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Using an Innovative Intervention to Promote Active Learning in an Introductory Microbiology Course

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Using an Innovative Intervention to Promote Active Learning in an Introductory Microbiology Course

Abstract
We found that actively engaging students in our introductory microbiology course was a challenge given our large class sizes and many non-majors taking the course as a program requirement. Therefore, we introduced a novel active learning strategy to our course. Students grouped into teams of three had to create PowerPoint virtual posters on one of three themes: (a) a report on a microbe or immunology story in the news, b) interview a research scientist, or c) research a microbiological topic of their choice. To assess the intervention's effectiveness, a pre- and post-course assessment was done. Pre-posttest analysis revealed a significant drop in surface learning and rise in deep learning. Also, there was a drop in the extrinsic (grade-dependent) goal orientation and affective (test anxiety) components. We found a decline in task value, self-efficacy for learning and performance, organization, critical thinking, time and study environment, and help seeking in students' post-test scores. Qualitative findings also indicated the importance of group activity, gaining extra knowledge outside the curriculum, and long-term course content retention. In conclusion, we propose that the creation of digital posters in teams is an effective strategy to increase student engagement in large classes.

Nous avons constaté qu'il était difficile de faire participer les étudiants dans notre cours d'introduction à la microbiologie, du fait de nos grandes classes et du grand nombre d'étudiants inscrits dans le cours qui n'avaient pas l'intention de faire une majeure dans ce domaine et pour qui le cours n'était pas une exigence de leur programme. Par conséquent, nous avons introduit dans notre cours une nouvelle stratégie d'apprentissage actif. Les étudiants ont été divisés en groupes de trois et chaque groupe devait créer une affiche virtuelle avec PowerPoint sur l'un des trois thèmes suivants : (a) présenter un rapport sur un microbe ou sur une histoire liée à l'immunologie présentée aux nouvelles, (b) interviewer un chercheur ou une chercheuse, ou (c) faire une recherche sur un sujet de leur choix lié à la microbiologie. Afin d'évaluer l'efficacité de l'intervention, une évaluation a été menée avant et après le cours. L'analyse des évaluations menées avant et après le cours a révélé que l'apprentissage de surface avait considérablement diminué et que l'apprentissage profond avait augmenté. Également, les composantes relatives à l'orientation des objectifs extrinsèques (liée aux notes obtenues) et affectifs (anxiété face aux tests) avaient diminué. Nous avons constaté une baisse dans la valeur des tâches, l'efficacité personnelle pour l'apprentissage et la performance, l'organisation, la pensée critique, le temps et l'environnement d'étude, ainsi que l'aide recherchée dans les résultats après le test des étudiants. Les résultats qualitatifs indiquent également l'importance de l'activité de groupe, l'acquisition de connaissances supplémentaires hors du programme de cours et la rétention à long terme du contenu du cours. En conclusion, nous proposons que la création d'affiches numériques par groupes est une stratégie efficace pour augmenter la participation des étudiants dans les grandes classes.

Keywords
active learning, digital poster, team-based learning, student engagement, undergraduate education; apprentissage actif, affiche numérique, apprentissage basé sur les groupes, participation des étudiants, enseignement au niveau du premier cycle

Cover Page Footnote

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Despite the several opportunities including diversity, cooperation, autonomy, proactivity, tolerance, and multiple dimensions/ideas generation (Jerez-Yáñez et al., 2018; Shah, & Salim, 2013), teaching high enrollment classes has always been, and continues to be, one of the greatest challenges for instructors (Hanover Research, 2010; Mgeni, 2013; Moodley, 2015; Mulryan-Kyne, 2010). Some of the major problems encountered include: the large space that makes communications impersonal (Thomas et al., 2011); sense of isolation - being surrounded by mostly strangers (Mulryan-Kyne, 2010); large number of students that make inclusive discussions challenging (Herman, & Nilson, 2018; Maringe, & Sing, 2014; Mgeni, 2013; Shah, & Salim, 2013; Thomas et al., 2011; Ward & Jenkins, 2013); "sage on the stage" environment because of the remote location of the instructor and his/her inaccessibility (Thomas et al., 2011); theatre-like seating arrangement that encourages student passivity (Hanover Research, 2010; Mulryan, 2010). A number of organizational and teaching strategies have shown promising results in mitigating this problem, including use of student response systems (Caldwel, 2007; Camacho-Miñano & Campo, 2014), provision of online information and forums (Brown et al., 2010), use of electronic presentation aids (Mcknight et al., 2016), and fostering student-faculty interactions (Komarraju et al., 2010; Smith et al., 2013; Wolff et al., 2015).

In teaching this prerequisite course for health professionals' education for nearly a decade, we have found engaging pre-health professional students in our introductory courses a larger challenge than for higher level courses in the major (Hosler, & Boomer, 2011; Siva et al., 2018). One reason for this is that students enrolled in these classes are from varying academic backgrounds. Another reason is students' motivation to obtain high scores to meet the requirements for entry into highly competitive professional programs (Donnison, & Penn-Edwards, 2012; Mirghani et al., 2014). Learning seems to be primarily focused on extrinsic factors "learning how to obtain the best possible grade" rather than intrinsic factors "learning about actual content/subject area" (Donnison, & Penn-Edwards, 2012; Meeks et al., 2013).

The American Association for the Advancement of Science (AAAS), in response to a national review of STEM (Science, Technology, Engineering, and Mathematics) education, identified the need to change the preparation of undergraduates to meet the social, economic and environmental challenges of the 21st century. Their shared vision for undergraduate biology education (Brewer et al., 2009) provides numerous recommendations for teachers, one of which is a focus on student-centered learning. Engagement of students, use of multiple modes of instruction, outcome oriented, inquiry driven and relevant courses, collaborative learning (Barkley et al., 2014; Dambal, et al., 2015; Goodsell et al., 1992; Zgheib, et al., 2016;), and integration of multiple forms of assessment (e.g., peer evaluation and collaborative test taking) (Blanch-Hartigan, 2011; Rezaei, 2015) are some of the strategies emphasized.

The relatively high volume of undergraduate student enrollment into our introductory microbiology course (275 to 434 students per year, since 2009) has been a constant challenge to engaging students and facilitating their interest in the subject and topics being addressed in the course. Through applying the pedagogical principles and strategies recommended by the AAAS, an innovative teaching and assessment activity that involved team-based learning (Michaelsen, 1983; Michaelsen et al., 1982), use of technology, and peer-evaluation was adopted with an aim to improve student engagement and to provide better feedback and assessment. While active learning (Bonwell, & Eison, 1991) and collaborative learning (Dillenbourg, 2003; Vygotsky as cited in Amalia, 2018, p. 1-2) interventions have proven successful in increasing student performance in STEM courses (Freeman et al., 2014), we were also interested in determining if our addition of one integrated project into a course with a traditional lecture-based delivery would produce a detectable improvement in the correlated components of student engagement, learning approaches and longer term content retention.

Theoretical Framework

Two theoretical frameworks guided this study: the Deep and Surface Learning Model (Marton et al., 1997), and the Active Learning Approach (Biggs & Tang, 2011) derived from the Constructivist Model (Bonwell, & Eison, 1991; Dewey, 1998; Piaget, 1952; Vygotskij & Cole, 1981). According to the former, surface learning is when learners try to capture the general content of a lesson just enough to pass an examination and meet the minimum course requirements, whereas the deep learning approach includes significant efforts by learners to interact with the content of a lesson in order to gain greater understanding of the subject matter's meaning (Biggs & Tang, 2011). Consequently, surface learners may increasingly use rote memorization of course content while their counterparts (deep learners) often exhibit positive affect toward the subject matter and meaningfully interact with the course (Biggs & Tang, 2011; Dambal et al., 2015; Meseke et al., 2010). Unlike surface learning, deep learning is often a result of engaging students as active participants in series of active learning activities that are relevant to them and the learning context (Bonwell, & Eison, 1991; Dewey, 1998). According to Bonwell and Eison (1991), active learning involves instructional methods that provide students with meaningful, active, and experiential roles in the learning process. Dissimilar to passive learning (surface learning), active learning classrooms treat students as co-constructors of knowledge and the making of meaning. Active learning classrooms, therefore, allow learners to share personal knowledge and assimilate new ideas from instructors into their pre-existing knowledge, associate new ideas with old ones, and modify their prior understanding based on learned knowledge (Vygotskij, & Cole, 1981). Thus, active learning is often complemented by collaborative learning strategies where instructors create a classroom context with opportunities for learners to engage in common tasks, interact with each other, and share knowledge (Dambal et al., 2015; Kibble et al., 2016; Najdanovic-Visak, 2017; Yang et al., 2012; Zgheib et al., 2016).

