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Correlation between Physics and Calculus Workshop Attendance and University Grades

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Abstract

The Student Learning Centre at the University of Ontario Institute of Technology offers various support services for students enrolled in first year calculus and physics courses; the most widely used of these services are focused workshops. The purpose of this study was to compare student academic performance between those who did and did not attend physics and calculus workshops. Data provided by the Office of Institutional Research and Analysis at UOIT was analyzed using pivot tables in MS Excel. Students enrolled in Physics I and Calculus I were categorized based on their Grade 12 physics and calculus marks, respectively. Students enrolled in Physics II and Calculus II were categorized based on their Physics I and Calculus I marks, respectively. Subgroups were then identified based on workshop attendance and correlated with first year university physics and calculus grades. Students within the same incoming grade category who did not attend any workshops served as the control group. A Pearson's Chi-square test was used to determine if statistically significant differences existed between the performance of students who attended workshops and those who did not. Analysis found that students who attended workshops had greater success rates in all first year calculus and physics courses compared to their non-workshop attending peers.

Keywords: physics, calculus, workshops, student success, support services, comparison

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Traditionally, introductory physics and calculus courses in university have disproportionately low success rates among students (Benford & Gess-Newsome, 2006). These courses have been identified as barrier courses and correlated with student attrition (Jiang & Freeman, 2011). Low success rates for first year calculus and physics courses have also been observed at the University of Ontario Institute of Technology (UOIT). In the fall of 2015, the average failure rate for all first year courses at UOIT was 11%, whereas the average failure rate for first year physics (PHY 1010) and calculus (MATH 1010) were 14% and 24%, respectively. These relatively high failure rates are especially concerning for these gateway courses, from which learned skills form the basis of more advanced science, engineering, and mathematics courses. Numerous studies have suggested various causes for the lower success rates for first year physics and calculus courses (Cuseo, 2007; Fayowski, Hyndman & MacMillan, 2009; Kerr, 2011). These include student academic underpreparedness and large class size.

Several authors report an increasing number of underprepared students entering post-secondary education. Some research suggests that this trend may be linked to the elimination of the Ontario Academic Credit (OAC) year in secondary school (Fayowski, Hyndman & MacMillan, 2009). As more students are entering university at an age where their brains have not yet fully developed their executive functions, their inability to analyze information and apply and interpret their knowledge presents a barrier to student success (Fayowski, Hyndman & MacMillan, 2009).

Studies have also shown that large class sizes have adverse effects on student learning. Students in large classes often experience a sense of isolation and anonymity (Kerr, 2011). These students were more likely to lose attention, become distracted, and were less likely to take responsibility for their own learning (Kerr, 2011). Large class sizes have also been found to reduce active participation and have been correlated with lower levels of academic achievement and performance (Cuseo, 2007). The limited opportunity for instructors to develop relationships with students and for students to form relationships with their classmates was also cited as a disadvantage to large classes (Kerr, 2011). Large class sizes are common amongst gateway courses, such as introductory calculus and physics, and have been shown to result in decreased student engagement with the course instructor, with classmates, and with the subject matter (Cuseo, 2007).

To improve student learning and success, various post-secondary institutions have introduced a variety of academic services and programs, such as one-on-one support, small group supplemental instruction, or workshops. While one-one-one support can be tailored and individualized to the specific needs of learners, there are many limitations to this type of service. First, with course enrollment in the hundreds or even thousands, it is typically not feasible to support all these students one-on-one. Additionally, students are not able to work collaboratively to problem-solve or engage in thoughtful discussion with their peers during one-on-one sessions. Furthermore, many students perceive one-on-one support as a type of remedial assistance, only intended for low-performing students (Fayowski & MacMillan, 2008). Thus, many mid- to high-performing students, who may have greatly benefitted from the support, often do not access the service.

In contrast, students of all abilities tend to access group services, such as workshops and supplemental instruction programs, as they are not viewed as remedial. The efficacy of a supplemental instruction program for first year calculus was evaluated by Fayowski and

MacMillan in 2008. They reported a significant increase in student grades when students attended these small, collaborative learning group sessions.

