered the prompts and sufficiently supported their work. At that time, they could record their consensus and turn in the worksheet to the facilitator. If there was more than a few minutes left, the group could then receive another worksheet. Usually, a group could complete one or two worksheets in a two-hour session.

We assumed that the quality of worksheet content plays a role in the potential success of the program. Based on suggestions from previous work, the activities were designed to to be difficult relative to the course homework assignments to emphasize that Merit is not a remedial intervention. To guide our creation of worksheets and to provide a diversity of experience to the participant, we also identified other activity parameters. As we continue developing Merit, we will explore the effect of these parameters. The parameters can be assessed by surveying instructional staff and, to a degree, student participants. The parameters are not categories of problems, because many parameters can apply to the same problem. The list of proposed parameters includes:

1. Similarity to course assessments
2. Conceptual difficulty
3. Procedural difficulty
4. Relatability to experience
5. Applicability to technology
6. Open-endedness
7. Surprise or discrepancy
8. Amount of guidance or "scaffolding"

Similarity to course assessments means that a problem would be easily recognizable to the non-Merit students in the course. Usually, such a problem is similar or identical to a previously given exam problem which challenged the general class population. When given in the Merit section, the analysis of such a problem might require deeper thinking than what would be required on the exam or it might be in the same form. The idea of using such a problem would be to give Merit students a forum to discuss some of the more difficult types of course assessments, to clearly link the Merit section to the course, and to give the students an easily-recognized performance benefit from participation. The down side of using many such problems is lowering engagement for those seeking breadth of experience, placing undue additional emphasis on the graded course assessments at the expense of broader learning and creating a sense that the goal of Merit is to help students get higher grades in our specific course.

Conceptual difficulty would often imply a level of abstraction required for the problem. As a result, students might have difficulty understanding the statement of the problem or making initial progress. For example, a problem might ask for "deriving a condition when both voltage sources are supplying power." Many of the students at the freshman level are not yet familiar with the formalism of conditions, which requires them to identify the variables at play and see what happens for the different ranges of the variables. Facing such conceptual difficulties, related to abstractions or generalizations, introduces higher order thinking. Another conceptual difficulty that is addressed by such a question is the erroneous assumption made by some students that voltage sources always supply power. Thus, these conceptual problems can also help break previously held misconceptions. The potential downside of the conceptual problems is the potential frustration when a student group cannot get going on a problem and someone introduces a negative view of the problem. Facilitation can help, but it can be a challenge to deliver it in a timely manner. Scaffolding a problem with easier questions prior to generalization is another technique. However, for some groups, this can lead to a missed opportunity for a meaningful discussion among members as they try to self-scaffold the problem by finding intermediate steps.

Procedural difficulty typically means that the students can engage with the problem and understand what is being asked. However, working through to the answer might be challenging because of the number of steps involved, or the challenging topology of the circuit makes it difficult to find the right sequence of steps. Such problems can help the students build confidence in their skills, explore techniques that can make solutions easier, build appreciation for algorithms and computers for solving more complex problems, and develop grit. The downside might be the perception of "busywork" unhelpful for other assessments, frustration with the process, and, for some students, learned helplessness.

Relatability to experience implies that the problems are connected to something that the students have encountered before, but, perhaps, have not analyzed. For example, students might estimate how appliances should be connected to the circuit breaker panel, and how they contribute to the total electricity bill. Such a problem brings into practice the concepts of peak and average power and helps students develop a sense of scale for currents and energy by connecting calculations to the things they have encountered previously. The potential risk is that some students might not enjoy the "mundane" applications and feel like they are learning less by revisiting familiar subjects.

Applicability to technology means that a problem is centered on a specific historical or modern application which the students may or may not have encountered before. We might give background and ask questions about wiring for a Civil War telegraph, AC/DC power adapters, microprocessor power consumption, thin film resistor fabrications, etc. The main use of these problems is student engagement. Also, these problems often help build connections to different engineering aspects. Often, students enjoy such problems, although their extent or wordiness makes them less aligned to the heavily weighted course assessments. Also, these problems form specific examples and don't necessarily develop abstractions and generalization.

Open-endedness relates to a problem formulation that does not call for a precise answer. Instead, the solution depends on the variable assumptions and goals chosen by students. For example, we ask about choosing a set of resistors, which, when combined with each other, can span a given range of resistances. Students might discuss, for example, whether it is better to span resistances on a linear or logarithmic scale, or whether it is better to span the range more evenly and sparsely, with some combinations outside of the target range versus a denser spacing with some gaps. Open-ended problems can benefit Merit because the solution process can really benefit from an extensive discussion among team members. In addition, the students are pushed towards higher-order thinking, which involves evaluation of different solutions. The risk is that, for many students, the open-ended process in the context of exact sciences is quite novel, and they might simply perceive these problems as ill-posed. Also, the assessments for our freshman-level class are rarely done with open-ended problem outside of a lab setting.