In summary, these two learning theories indicate that students learn best and are able to apply new knowledge when: (a) they engage in a course through meaningful participation (deep learning), and (b) when pedagogies actively facilitate meaningful ways for students to engage in the acquisition, processing, and application of new course content. These theoretical principles motivated and guided the design of the intervention, data gathering, analysis, interpretation, and discussion of our findings.

Objectives

The main purpose of this study was to measure the impact of the introduced active learning activity on learning approaches, and content retention, as well as detect attitudes and actions consistent with increasing student engagement, and thereby support or refute our hypothesis that inclusion of this learning activity would have a beneficial impact on these three metrics. A secondary practical outcome was to examine the feasibility of a team-based work evaluation approach in our setting.

Method

Setting

At the University of Saskatchewan, biomedical science (BMSC) courses provide the foundations required for all health professions programs. Our study involved the introductory microbiology course BMSC 210. The course is taught twice a year (fall and winter terms) in large class settings. The course was initially designed to primarily target students with biomedical science majors in microbiology and immunology, biochemistry, anatomy and cell biology, physiology, and pharmacology. Course learning objectives expect that students will be able to (a) explain the fundamental differences between bacterial cells, archaeal cells eukaryotic cells, and viruses in terms of their structure, physiology, and genetics; (b) describe the ways in which microbes grow and reproduce and outline the basic physical and nutritional requirements for bacterial growth; (c) discuss the properties and uses of agents such as antiseptics, disinfectants, and antibiotics in controlling the growth of microbes and limiting disease; (d) describe the key elements of the human immune system, how it responds to foreign agents, and how agents such as bacteria and viruses can circumvent this response; (e) outline the ways in which pathogenic microorganisms can be transmitted between hosts and how transmission can be prevented; and (f) discuss examples of specific bacterial and viral infections from the point of view of how the infection process occurs and how it will eventually be resolved. This course also serves as a popular elective to other majors in multiple colleges. Students in four iterations of the course (2014-15) participated in the study.

The course is team-taught by three instructors, with each delivering specific modules. The primary method of teaching is lectures. Students are assessed using written mid-term and final examinations. With the introduction of the innovation, the assessment was modified to include instructor rating of digital posters (10% of grade) and associated peer assessments (8% of grade for poster reviews, 2% of grade for team-member reviews) generated as part of the intervention.

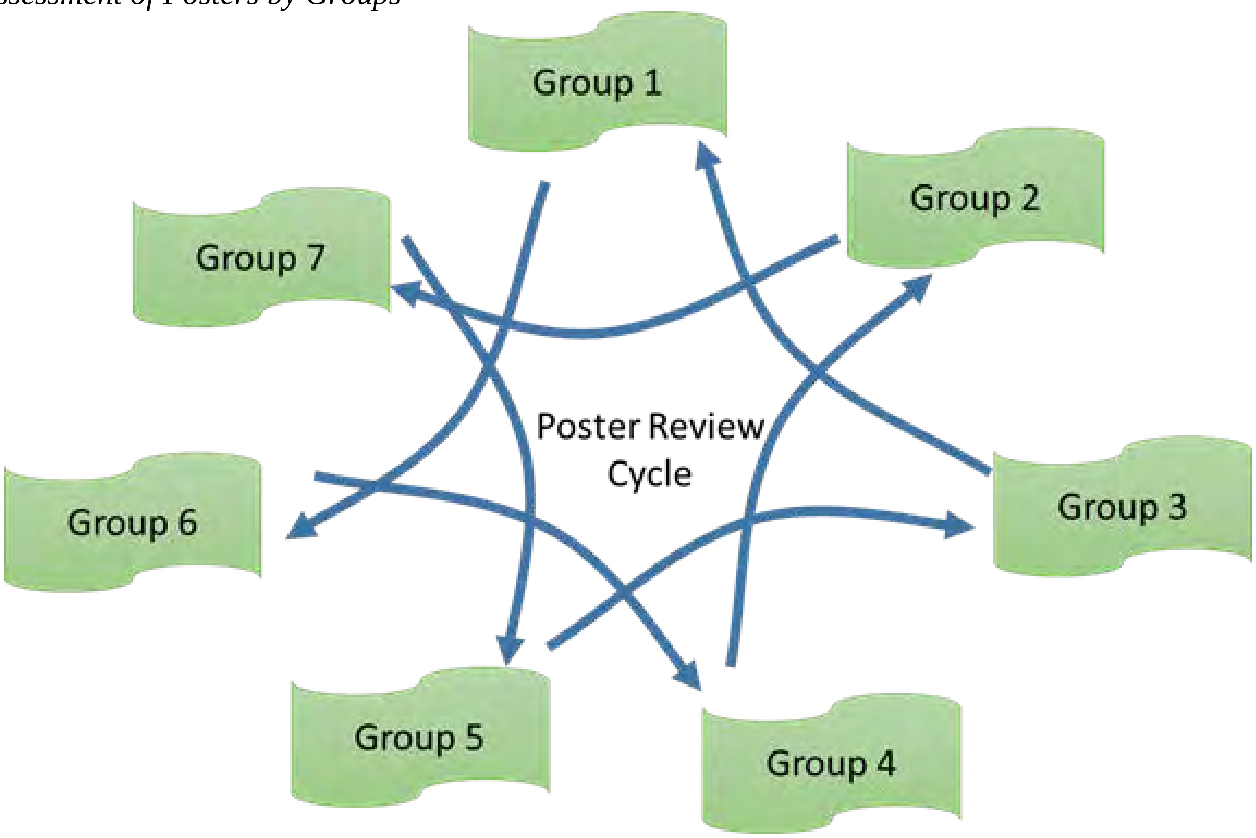
Intervention Design

The intervention involved the creation of digital posters by groups of students on topics of their choice during the course. The posters were assessed by both peers and instructors. At the beginning of the course, students were randomly divided into large groups (seven for the first iteration, four for subsequent). Each large group was further divided into random teams of three students (Figure 1). Student teams were tasked to create a PowerPoint digital poster (a single slide concisely conveying information in an easily understood and appealing fashion) on one of three areas of investigation: (a) Microbes in the News (allows students to explore all the ways microbes affect lives every day); (b) Interview a Local Scientist (provides an opportunity for students to see how it is possible to get from where they are, to actually conducting research); or (c) Microbial Topic of Your Choice (approved by the course coordinator). The latter topic allowed the students to pursue topics in microbiology that may have sparked their initial interest in the subject. These three options are all intended to allow the students to interact with the course information in a more exploratory and applied manner beyond the typical didactic format of a large class setting.

Production of a poster was purposed to allow focused re-iteration of the information in a more personal way that could then be shared with a large class and thus increase student exposure to a broader array of student-selected topics. This markedly differs from the approach our program had used to deliver introductory microbiology education in which all material was selected by and presented by instructors. Additionally, the students in each of the large groups were assigned to peer review posters submitted by teams from a different designated large group which exposed them to knowledge outside their team's task. To facilitate dissemination of their findings to their peers, all posters were made available to all students for viewing within the course site.

Figure 1

Peer Assessment of Posters by Groups



Note. The graphic represents the division of the student teams into seven major submission and review groups. Posters created and submitted by teams from a given group were assigned to be reviewed by students assigned to a separate submission group. The intent of this arrangement is to ensure students in each submission group are exposed to ideas explored by diverse teams and each submitted poster has had sufficient peer review.

Recruiting Scientist for Interviews

To facilitate the interviewing of local scientists by a student team, an email cover letter was sent to individual local faculty and government scientists involved in some aspect of microbiology, virology, or immunology and whose research interests could be gleaned from their web page statements. The letter stressed potential benefits to the students as well as the interviewee and laid out expectations of what the interview would entail and the expected time commitment. Principal investigators were also encouraged to provide contact information for trainees in their labs at post-doctoral, Ph.D., and M.Sc. levels as well as senior undergraduates participating in research projects in order to provide an opportunity for interviews with scientists at various levels of advancement in the field. The positive response rate was very high allowing for an excess of volunteers over requests for interviews in each course iteration included in this study.