The Student Learning Centre at UOIT offers a variety of programs and services to help students strengthen their academic skills, several of which are aimed to support students enrolled in first year physics and calculus. Services include one-on-one support from Academic Subject Specialists and Peer Tutors, drop-in learning commons support, and focused workshops. Of these, the most widely utilized services are the physics and calculus workshops. These regular, focused, interactive workshops are designed to support students, while providing them with the opportunity to work both independently and collaboratively to enhance their problem-solving skills. Contributing to the success of this program is the ongoing collaboration between the Academic Subject Specialists who facilitate these workshops and the faculty members who deliver the supported courses. This allows for workshops to align with course content and meet the specific academic needs of the students. Attendance for these workshops, which supplement the learning that occurs during lectures, tutorials, and laboratories, is voluntary and has been consistently high. Results from student surveys indicate that many students attribute much of their academic success to these workshops; however, the relationship between workshop attendance and student grades has yet to be quantified.

Methods

All quantitative data used in this study were provided by the Office of Institutional Research and Analysis at UOIT. Data from six different courses offered during the 2015-2016 academic year were provided: PHY 1010 (Fall), PHY 1010 (Winter), PHY 1020, MATH 1010 (Fall), MATH 1010 (Winter), and MATH 1020. Data sets included all students registered for each course, along with their Ontario Grade 12 physics or calculus mark (where applicable), the number of workshops they attended, as well as their final university physics or calculus mark. Pivot tables were created for each data set using MS Excel. Student data were grouped by incoming grade categories. For Physics I and Calculus I, incoming grade categories were based on Grade 12 physics (SPH4U) and calculus (MCV4U) marks, respectively. Categories were set as follows: less than 70%, between 70% and 79%, and greater than or equal to 80%. Subgroups were then identified based on workshop attendance, and correlated with Physics I and Calculus I grades. For Physics II and Calculus II, incoming grade categories were based on Physics I and Calculus I marks, respectively. Categories were set as follows: 50% to 59%, 60% to 69%, 70% to 79% and greater than or equal to 80%. Students within the same incoming grade category who did not attend any workshops served as the control group. Success was defined by three criteria: the percentage of students in each category that a) received the university course credit (final mark >/= 50%), b) received a final mark greater than or equal to 70%, and c) received a final mark greater than or equal to 80%. A Pearson's Chi-square test was used to determine if there was a difference in student grades between students who attended workshops and those who did not. Differences were considered significant at p values less than 0.05.

Results

Workshop Attendance

Table 1 summarizes the total number of students enrolled in each course, the number and percentage of the students who attended at least one workshop, as well as the average number of workshops attended by each of these students.

Table 1. *Workshop attendance by course.*

Course	Total enrollment	No. of students that attended one or more workshops	% of students that attended one or more workshops	Avg. no. of workshops attended
PHY 1010 (Fall)	870	289	33%	2.7
PHY 1010 (Winter)	124	56	45%	4.4
PHY 1020	705	265	38%	3.1
MATH 1010 (Fall)	876	243	28%	2.7
MATH 1010 (Winter)	201	76	38%	2.2
MATH 1020	814	273	34%	2.9

To determine if workshops were attended predominately by low-, medium-, or high-performing students, workshop attendance by incoming grade category was evaluated. Figure 1 summarizes workshop attendance for each incoming grade category. For all PHY 1010 and MATH 1010 courses, these incoming grades were based on the students' Grade 12 physics or calculus marks, and were categorized as less than 70%, between 70% and 79% and greater than or equal to 80%. There was also a group of students, referred to as "NO MARK", for whom a Grade 12 physics and/or calculus mark was not available. These students did not take these courses in the Ontario secondary school system. For PHY 1020 and MATH 1020, incoming grades were based on PHY 1010 and MATH 1010 marks, respectively. These were categorized as between 50% and 59%, between 60% and 69%, between 70% and 79%, and greater than or equal to 80%.

Students from all incoming grade categories access workshop services at UOIT. For PHY 1010 (Fall and Winter) and MATH 1010 (Fall and Winter), a greater percentage of students who did not take Grade 12 physics/calculus in Ontario attended workshops than those who did. Furthermore, for the MATH 1010 courses, students who received 70-79% in Grade 12 calculus were more likely to attend calculus workshops than those who earned less than 70% or greater than or equal to 80%.