Surprise or discrepancy is a useful quality in a problem, which has either an unexpected answer or an unexpected goal. There is a whole class of numerical problems in which an answer is unexpectedly zero for a certain delicate balance of other parameters. Sometimes, it is a very meaningful point, as in a Wheatstone bridge circuit, and the students might pause to think about it and to discuss it. Sometimes, the origin of the surprise is not quantitative. For example, students might be surprised to note that one can scale an area of a thin-film resistor without changing resistance. While this fact is easy to see from analyzing the resistance formula, it does motivate a short contemplation or a conversation among students. On the other hand, the sole focus on the discrepant problems might train the students to expect "tricky" answers or become too mistrustful of their intuition to the point that they are reluctant to make predictions.

Amount of scaffolding relates to a number of intermediate steps outlined in the statement of the problem. Usually, these are given as parts of a problem, but sometimes they are given as hints. For example, in the problem which asks to find a set of voltages which result into a certain LED to be turned on, we might first ask the students a number of questions regarding whether the LED is turned on for specific voltage sets. Only after considering multiple specifics would students attempt to generalize the solution. Certainly, this technique makes it easier for students to get started on a challenging problem, avoiding potential frustration. On the other hand, by giving the students a lot of directions prevents them from developing the ability and getting the satisfaction of navigating their own path towards the goal. Excess scaffolding may also reduce student interaction.

V. Facilitating the Merit Section

The typical day of the Merit section involves students working on one or two challenging worksheets together in groups of three or four. Since grading is based on participation, the TA encourages students to stay on task and not get too side-tracked when non-class related conversations go on for too long. Students are given a 10-minute break after an hour. During the break, students are encouraged to socialize with one another instead of using electronics.

In general, the TA acts as the guide-on-the-side rather than the sage-on-the-stage. Whenever a group becomes stuck on a problem, the group may ask the TA for help. The TA will remind them about concepts learned in class and will usually answer their questions with another question. For example, the students may ask, "How do I go about solving this problem?" The TA may then ask, "What circuit-analysis techniques do you know?," and, if needed, 'Have you considered using current or voltage divider rule? Be sure you know when to apply each one." The group will respond, "Oh, we hadn't thought of that yet," and they will make another attempt to solve the problem while looking up the concepts.

When a group finishes a worksheet, the TA looks over their answer as they share their reasoning. If the thought process is missing key concepts or if key concepts are misapplied, the TA points out the flaws by asking insightful questions, for example, "Did you remember to include the voltage drop across the current source?" This way the TA encourages students to think through the concepts rather than focus on getting the right answer. At the end of each worksheet, there is a place to write down the time when the group reached consensus. Some groups sometimes finish both worksheets while some groups do not finish even the first worksheet. However, the goal is not to finish all the worksheets but to develop meaningful collaborative experiences and problem-solving skills.

Usually observations take the majority of the TA's time but it depends on how many questions the students ask. The TA observes each group and each student to evaluate group dynamics and gauge each student's engagement. The TA jots down these observations during class and afterwards writes a reflective journal for each week. Groups may be changed after evaluating group dynamics. The TA also takes notes on what kind of questions the students were asking and what part of the problem they were stuck on. This process helps the TA become a reflective teacher and get a better grasp of the students' level of understanding.

VI. Effects on Students' Sense of Belonging

One of the primary goals of the Merit discussion section is to increase student retention, particularly among students from underrepresented demographics vulnerable to dropping out [3]. Students are particularly likely to drop out of engineering in their freshman year [1]. During the first six weeks, student are most sensitive to feelings of marginality. Particularly, a lack of social support and social relationships makes some freshman particularly likely to drop out [12]. A student's subjective evaluation of his or her 'fit' into the college environment, their "Sense of Belonging", is an important factor in student retention. All else being equal, students with higher sense of belonging are more likely to persist in college [12]. The Merit program aims to increase this sense of belonging, by establishing a tighter sub-community within the larger campus.

We are using the instrument from Hoffman et al. [12] to evaluate any change in sense of belonging created by the Merit discussion section. The instrument has fifty Likert scale items evaluating student/peer relationships. Some survey items include: "I feel comfortable volunteering ideas or opinions in class," "Class sizes are so large I feel like a number," "I rarely talk to other students in my classes."

The laboratory section that runs at the same time as the Merit session serves as the comparison group. This ensures lack of overlap in sample and controls somewhat for willingness to sign up for a 9AM class. The instrument was administered to students in both the MERIT and control sections during the third week of classes and again during the last week of classes. The results of this survey from the Fall and Spring semesters will be reported in a future publication.

VII. Conclusions and Future Work

Our initial impressions of implementing a Merit discussion section for ECE 110 have been positive, and we expect that we will continue to offer the program. In future work, we will use the data we are collecting to provide a thorough evaluation of the effectiveness of the program for our intended outcomes. Future work will use student feedback, reflections from the instructors' observations, and students' worksheets to more fully explore which of these problem parameters best support students' learning and engagement during Merit discussion sections. The sense of belongingness survey and student retention data will be used to evaluate the impact of Merit on the targeted underrepresented student populations.

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