Recruitment of Students for Post-Intervention Focus Groups

Students from each of the courses were recruited by email invitations for focus groups. The invitations cumulated in three focus groups with 5-6 students per group. All focus groups discussions were audio-recorded, with participants' permission, and transcribed verbatim for analysis. The completed transcripts were subjected to regular coding using N Vivo; a research assistant was hired to code and come up with themes (KP also coded), and consensus on themes was attained. Students volunteered; incentivized by provision of lunch. The resulting student volunteers participated in focus groups facilitated by the author (KP), who was involved in the study, but not in the teaching of the course. As such, the students felt free to express their views on the intervention to the facilitator.

Evaluation

At the beginning of each course, students were oriented to our study's assessment process by one of the authors (KP). In addition, a pre-course online survey was administered to collect demographic and background data such as type of major, gender, prior knowledge level of subject, among others.

Peer Assessment of Posters

Each individual student was tasked with reviewing eight posters created by teams from another large group. This arrangement was devised to have separate periods of time when students in each group would be focused on either creating their poster or having access to posters created by students of another group (Figure 1). It was anticipated that separating the two assignments (i.e., creation of a team poster and peer-reviewing posters) would extend the out of class exposure of students to new ideas beyond those covered in lectures (in recent offerings this process has been more efficiently streamlined, see lessons learned). To facilitate efficient peer review, an online survey tool (Fluid Surveys) was utilized to collect student reviews. Three individual surveys were designed, one for each poster topic area (Appendix A). In the first iteration of the course included in this study, these were sent to students as individual surveys. For the second and subsequent iterations, the surveys were combined into one branching survey in which the student completing the peer review survey would select the topic area of the poster being reviewed and be branched to the relevant survey questions. Surveys were not anonymous (students received credit for completing) and included open ended questions to ensure that the reviewing student had read and understood the poster. This approach allowed the instructor to assess whether the student had met one of the principle intentions of the review process which was to extend exposure to topics in the subject area that were beyond those addressed in lectures. At the end of the course, each team received the collated freeform comments (minus source identifiers) from classmates that reviewed their poster using the survey tool (in recent offerings, this valuable information is provided earlier as formative feedback – see lessons learned).

Students were briefly walked through the survey rubrics during class time. Students were provided two weeks to complete all reviews. Grading of each review was scored as complete or incomplete, with full marks awarded for each complete review and a mark of zero for incomplete reviews. Each review was weighted 1%, equaling 8% of the final grade (in subsequent offerings this has been reduced to 0.5% per review for a total of 4% of the final grade with no ill effects).

Poster Assessment Rubrics

Rubrics for poster assessment were created by the authors for each of the three poster project topic areas using criteria, descriptions and performance levels (Appendix B). Criteria included organization, grammar and spelling, creativity, and science content as well as topic-specific categories such as science content and literacy, interview facts, newsworthy facts, and links to science facts and thoughts, for Microbial Topic of their Choice, Interview a Scientist, and Microbes in the News, respectively. The rubrics were shared with students at the beginning of the course in order to strategically provide direct guidance to students as they researched relevant information needed to complete their posters.

Team Participation Assessment

To encourage full participation of team members in the poster project, each member was required to evaluate every other team member on level of contribution, participation, and demeanor as well as include any comments using an online survey tool developed with Likert scale questions on contributions in various categories including work tasks, leadership, team cohesion, communication and quality of work as well as an open text comment section (Appendix C). It was anticipated that prior knowledge of the team member peer evaluation expectation would encourage more student participation. The peer evaluation process would also help instructors identify problem students by triangulating data, since every student was evaluated by two peers. In addition, each student had to submit a review of their own performance and contribution. To facilitate team communication and collaboration the individual teams were created and given space within the learning management system (Bradford et al., 2007). Team member participation survey results were held in confidence by the course coordinator.

Pre – and Posttest Survey Instruments

Both baseline and post-test assessments of student motivation and learning approaches was done using the Motivated Strategies for Learning Questionnaire (MSLQ) (Crede & Phillips, 2011; Pintrich & Groot, 1990) and the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) was used (Kember et al., 2004), respectively. The MSLQ is an 81-item instrument that uses a 7-point Likert scale (Very true of me - Not at all true of me). It consists of two sections: a Motivational Section and a Learning Strategies Section.

The Motivational Section appraises goals and value beliefs (e.g., a student's beliefs about skill to succeed and anxiety about tests in a course). The Learning Strategies Section assesses the use of different cognitive and metacognitive strategies and student management of different resources. This instrument has been extensively used and reportedly has an acceptable reliability and validity (Pintrich & Groot, 1990; Pintrich et al., 1991), though the validity of some components is now coming into question (Tock & Moxley, 2016). The R-SPQ-2F is a 20-item instrument that uses a 5-point Likert scale. It is used to identify the learning (surface or deep) approaches used by students in a course (Kember et al., 2004), and has high validity and reliability (Mogre & Amalba, 2014; Xie, 2014).

Retention Assessment. Students enrolled in the courses were contacted six months to one year after completion of the course to complete an online survey that tested their recall of poster topics and content. Students were asked to give the category and title of their poster (without referring to resources) and provide two key points they remember relating to the content of the poster. The quality of the key points was rated on a 4-point scale (1-remembers nothing; 2-remembers something, but irrelevant; 3-remembers something of importance; 4-remembers key facts relating to subject) by authors KP and HB independently. Average rating above 2 was considered as content retention.

Intervention Effectiveness Assessment. Three focus groups were held with students to gather qualitative data on the effects of this innovative assignment. The students were asked to give their views on the quality of the assignment, process of assessment, impact of the assignment on their learning, career path and workload.

Analysis

The data collected from different cohorts of students were pooled and analyzed using SPSS v 14.0 software. The qualitative data from focus groups were transcribed, coded, and analyzed for themes. Descriptive statistics of the sample were generated using means for continuous variables and counts with proportions for categorical variables. The number of students undertaking each poster type, the instructor's grade, and distribution of frequencies of recall categories at 6-12 months post intervention were similarly described. Mean pre-intervention and post-intervention levels of deep and surface learning were compared for the students as a whole using the Independent T-test. Qualitative content analysis was done on focus groups data to derive relevant themes on the intervention's effectiveness.

Ethics Approval

This study was approved by the Behavioral Research Ethics Board of the University of Saskatchewan. The students were oriented to the study at the start of each course and informed consent was obtained from all participants.

Results

Participants

Of the 821 students enrolled in the course over the four iterations, 238 participated in the study, of which 76.5% (N=182) were female. In terms of cognitive load during the term, on an average, courses equivalent to 14.5±3.96 credits (full load=15 credits) were being taken by students. Outside classes, a majority of students (56.5%) mentioned that they were not working, while 22.8% worked 1-10 hours/week, 15.8% worked >10-20 hours/week and 4.9% worked for >20 hours/week.

Table 1 shows the distribution of students based on their major subjects in undergraduate training. 63% of students were in their second year of an undergraduate program, 21% in third, and 10% in fourth year. Figure 2 illustrates the students' perception of knowledge in microbiology and immunology prior to taking the course. On the whole, the students expressed some knowledge in the subjects. While only 37 % of these students expressed an interest in pursuing scientific research as a student or professionally in microbiology and immunology, 63% expressed research interest in other basic science subjects. The majority of students were taking this course as a program requirement.