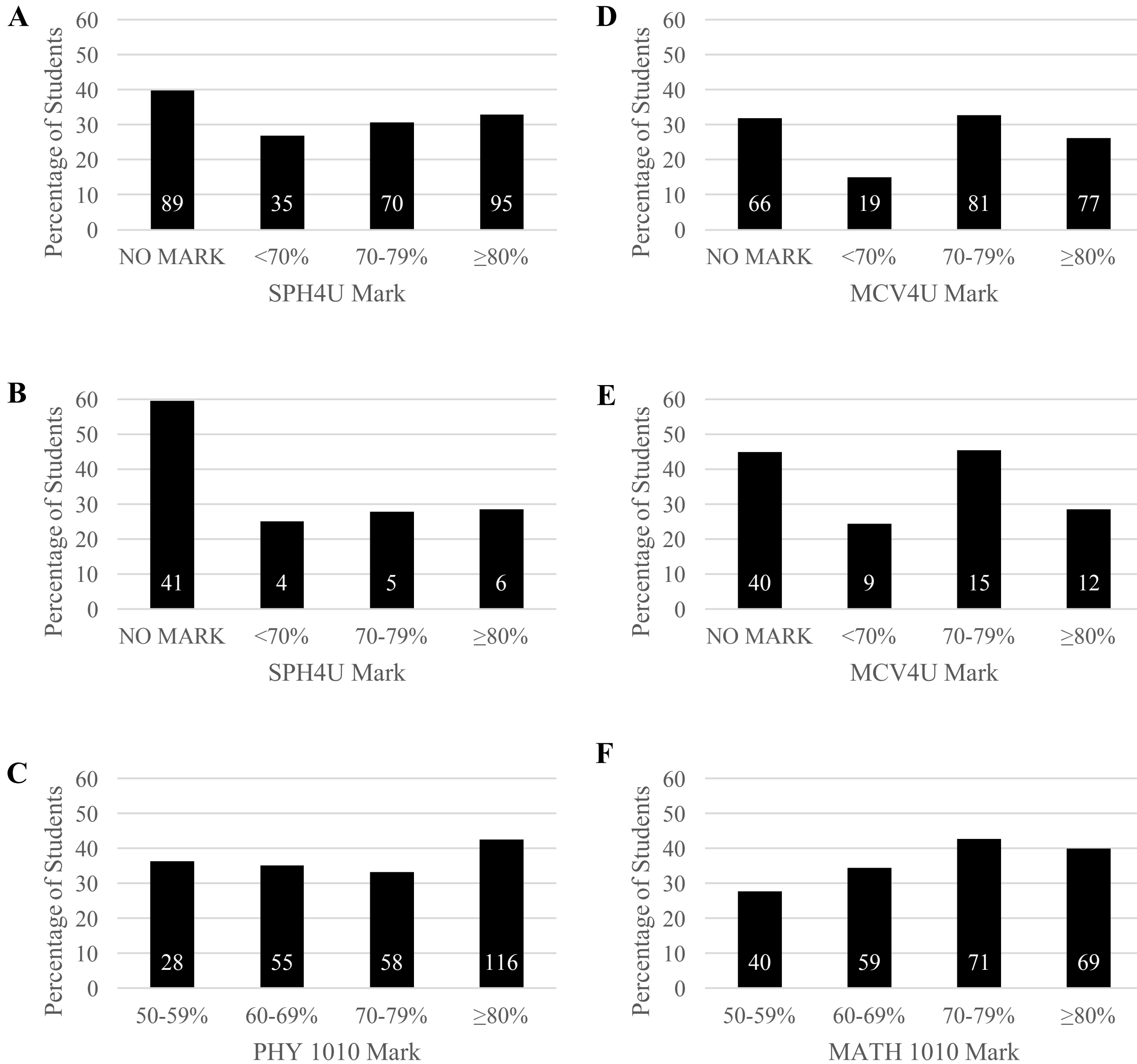

Figure 1. Workshop attendance by incoming grade category for **(A)** PHY 1010 (Fall), **(B)** PHY 1010 (Winter), **(C)** PHY 1020, **(D)** MATH 1010 (Fall), **(E)** MATH 1010 (Winter), and **(F)** MATH 1020. Incoming grade category for PHY 1010 and MATH 1010 was based on Grade 12 physics (SPH4U) and calculus (MCV4U) marks, respectively. Incoming grade category for PHY 1020 and MATH 1020 was based on PHY 1010 and MATH 1010 marks, respectively. Numbers within bars represent sample size.

Workshop Attendance and University Success Rates

To determine if workshop attendance was correlated with university success, students were grouped into three categories based on the number of workshops they attended: no workshops, one to three workshops, and greater than three workshops. The percentage of students in each of these categories who achieved success is shown in Figure 2. Success was defined by three criteria: students receiving the credit, students who received a final mark at or above 70%, and students who received a final mark at or above 80%. For all courses, students who attended one to three workshops were significantly more likely to pass the course than those who did not attend any workshops. Furthermore, with the exception of MATH 1010 (Fall), a greater percentage of students passed the course when they attended more than three workshops. For the physics courses, students who attended more than three workshops were also significantly more likely to earn a mark at or above 70%, as well as at or above 80%. For the calculus courses, students who attended one to three workshops were significantly more likely to earn a mark at or above 70% as well as at or above 80% compared to their non-workshop attending peers. This effect was sometimes more pronounced when students attended more than three workshops; however, findings were not always significant, particularly as the sample size was small.

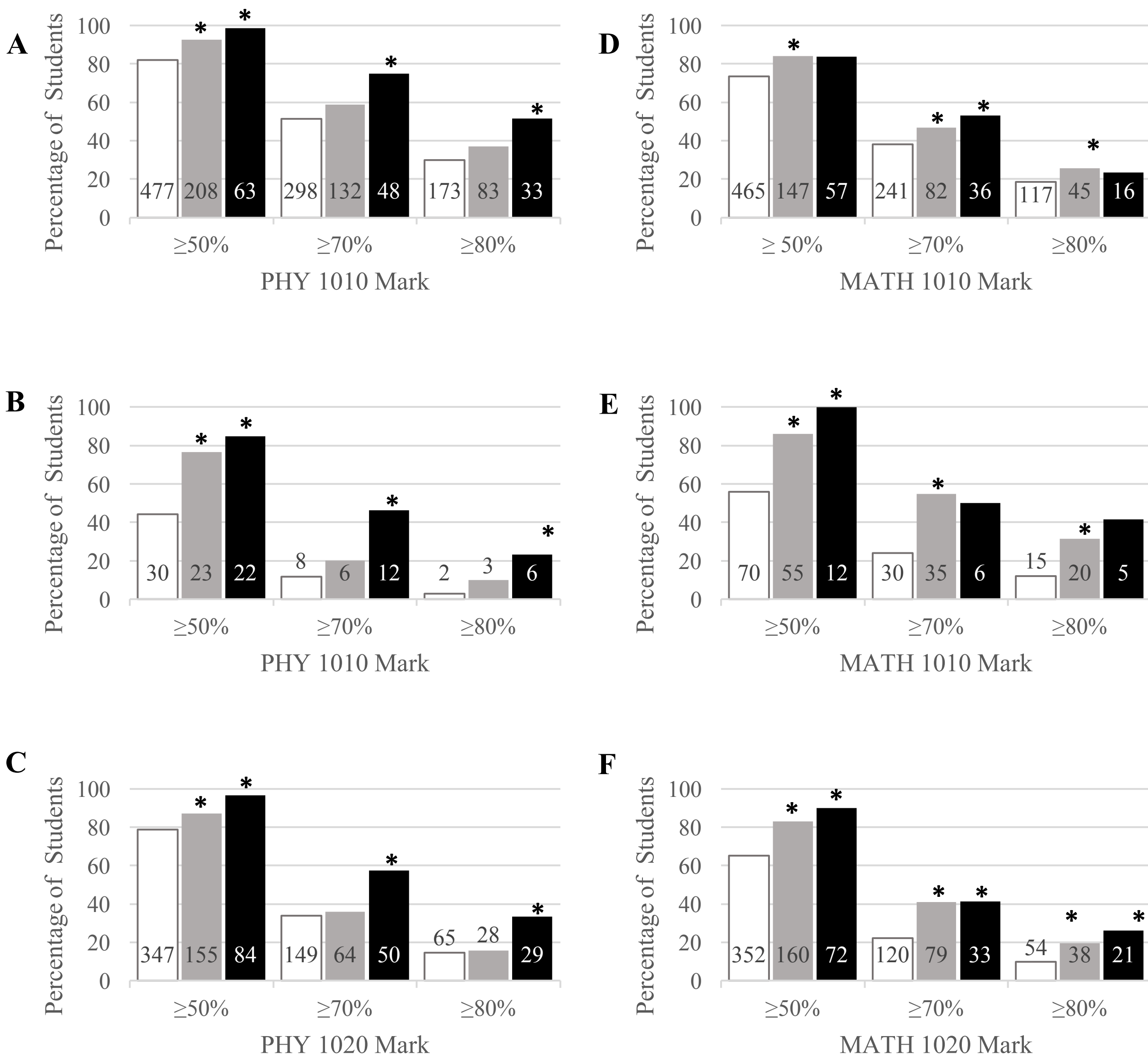

Figure 2. Percentage of students who attended zero (white), one to three (grey), and greater than three (black) workshops enrolled in **(A)** PHY 1010 (Fall), **(B)** PHY 1010 (Winter), **(C)** PHY 1020, **(D)** MATH 1010 (Fall), **(E)** MATH 1010 (Winter), and **(F)** MATH 1020, who received the course credit (≥ 50%), and who received a final mark greater than or equal to 70% or 80% (≥70%, ≥80%). Numbers within/above bars represent sample size. * denotes significance compared to students who attended no workshops. Significance assigned at $p<0.05$.