Table 1
Demographic Distribution of Participants by Majors

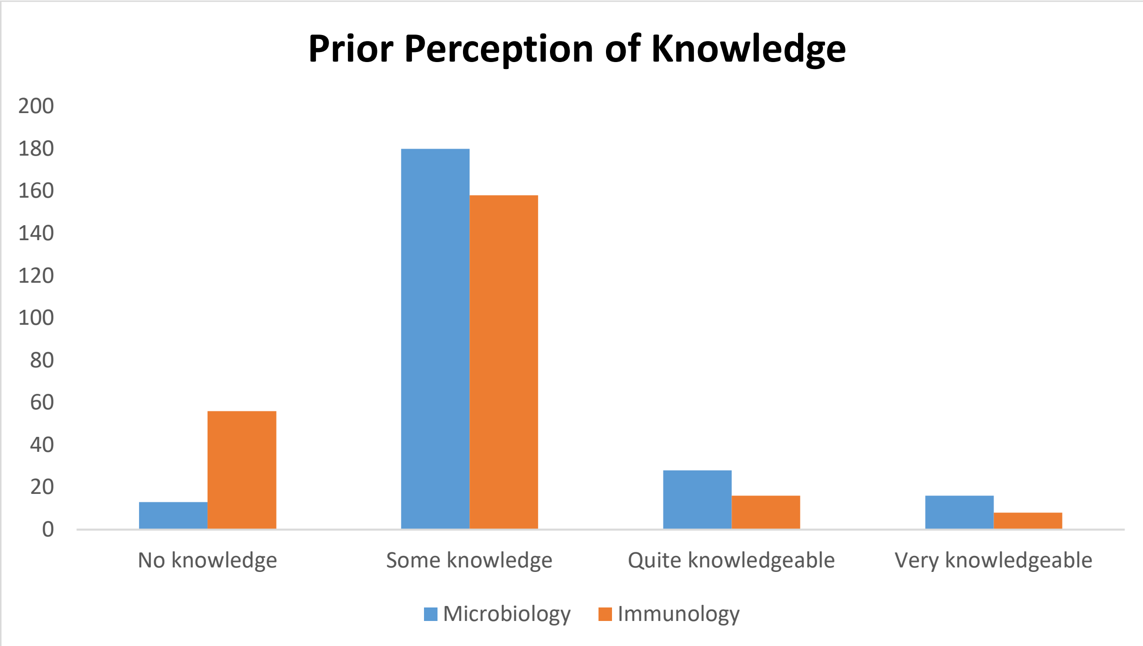
Variable	Frequency (*n*)	Percentage (%)
Nursing	3	1.42
Microbiology & Immunology	21	9.9
Biochemistry	26	12.26
Anatomy & Cell Biology	31	14.62
Biology	33	15.57
Physiology & Pharmacology	76	35.85
Others	12	5.66
Not applicable	10	4.72
Missing	27	

Notes. Distribution of students by majors. Students were asked to identify their major as part of the study survey. Numbers have been combined across the four offerings reported in our study.

Digital Posters

A total of 194 posters were created by the students in the four course offerings. Table 2 shows the number of posters based on the categories chosen. All three categories were of equal interest to students.

Figure 2
Students' Perception of Knowledge in Microbiology and Immunology Prior to the Start of the Course



Note. Students were asked to reveal their perception of how much they knew about microbiology and immunology prior to the start of the course. Numbers have been combined across the four offerings reported in our study.

Table 2
Distribution of Category of Posters as Chosen by Students and Grades

Category of Poster	Number of posters *N* (%)	Average Grade (by Instructor) /10 (Standard Deviation)
Interview a Scientist	61 (31%)	8.66 (SD 0.79)
Microbe in the News	63 (33%)	8.65 (SD 0.86)
Team chosen Topic	70 (36%)	8.60 (SD 0.95)

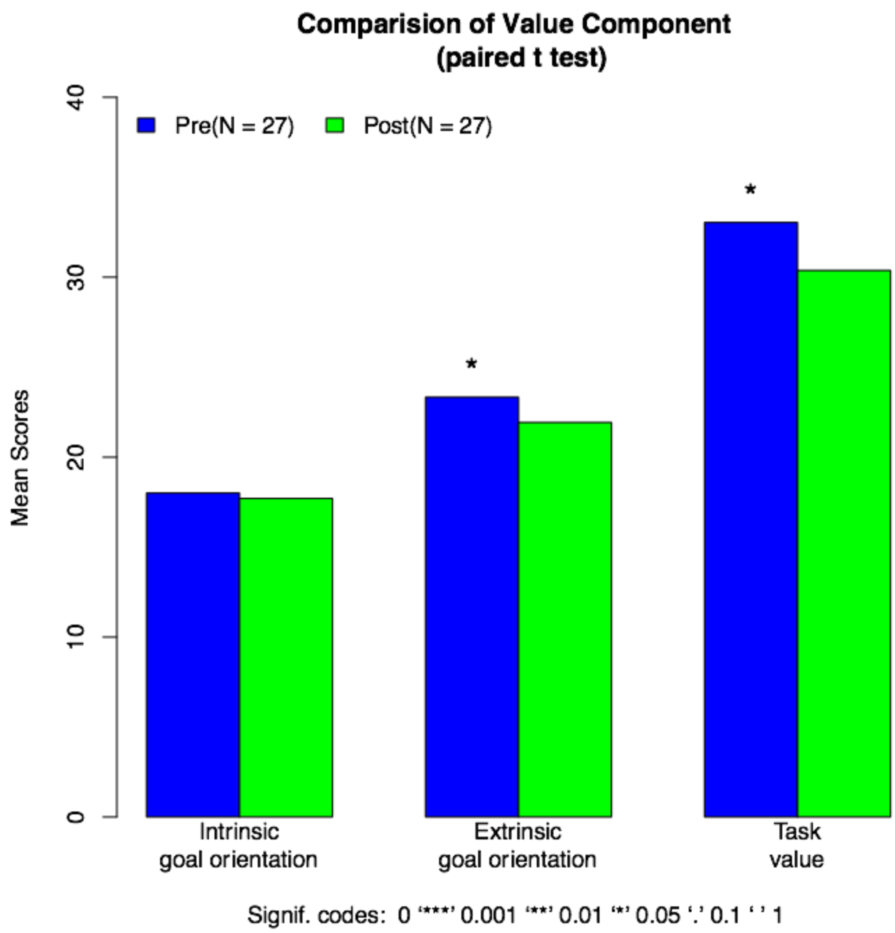
Motivational Analysis (MSLQ)

Pre-posttest results showed several improvements in the different domains of students' motivational orientations and use of learning strategies. Results from the Motivation Scale of the MSLQ showed different pre-posttest changes. On the Value Component of the scale (Figure 3), we observed a significant drop in students' extrinsic goal orientation ($p < 0.05$). Furthermore, Figure 4 also showed a significant reduction in the Affective Component ($p < 0.00$): test anxiety at the end of the course as compared to the scores at the beginning of the course. However, there was a significant reduction ($p < 0.001$) in students' post-intervention self-efficacy for learning and performance (Figure 4).

Pre- and post-test variations in the Learning Strategies Scales of the MSLQ were also observed. Particularly, on the Cognitive and Metacognitive Strategies domain, significant drops were observed in students' organization ($p < 0.05$) and critical thinking ($p < 0.05$) (Figure 5). In addition, there were improvements in self-regulation as well (Figure 5). Improvements were seen in the Resource Management domain of the MSLQ (Figure 6). For instance, post-intervention results (Figure 6) showed a significant drop in all areas, especially, time and study environment ($p < 0.05$) and help seeking ($p < 0.05$) among students. Although not statistically significant, reductions were equally seen in students' effort regulation and peer learning activity.