Students were then grouped by their incoming grade category to assess whether there was a correlation between workshop attendance and success, when incoming grades were controlled for. Figure 3 shows the percentage of students within various incoming grade categories who did not attend any workshops and those who attended one or more workshops and received the corresponding university course credit. In all cases, a greater percentage of students who attended workshops received the course credit. For the PHY 1010 (Fall and Winter) courses, mid- to high-performing students (with Grade 12 physics marks greater than or equal to 70%) were significantly more likely to pass the course if they attended one or more workshops, compared to those who did not attend any workshops. In addition, for the PHY 1010 (Winter) course, low-performing students (with Grade 12 physics marks below 70%) who attended one or more workshops also had significantly higher pass rates than their peers who did not attend any Physics I workshops. Low- and mid-performing students in PHY 1020 (those who received PHY 1010 marks below 80%) were significantly more likely to pass PHY 1020 if they attended one or more Physics II workshops, compared to those who did not attend any workshops. For the MATH 1010 (Fall) course, students who did not take Grade 12 calculus in Ontario as well as those who earned a Grade 12 calculus mark between 70% and 79% were significantly more likely to pass MATH 1010 if they attended Calculus I workshops. For the MATH 1010 (Winter) course, students within all incoming grade categories, including those that did not take grade 12 calculus in Ontario, were significantly more likely to pass MATH 1010 if they attended Calculus I workshops. Low- to mid-performing students (with MATH 1010 marks below 80%) were also significantly more likely to pass MATH 1020 if they attended Calculus II workshops.

Similarly, as shown in Figure 4, a greater percentage of students who attended workshops earned an “A” (≥80%) in the corresponding university course compared to those who did not attend any workshops. Since few students achieve an “A” in first year physics and calculus courses, sample sizes were often too small to find statistical significance. Nonetheless, students with Grade 12 physics marks below 70% and above 80% were significantly more likely to achieve an “A” in the PHY 1010 (Fall) course if they attended workshops. For the PHY 1010 (Winter) course, high-performing students with a Grade 12 physics mark at or above 80% were significantly more likely to earn an “A” in PHY 1010 if they attended Physics I workshops. For PHY 1020, students that had received a PHY 1010 mark between 70% and 79% were significantly more likely to earn an “A” in PHY 1020 if they attended Physics II workshops. For the MATH 1010 (Fall) course, although a greater percentage of students within each incoming grade category who attended Calculus I workshops achieved an “A” than those who did not attend workshops, these findings were not shown to be statistically significant. For the MATH 1010 (Winter) course, while a greater percentage of students within all incoming grade categories who attended workshops earned an “A”, only those who did not take Grade 12 calculus in Ontario and those with a Grade 12 calculus mark below 70% were shown to be statistically significant. For MATH 1020, students with MATH 1010 marks ranging from 60-69%, 70-79% and at or above 80% were all significantly more likely to receive an “A” in MATH 1020 if they attended Calculus II workshops. No students that received a “D” (50%-59%) in MATH 1010 earned an “A” in MATH 1020, regardless of workshop attendance.

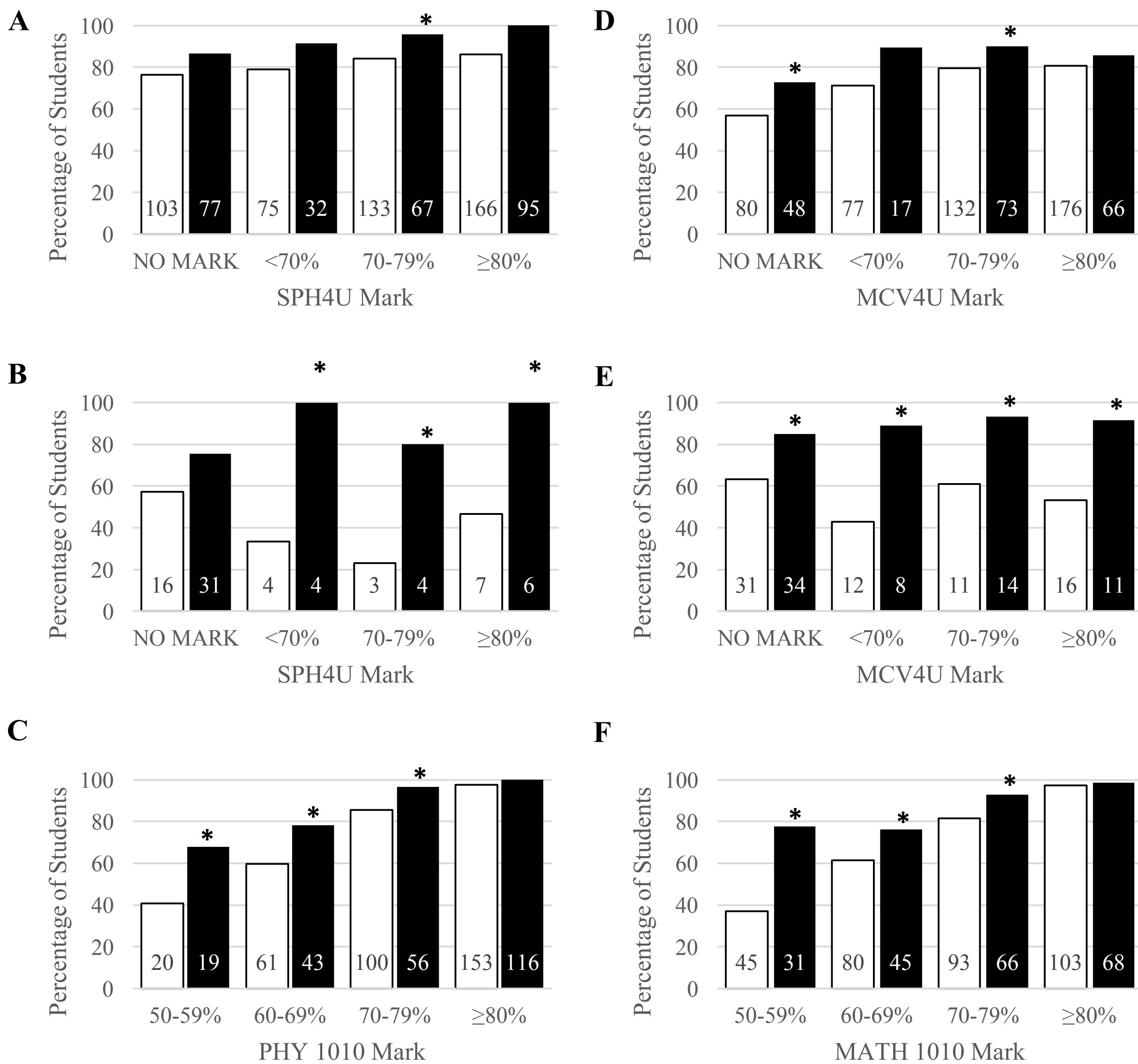

Figure 3. Percentage of students within various incoming grade categories who did not attend (white) and attended (black) at least one workshop who received the course credit for **(A)** PHY 1010 (Fall), **(B)** PHY 1010 (Winter), **(C)** PHY 1020, **(D)** MATH 1010 (Fall), **(E)** MATH 1010 (Winter), and **(F)** MATH 1020. Incoming grade category for PHY 1010 and MATH 1010 was based on Grade 12 physics (SPH4U) and calculus (MCV4U) marks, respectively. Incoming grade category for PHY 1020 and MATH 1020 was based on PHY 1010 and MATH 1010 marks, respectively. Numbers within bars represent sample size. * denotes significance compared to students that attended no workshops within the same incoming grade category. Significance assigned at $p<0.05$.