Figure 3

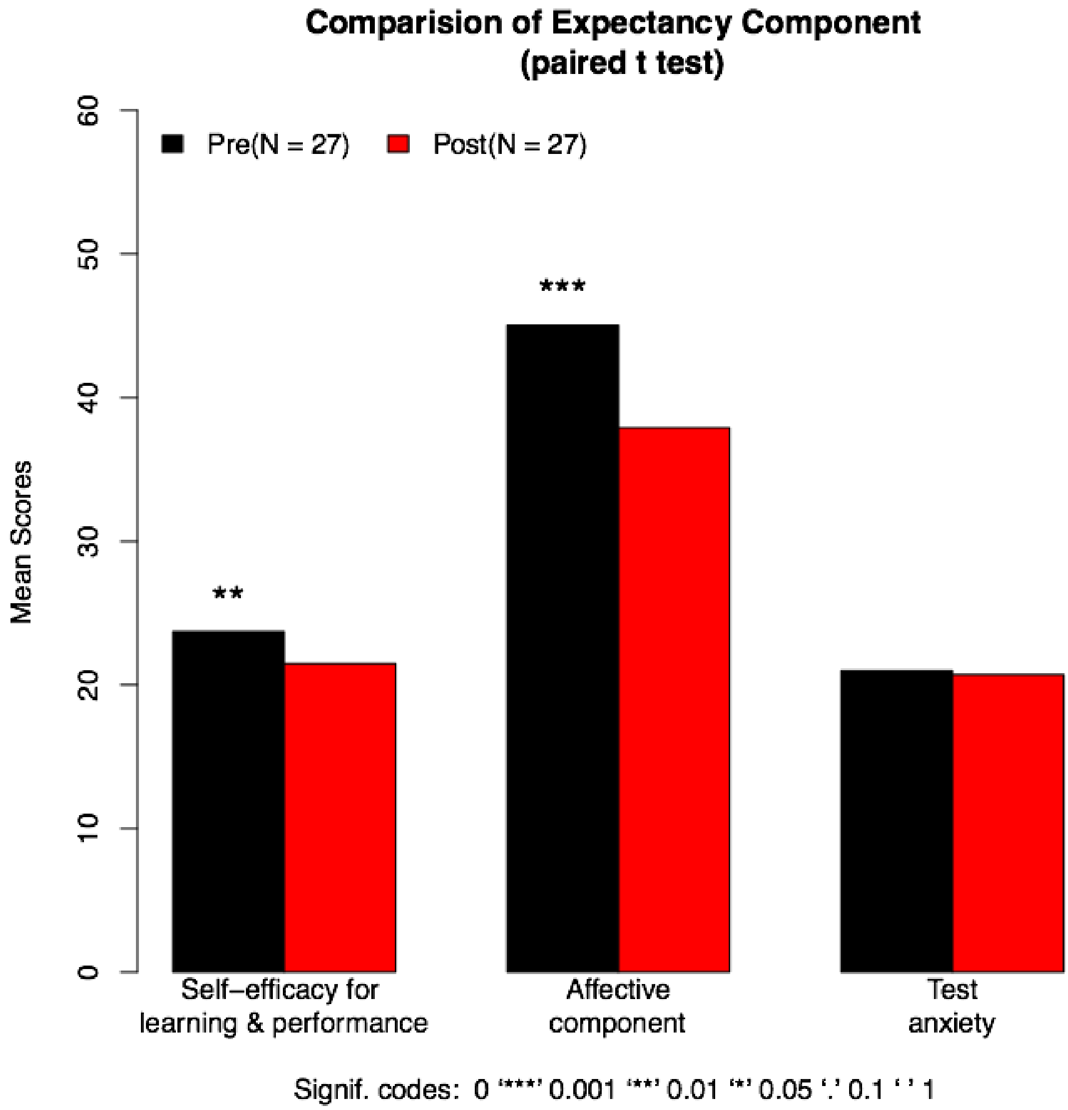
Changes in Students' Motivational Orientations in Pre- and Post-Course



Note. Changes as determined by the MSLQ that was administered online. Pre – course N=27; Post-course N=27. * $p < 0.05$. A significant drop was recorded in extrinsic goal orientation and task value scores.

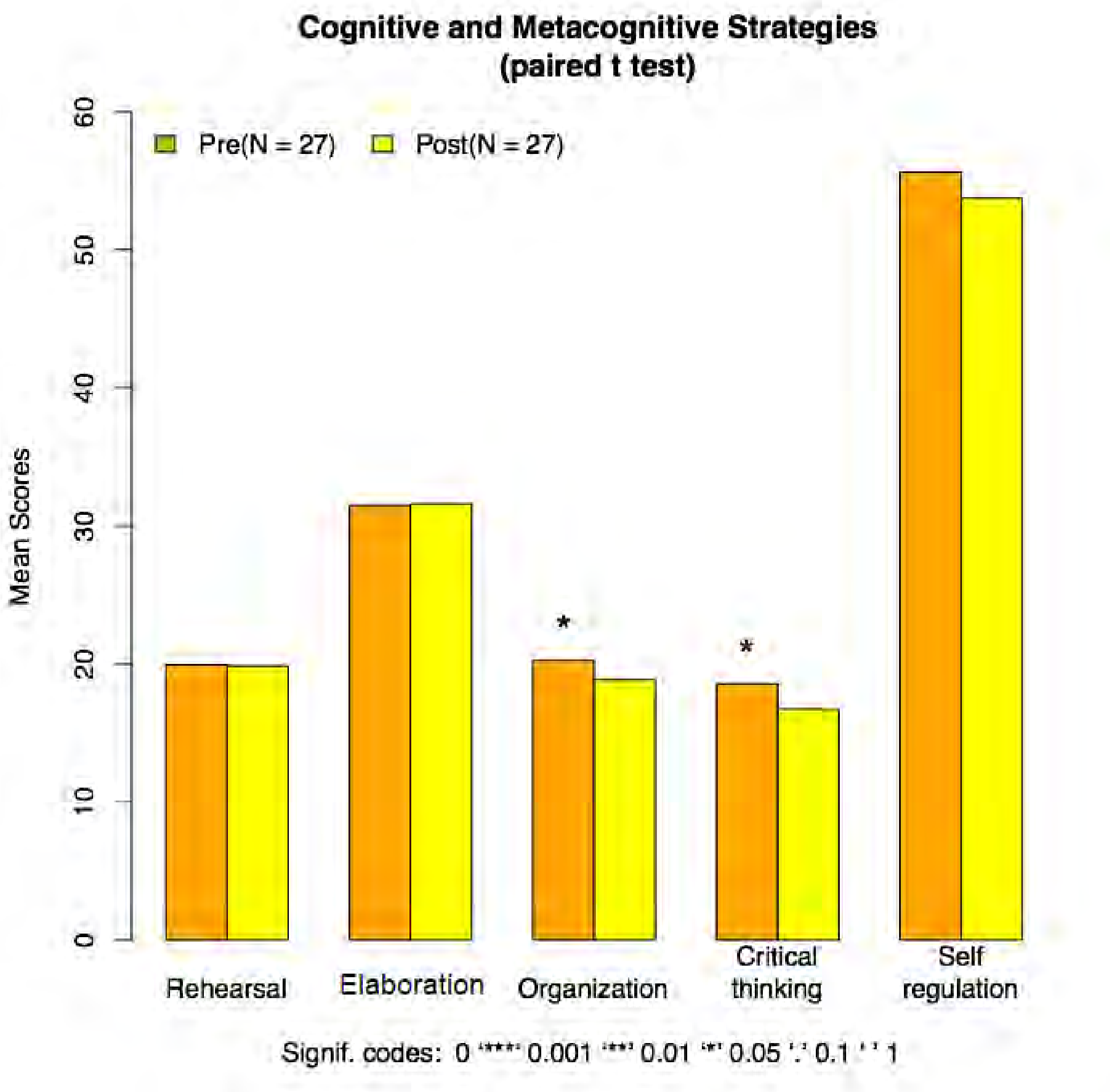
Figure 4

Changes in Students' Motivation and Use of Learning Strategies Pre- and Post-Course



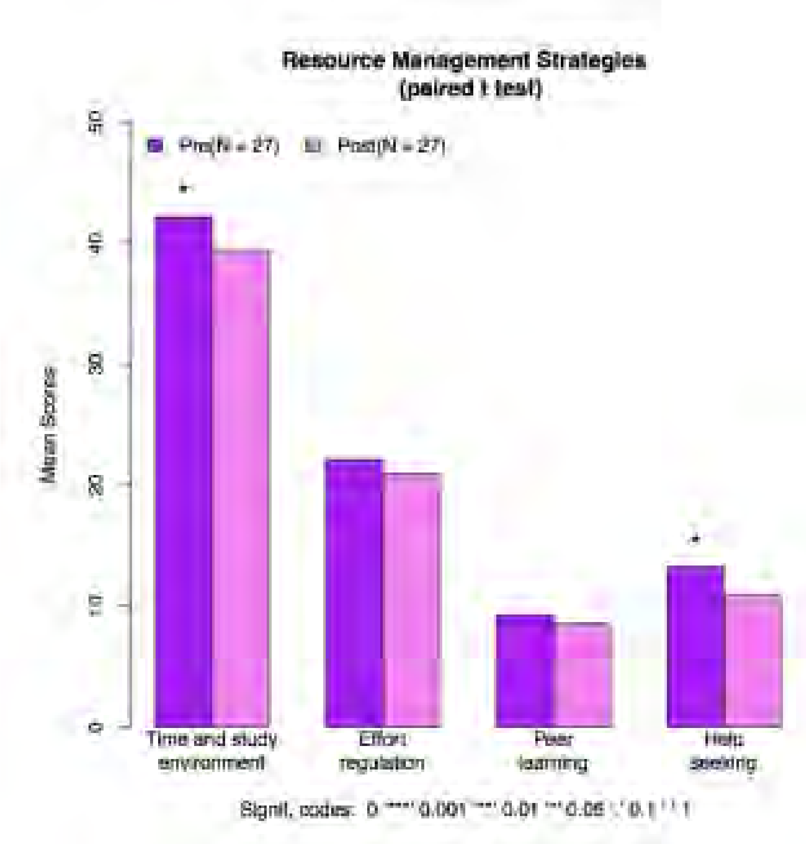
Note. Changes as determined by the MSLQ that was administered online at the beginning and end of the course. Pre – course *N*=27; Post-course *N*=27. ** $p < 0.01$, *** $p < 0.001$. It shows a significant reduction in post-test self-efficacy and affective component scores.