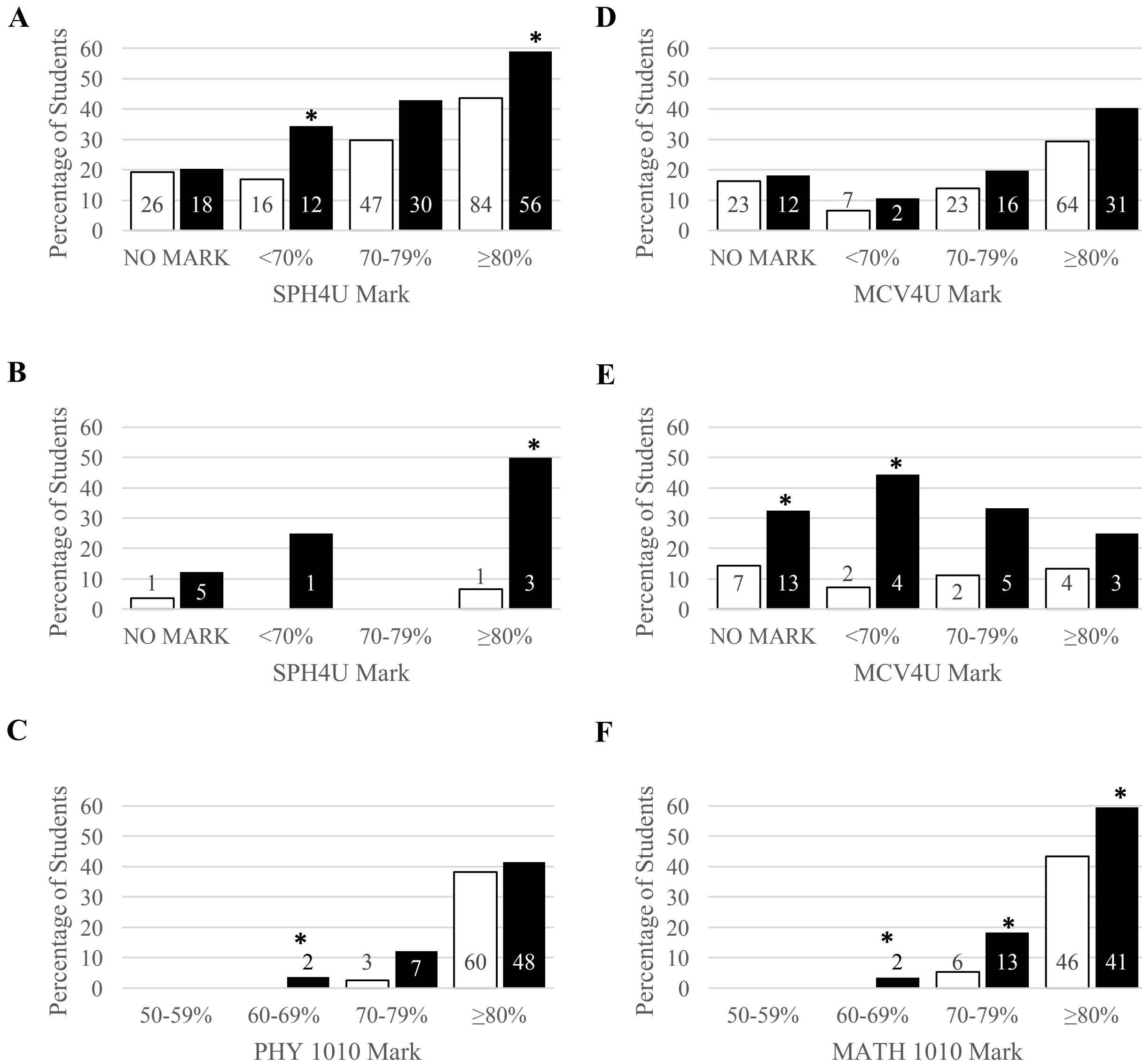

Figure 4. Percentage of students within various incoming grade categories who did not attend (white) and attended (black) at least one workshop who received a mark that was greater than or equal to 80% in **(A)** PHY 1010 (Fall), **(B)** PHY 1010 (Winter), **(C)** PHY 1020, **(D)** MATH 1010 (Fall), **(E)** MATH 1010 (Winter), and **(F)** MATH 1020. Incoming grade category for PHY 1010 and MATH 1010 was based on Grade 12 physics (SPH4U) and calculus (MCV4U) marks, respectively. Incoming grade category for PHY 1020 and MATH 1020 was based on PHY 1010 and MATH 1010 marks, respectively. Numbers within/above bars represent sample size. * denotes significance compared to students that attended no workshops within the same incoming grade category. Significance assigned at $p<0.05$.

Discussion

The findings from this study indicate that students were more likely to achieve success in first year physics and calculus courses if they attended workshops. In general, students who attended workshops were more likely to pass the course, receive 70% or above, and receive an "A" compared to their non-workshop attending peers. Furthermore, the results presented suggest that students who attend more than three workshops are more likely to be successful than those who attend one to three workshops. In all cases, a greater percentage of students who attended workshops achieved success in their course (based on all three success criteria), compared to their non-workshop attending peers. These findings were not always statistically significant, however, as when students were divided based on their incoming grade category and grouped by workshop attendance, sample sizes began to dwindle and statistical significance became increasingly difficult to determine.

Results from this study were consistent with those of Fayowski and MacMillan (2008), who found that students who attended a supplemental instruction program for first year calculus were significantly more likely to earn "A" and "B" grades compared to students who did not participate in the program. Similarly, Sharma, Medez, and O'Byrne (2005) showed that students who attended non-compulsory, student-centred physics workshops performed better on their physics exam than their non-workshop attending peers. Furthermore, they showed that examination marks improved significantly with increased workshop attendance.

As workshop attendance is completely voluntary at UOIT, a self-selection effect can occur. To control this effect and minimize self-selection bias, students were grouped by their incoming grade category, a variable which has been shown to be a good predictor of student success (Fayowski, Hyndman, & MacMillan, 2009; Winter & Dodou, 2011). For students enrolled in PHY 1010 and MATH 1010, their incoming grade category was based on their Grade 12 physics and calculus marks. For consistency, only marks of students who attended these courses in the Ontario secondary school system were analyzed; students who took these courses outside of Ontario were grouped in a “NO MARK” category in order to avoid distorting the results. Studies have shown that a student’s Grade 12 mathematics grade is a good indicator of their performance in Calculus I (Fayowski, Hyndman, & MacMillan, 2009). Similarly, Winter and Dodou (2011) report that Grade 12 math and physics exam marks are good predictors of academic performance in first year university engineering programs. Thus, grouping students according to their grade 12 physics and calculus marks was an ideal way to control for course-specific ability. For students enrolled in PHY 1020 and MATH 1020, their incoming grade category was based on their PHY 1010 and MATH 1010 marks. This decision was based on the assumption that a student’s mark in Physics I and Calculus I was a better indicator of their performance in Physics II and Calculus II, than their Grade 12 physics and calculus marks.

Students with a range of academic abilities attend physics and calculus workshops at UOIT. This supports the notion that workshops are not viewed as a remedial service since high-performing students attend them. Workshops attract mid- to low-performing students as well. Additionally, a high proportion of students that did not take Grade 12 physics or calculus in the Ontario secondary school system attended workshops. It is likely that this group consists primarily of mature, transfer, pathways, and international students. Studies have shown that these non-traditional students typically have much higher attrition rates than domestic students entering university directly from secondary school (Deng, Lu, & Cao, 2007; van Rhijn, 2015). Thus, the Student Learning Centre at UOIT supports students from a wide variety of backgrounds through these workshops. In all cases, students within each incoming grade category, including those without a Grade 12 physics or calculus mark who attended workshops were more likely to achieve success compared to those who did not attend workshops within the same incoming grade category.

A variety of features of these workshops likely contribute to the success of the program. The Academic Subject Specialists who facilitate the workshops collaborate closely with the course instructors to ensure that workshop content is always relevant and consistent with the instructor's learning objectives. Also, workshops begin during the first week of class, and are offered on a weekly basis throughout the course. This allows students to obtain assistance as soon as they need it, before they encounter academic difficulty. Additionally, workshops are designed to promote a high degree of student collaboration and problem-solving. Students are not simply shown how to solve problems; rather, they work together to problem solve and access support as they need it. The collaboration which takes place during workshops often extends beyond the classroom and leads to the formation of peer study groups. Collaborative learning has been shown to enhance students' academic achievement and knowledge retention (Tran, 2014). Students not only develop the subject-specific skills required for these courses, but the Specialists also model for them good study strategies and guide them to available resources. Finally, workshops are typically delivered in smaller classrooms. Whereas lecture halls at UOIT seat up to 200 students, workshop capacity is strategically limited to 36 students. These small workshop sizes promote the development of a learning community, where students feel safe to take academic risks, ask questions, and engage in discussions regarding the course material.

This smaller learning community fosters the development and strengthening of relationships, both among students, as well as between the Academic Subject Specialists and the students. The importance of such relationships has been well-documented as they have been strongly associated with student retention, academic achievement, critical thinking, and educational aspiration (Cuseo, 2007).

This study has demonstrated a positive impact of first year physics and calculus workshops on student success, a finding which supports UOIT's ongoing efforts to develop and deliver these workshops. Future research should aim to extend this study by investigating the impact of other services offered, including one-on-one, drop-in, and peer-assisted study sessions on student success.

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