Figure 5
Changes in Students' Use of Learning Strategies Pre- and Post-Course



Note. Changes as determined by the MSLQ that was administered online at the beginning and end of the course. Pre – course *N*=27; Post-course *N*=27. * $p < 0.05$. There is a significant reduction in post-test organization and critical thinking scores.

Figure 6
Changes in Students' Use of Learning Strategies Pre- and Post-Course



Note. Changes as determined by the MSLQ that was administered online at the beginning and end of the course. Pre – course *N*=27; Post-course *N*=27. * $p < 0.05$. It shows a significant reduction in post-test scores in help seeking, and time and study environment.

Learning Strategies Analysis (R-SPQ-2F)

The post-test results (Figure 3) revealed a significant decline in students' engagement in surface learning ($p < 0.001$) and a significant rise in their use of the deep learning strategy ($p < 0.05$).

Focus Groups

Three focus groups were conducted after completion of the course. Several important themes (i.e., intervention success factors) were discovered from the thematic analysis. First, we found that the activity increased student engagement in the course. Most of the participants indicated that the course was interactive. One of the participants stated, "I liked it because it was more interactive than just assignments or going to lectures every day." This was an important benefit for a majority of participants in the study.

A second emerging theme associated with the intervention was the importance of group activity – meeting and working with new people. Some participant statements regarding this theme included: "I liked it because it was more interactive than just assignments"; "it was a good way to meet people"; and "the only thing I learned – it was just sort of how to communicate with different people I wouldn't usually talk to or communicate with."

This group work component seems to have increased students' competency in teamwork and communication, and helped them build conflict resolution skills, as we discovered that conflict occurred among some teams and students had to learn to resolve it. As one participant noted "…eventually we're going to have to work with people. We have to collaborate and so getting to know this and getting to deal with people who are A type or B type, really helps."

The third theme was content related—obtaining new knowledge which was not part of the formal course. Two statements of participants supporting this theme were: "I had never heard about this microorganism before so it was neat to learn about something new and something that is so important to the earth's ecosystem."; and "I found the facts about Herd immunity quite interesting. I didn't know only 95% vaccination rate was required for herd immunity" (students' comments following peer evaluation of poster). Interestingly, most of the participants did not find the workload involved in the intervention challenging. According to one participant "It was a reasonable amount of work, it wasn't overwhelming." Another participant also indicated that "It was like a decent amount of work for the weighting – 10%. I guess it's 20% with all of the evaluations and stuff. It almost seemed like easy points to be honest. So that was good. I like that." This is an important finding, as it would have been rather quite challenging to implement the intervention if participants had perceived the workload negatively.

Content Retention

One hundred and seventy-five students responded to the online survey sent six months to one year after completion of the course. Interestingly, all students remembered the category of their posters and the title. The average score was 3.03 (SD ± 1.00), thus close to half (42%) of students remembered something key about their posters months after completing the course.

A distribution of students based on scores as rated independently by authors is provided (see Table 2). Among the group that interviewed a scientist, 12% did not recall anything relating to their poster, 13% remembered something, but irrelevant, 32% remembered something of importance, and 43% remembered key content relating to the poster. In the second group (Microbe in the news), 3% could not recall anything about their poster, 25% recalled something irrelevant, 37% recalled something important, and 35% recalled something key relating to their poster. Also, among the last group (Team chosen topic), 6% failed to recall anything associated with their poster, 17% remembered something, but irrelevant, 27% recalled something of importance, and 50% recalled key content about their poster. Combining all groups, 7% were unable to recall anything about their poster, 18% did recall something, but irrelevant, 33% recalled something of importance, and 42% remembered some key content relating to their poster.

Discussion

It was no surprise finding more females than males in this course, as previous studies have already shown this in Canadian higher education (Tercotte, 2011). However, to reiterate the challenges faced in motivating students in undergraduate biology education (Tercotte, 2011), most students expressed that they were taking this course because it was a requirement, and only 33% stated that they may pursue research in these subjects as a career path.

In 2009, a Vision and Change national conference resulted in a call to action to improve teaching and learning of undergraduate biology (Tercotte, 2011). Some of the needs identified were to facilitate active learning, for students to understand how closely science is integrated within society, to increase competency in communication and collaboration, to be current in biology, and to have experience with modelling, simulation, computational, and systems level approaches to biological discovery and analysis (Tercotte, 2011). The introduction of student team-created digital posters in the curriculum of our course puts into action many of the needs identified.

Our qualitative results revealed several outcomes of the intervention. First, the active learning assignment we incorporated into our introductory microbiology course helped to increase student engagement in the course, which seem to have made some impactful changes on them (Bonwell, & Eison, 1991). For instance, it seems students did not only gain competence at creating posters and providing effective feedback (Dupras, & Edson, 2011; Spandorfer et al., 2013; Vickerman, 2009), but were also able to retain and recall content of their posters six months to one year after the intervention (Dambal, et al., 2015; Najdanovic-Visak, 2017; Yang, Woomer, & Matthews, 2012; Zgheib, et al., 2016).

There are several implications of our qualitative results. The above average recall of important poster content among students who researched “Microbes in the news” seems to suggest that this group reflective exercise may have helped students stay current on relevant science and other relevant topics (that are part and parcel to multiple integral facets of everyday life and global society), as well as evoked interest in their peers who undertook the peer review (Tsang, 2011).

Students who chose to interview scientists seem to have also benefited from the activity as they had an opportunity to explore the scientists’ lived experiences, which perhaps contributed to their superior recall of key poster content after the intervention. The experiential learning (Dewey as cited in Miettinen, 2000) component of exposing students to a real scientist variously engaged in the multiple, varied career paths may have enabled the students to begin to appreciate the diversity of career choices that are open to them (Coker, 2009).

Moreover, the highest post-intervention recall of key poster information was among the “Team chosen topic” group, which seems to indicate that the freedom to choose their own topic may have elicited more effort and intrinsic interest in students of this group, hence leading to more cognitive investment. Freedom to choose a topic may thus be an essential facilitator in interactive engagement of students in this intervention.

Other important qualitative findings included an increase in students’ engagement with the course content (as one participant reported, “I liked it because it was more interactive than just assignments or going to lectures every day”); the relevance of team work to the success of the intervention (it offered participants opportunities to socialize, develop interpersonal communication, conflict resolution, and collaborative skills); and the presence of a strategic indirect way to guide to students outside of the classroom during their research activity. We found students’ positive perception of the workload to also be a significant facilitator in the success of the intervention.

The significant increase in deep learning and decrease in surface learning aligns strongly with the desired outcome of our intervention. This finding agrees with previous evidence on surface and deep learning (Biggs & Tang, 2011; Dambal et al., 2015; Marton &Saljo, 1976; Meseke et al., 2010). The intention of some students was to understand the meaning (deep approach) while other students primarily wanted to reproduce what they had learnt (surface approach). Similar approaches to learning have been found to correlate with the learning activity as well as student motives (Biggs & Tang, 2011; Entwistle et al., 2001). These approaches are, however, changeable and can be influenced by factors in the learning environment, student's prior knowledge, among others (Gijbels et al., 2014). Thus, our observed retention of poster-content knowledge six months to one year after completion of the course is in line with the evidence (Emke et al., 2015; Marton & Saljo,1976) and indicates that this assignment was impactful. It is possible that some of the active, collaborative, and experiential learning elements of our poster creation activity were at least in part responsible for the measured increase in deep learning.

In terms of motivation, the mixture of both positive (e.g., less dependence on external motivation, drop in test anxiety) and negative findings (e.g., drop in task value, self-appraisal), makes it difficult to interpret and draw conclusions regarding changes in motivation. Our observation of a drop in students' posttest value component implied a reduction in external motivations that drive the students' perception of the importance of and interest of the poster creation activity (Pintrich, & Groot, 1990). This was supported by a corresponding drop in the students' affective component scores (i.e., test anxiety) (Pintrich, & Groot, 1990). Although students' expectancy component scores (i.e., self-efficacy) dropped as well, we believe this does not contradict the success of the intervention as it is expected students may experience some amount of self-doubt being exposed to this kind of activity for the first time (Pintrich & Groot, 1990). Thus, it is no surprise there were improvements in the students' post-intervention self-regulation and resource management scores. Also, the reduction in students' post-intervention organization and critical thinking skills may have been linked to their self-reported low sense of self-efficacy/control and the fact that this was an unfamiliar activity they were encountering for the first time. However, contrary to our expectation was the decline in students' help-seeking, as one would expect students with a perception of low self-efficacy to be willing to seek extra help. Further investigations are required by future studies in order to help clarify these findings.

Notwithstanding these results, our poster creation activity utilized several strategies which may have leveraged on student's intrinsic motivation (Kyndt et al., 2011). Providing the choice for students to choose topics in their area of interest and connecting microbiology to the non-academic world by encouraging students to look at current news as well as interview scientists are examples. As reported by others, the greater the students are intrinsically motivated, the more they are likely to adopt a deep approach to learning (Kibble et al., 2016; Schmitt-Harsh & Harsh, 2012; Kyndt et al., 2011). The increase in deep approach to learning and decrease in surface approach in this study, and the linkage of the topic to the outside world (Bozzone & Doyle, 2017), as expressed by students in the focus group, reiterates that such forms of student engagement has great potential for engaging students with the topic and with learning, even in a large classroom setting.

Lessons Learned

Creating functioning small teams from randomly assigned students in the class is not always successful. During each offering of the course there was at least one team that expressed an inability to work well together. The reported difficulties included personality clashes, different desired levels of achievement and corresponding effort invested, as well as difficulty scheduling common times to work together. Ideally, dedicating time to team development exercises and utilizing published team-building frameworks for team creation would very likely further improve team collaboration outcomes. However, even without specific team training a very large proportion of the randomly assigned teams were functional and many students informally commented on enjoying meeting and working with new people.

Provision of individual student comments back to the teams that created each poster was provided as summative feedback during the course of our study. We have realized this information would have a more significant impact if provided as formative feedback after submission of a draft version of the team poster. Ideally, teams would then be allowed an opportunity to modify their posters for submission and summative assessment. We have recently altered the project to have a first submission that is peer reviewed. Comments given for each specific poster are then provided back to the posters' authors and that feedback in parallel with TA grades and comments (using the grading rubrics) is considered in creating the final version that is submitted later in the term and graded by the course TA using the same grading rubric. Draft submission is weighted at 3% of the course grade, and final submission is weighted at 6% of the course grade. We have also included a near-end of term Poster Day event where students are able to present their posters. These two modifications have been very well received.

Team work peer evaluation was observed to be of only moderate usefulness in determining contributions from individual students in cases of conflicting reports on participation. This was due to many students simply clicking on the "good" response for all questions and not adding any comments. As a result, some teams had only one student reporting a problem. This information makes it difficult to resolve personality conflicts from lack of participation. Since the collection of data for this study, the teamwork peer evaluations have been modified to include the mandatory free text question, "What did this team member do in preparing your team poster?" A second check box type question has also been added which asks, "What do you feel would be fair given this team member's efforts?" The response choices are "This team member's grade should be: reduced 10% relative to the rest of the team; the same as the rest of the team; increased 10% relative to the rest of the team; zero: this team member did not contribute." The inclusion of these two questions has eliminated many ambiguous participation questions. For example, one student may indicate that student x has contributed nothing, however if the third student lists a number of contributions of student x, and these are collaborated by student x's self-evaluation, it is apparent the first student was either ill-informed or had a personal conflict with student x.

Organization and timing of each of the individual aspects of the team projects is not a trivial exercise. Grading of peer reviews and peer poster reviews was by necessity accomplished by counting the number of complete reviews submitted by each student. Note, this approach was deemed acceptable for the goal of the assignment, which was explicitly to enhance the diversity and amount of content explored by each student. Capturing this data would have been prohibitively laborious without the online survey tool, which provided the ability to download the complete data set for each survey in a spreadsheet format. Sorting and counting (done in Microsoft Excel) required at least an intermediate understanding of Excel commands and functions. Sharing of peer review open-ended poster comments required collating comments for each individual poster and emailing those responses to each individual team. This was moderately time intensive, requiring a number of hours in total. In addition, any increase in the number of assignments will proportionally increase the number of enquiries from students asking for clarification on specific points. Email communications increased significantly as a result of introduction of the project. Given the increase in workload, it is vital for large class instructors implementing such active learning interventions to be supported by teaching assistants.

Limitations

Although a significant change in approaches to learning was seen, it has to be acknowledged that other parallel activities that students were involved in during the administration of the course may have influenced the approaches as well. Given that students from various academic backgrounds were admitted in this course, it was not possible to identify such influences. Unfortunately, our data analysis did not consider the influence of demographic variables in the outcome of the intervention for different participants including age, gender, and different backgrounds of participants among others. Although our findings may generalize to other similar class settings, we cannot advance such an assertion in the current study. Also, not every participant completed both the pre and post course questionnaires, and as a result some data collected may be subject to bias and further limit the generalizability of our results.

Future Studies

It would be of interest to determine whether student skills developed through working on their poster projects transferred to their future academic studies and whether any distinguishable patterns emerge in relation to student pre-course variables and or post-course variables. One of the key takeaways from this study is the feasibility of designing and delivering a cooperative and active learning activity to larger introductory STEM courses that cater to both majors and non-majors. It would also be of interest to do a longitudinal study to directly enquire as to whether the "interview a scientist" activity resulted in a subset of students choosing to pursue a career in research.

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Appendix A
Poster Review Survey Questions

Category – Microbes in the news.

Q1. What is your name?
Q2. What is your student number?
Q3. What Group is the poster you are reviewing?
Q4. What Team is the poster you are reviewing?
Q5. What category of poster is this? (choose from a pull-down menu of the three types)
Q6. – Q9 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “News Worthy Facts. Provide the answer that best reflects your analysis of this poster:
Q6. There was a news item reported on that is relevant to this course.
Q7. News story was integrated with other known “facts” on the microbe.
Q8. There was evidence of excellent use of additional resources beyond the news story.
Q9. Current research areas relative to the news story were presented.
Q10. What aspects of the news story presented, or the microbe behind the story did you find the most interesting or new to you? Why?
Q11. What additional directions of research would you like to see investigated on this topic? Why?
Q12-16 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “Grammar, Spelling and Creativity”
Q12. Organization of the poster aided my ability to understand the content.
Q13. All required sections were present and clear.
Q14. There were no grammatical and spelling mistakes.
Q15. The presentation style was engaging and stimulating.
Q16. This poster revealed that its creators were interested in the topic, and motivated to put in sufficient time and effort.
Q17. What suggestions can you provide the creators of this poster to improve for next time?
Q18. Have you completed all questions above? (Yes/No choice button).

Category – Team chosen topic

Q1. What is your name?
Q2. What is your student number?
Q3. What Group is the poster you are reviewing?
Q4. What Team is the poster you are reviewing?
Q5. What category of poster is this? (must choose from a pull-down menu of the three types)
Q6. – Q9 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “Science content and literacy. Provide the answer that best reflects your analysis of this poster:
Q6. Poster had concepts fully and properly explained.
Q7. Content was accurate and well supported.
Q8. Resources/references were used to the most advantage.
Q9. Topic chosen was relevant to this course.
Q10. What aspects of this topic did you find new or the most interesting? Why?
Q11. How did the poster information relate to what we have addressed in this course?
Q12-16 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “Grammar, Spelling and Creativity”
Q12. Organization of the poster aided my ability to understand the content.
Q13. All required sections were present and clear.
Q14. There were no grammatical and spelling mistakes.
Q15. The presentation style was engaging and stimulating.
Q16. This poster revealed that its creators were interested in the topic, and motivated to put in sufficient time and effort.
Q17. What suggestions can you provide the creators of this poster to improve for next time?
Q18. Have you completed all questions above? (Yes/No choice button).

Category – Interview a scientist

Q1. What is your name?
Q2. What is your student number?
Q3. What Group is the poster you are reviewing?
Q4. What Team is the poster you are reviewing?
Q5. What category of poster is this? (must choose from a pull-down menu of the three types)
Q6. – Q9 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “Interview Facts”. Provide the answer that best reflects your analysis of this poster:
Q6. The interviewee’s educational path was well explained
Q7. Interviewee’s initial interest in science was well explained
Q8. The interviewee’s current interests were logically presented and understandable.

Q9. The poster placed the interviewee’s work in a broader context.
Q10. What aspects of the interviewee's educational/career path were surprising/of most interest to you? Why?
Q11. What additional question(s) would you have asked the interviewee if you had performed the interview? Why?
Q12-16 are Likert scale questions with answer choices of “Strongly Disagree” “Disagree” “Neutral”
“Agree” and “Strongly Agree”. Lead in statement “Grammar, Spelling and Creativity”
Q12. Organization of the poster aided my ability to understand the content.
Q13. All required sections were present and clear.
Q14. There were no grammatical and spelling mistakes.
Q15. The presentation style was engaging and stimulating.
Q16. This poster revealed that its creators were interested in the topic, and motivated to put in sufficient time and effort.
Q17. What suggestions can you provide the creators of this poster to improve for next time?
Q18. Have you completed all questions above? (Yes/No choice button).

Appendix B
Poster Grading Rubrics

BMSC 210.3 Poster Rubric – Microbes in the news

Relative Weighting	Category	Unsatisfactory	Basic	Proficient	Advanced	Grade
5	Newsworthy Facts Links to Science facts and thoughts	• Definitely a microbe in the news, but no explanation about what else is known about the bug	• Here's "The Story" but very little expansion on the topic • Very brief discussion of what else is known about the microbe in question • Only a brief statement of current investigations	• Evidence of integration of the news story with known facts on the microbe • Clear and lucid explanation of current investigations	• Excellent integration of the news story with known facts on the microbe • Clear and lucid explanation of current investigations • Evidence of original thought on aspects of the story and/or microbe i.e. maybe suggestion of future experiment or line of enquiry • Evidence of use of additional resources	/5
2	Organization	• Clutter, no definitive sections • Not all sections present	• No headings, but sectioned • Hard to follow without assistance/multiple e attempts • Missing parts • Obvious refinement required	• All sections present, but could be clearer • Requires a reread for clarity • Some evidence of refinement	• Defined sections • Clear headings • Flows nicely to assist the reader without help/rereads • Is a finished product	/2
1	Grammar / Spelling	• There are **more than 4-6 mistakes** on the poster	• There are **4-6 mistakes** on the poster	• There are **1-3 mistakes** on the poster	• There are **no mistakes** on the poster	/1
2	Creativity	• Bland no variability • No use of color diagrams • Boring to look at, does not catch your attention • Interest, effort and time obviously absent	• Very little use of color or pictures but enough to engage and hold attention	• Some use of color, diagrams, etc. • Will engage but will not stimulate	• Interesting, engaging, visually stimulating • Aesthetically appealing use of color, diagrams and text • Interest, motivation, effort and time obviously present	/2

Grading Rational:

/10

BMSC 210.3 Poster Rubric – Interview a Scientist (Microbiologist/Immunologist) on campus.

Relative Weighting	Category	Unsatisfactory	Basic	Proficient	Advanced	Grade
5	Interview Facts	• No information on interviewee's educational history/ path • No explanation of why interviewee became interested in science, microbes or Immunity • No explanation of current interests/ investigations	• Incomplete info on educational history/path • Very brief explanation of interviewee's initial interest in science, microbes, Immunity. • Only a brief statement of current interests/ investigations	• Full educational history/path • Good Explanation of interviewee's initial interest in science, microbes, immunity • Clear and lucid explanation of current interests and investigations	• Full educational history/path • Good explanation of interviewee's initial interest in science, microbes, immunity • Clear and lucid explanation of current interests and investigations • Evidence of use of additional resources to place interviewee's work in a broader context	/5
2	Organization	• Clutter, no definitive sections • Not all sections present	• No headings, but sectioned • Hard to follow without assistance/multiple e attempts • Missing parts • Obvious refinement required	• All sections present, but could be clearer • Requires a reread for clarity • Some evidence of refinement	• Defined sections • Clear headings • Flows nicely to assist the reader without help/rereads • Is a finished product	/2
1	Grammar/ Spelling	• There are **more than 4-6 mistakes** on the poster	• There are **4-6 mistakes** on the poster	• There are **1-3 mistakes** on the poster	• There are **no mistakes** on the poster	/1
2	Creativity	• Bland no variability • No use of color diagrams	• Very little use of color or pictures but enough to engage and hold attention	• Some use of color, diagrams, etc. • Will engage but will not	• Interesting, engaging, visually stimulating • Aesthetically appealing use of	

		• Boring to look at, does not catch your attention • Interest, effort and time obviously absent		stimulate	color, diagrams and text • Interest, motivation, effort and time obviously present	/1

Grading Rationale:

/10

BMSC 210.3 Poster Rubric – Interesting microbe/immunologytopic chosen by the team.

Relative Weighting	Category	Unsatisfactory	Basic	Proficient	Advanced	Grade
5	Science Content and Literacy	• No analysis of science topic • No explanation of microbial connection • No use of resources	• Poor explanation of science topic or misinterpretation • Inaccurate microbial connection • Only one resource used	• Adequate and appropriate explanation of the scientific facts – though could be developed further • Good evidence that more than one resource was used	• Concepts fully and properly explained • Some evidence of personal insight/thoughts on the topic • Content is accurate and well supported • Excellent use of resources	/5
2	Organization	• Clutter, no definitive sections • Not all sections present	• No headings, but sectioned • Hard to follow without assistance/multiple attempts • Missing parts • Obvious refinement required	• All sections present, but could be clearer • Requires a reread for clarity • Some evidence of refinement	• Defined sections • Clear headings • Flows nicely to assist the reader without help/rereads • Is a finished product	/2
1	Grammar / Spelling	• There are **more than 4-6 mistakes** on the poster	• There are **4-6 mistakes** on the poster	• There are **1-3 mistakes** on the poster	• There are **no mistakes** on the poster	/1

2	Creativity	• Bland no variability • No use of color diagrams • Boring to look at, does not catch your attention • Interest, effort and time obviously absent	• Very little use of color or pictures but enough to engage and hold attention	• Some use of color, diagrams, etc. • Will engage but will not stimulate	• Interesting, engaging, visually stimulating • Aesthetically appealing use of color, diagrams and text • Interest, motivation, effort and time obviously present	/2

Grading

	/10

Rationale:

Appendix C
Team "Peer Review" Survey

Q 1. Your name:
Q 2. Your student number:
Q 3. Team member being reviewed:
Q4. – Q13 are Likert scale questions with answer choices of "Strongly Disagree" "Disagree" "Neutral"
"Agree" and "Strongly Agree". Lead in statement. Provide the most accurate description of your team member's participation.
Q 4. Played a strong role in initiating ideas or actions
Q 5. Showed a willingness to take on responsibilities
Q 6. Accepts responsibilities for tasks determined by group
Q7. Helps promote team spirit
Q8. Respects differences of opinions, willing to negotiate and make compromises
Q9. Acknowledges others' good work and provides positive feedback
Q 10. Communicates online in a friendly tone
Q 11. Keeps in close contact with the rest of the team so that everyone knows how things are going
Q 12. Produces high quality work
Q 13. Does their fair share of the work load?
Q 14. Specific comments? (open text response)