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Impact of an In-Class Biochemistry Mini-conference on Students' Perception of Science

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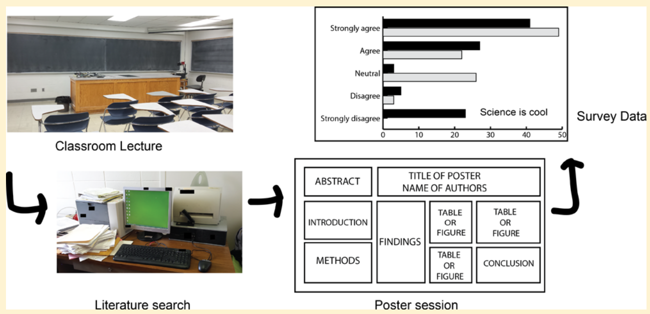
Supporting Information



ABSTRACT: The work presented here is the summary of a 3 year study that aimed to uncover how students' perception of science changes with the chance to participate in a mini-conference that is incorporated into the biochemistry lecture course. Students were asked to work in groups of 2 or 3 and research a topic that is related to the material covered in class. Their research was presented during the last lecture of the course, and the presentation was conducted similar to a conference poster session. The students' grades on this assignment were entirely based on peer evaluation and not on evaluation by the instructor. A survey was conducted before and after this assignment to gauge how the experience changed students' perception of science. The study was conducted with both STEM majors and non-STEM majors to allow comparison of how these two groups of students were affected by the experience.

KEYWORDS: *Second-Year Undergraduate, Upper-Division Undergraduate, Biochemistry, Collaborative/Cooperative Learning, Inquiry-Based/Discovery Learning, Testing/Assessment, Biotechnology*

The general public is often asked to make decisions at the personal and political level about scientific topics, such as vaccination of children, usage of genetically modified crops, or climate change. Since the 1950s, it has been evident that even nonscientists should have an understanding of how science works so that they can make those decisions as informed citizens. It has been documented, however, that even though nonscientists learn about science in school settings, they cannot readily apply this knowledge to everyday life.[1,2] Making matters worse, the general population is bombarded by misinformation that is disguised as scientific literature, especially on hot-button scientific topics, such as the ones listed above. A recent survey conducted by the Pew Research Center[3] showed that even though a clear majority of adults believe that science made a positive contribution to their lives and government investment in science largely pays off, their views on specific scientific issues appear to be guided by popular media and not by science. Of those surveyed 57% consider genetically modified crops safe to consume and only 47% of adults believe in the usefulness of animal research. By contrast, the scientific community appears to be in consensus over the safety of GM foods and the usefulness of animal research. Scientists and nonscientists appear to be in agreement in blaming K−12 STEM education for low science literacy rates.[3] Quality STEM education is not simply needed so that citizens can make informed decisions but is also an important contributor to success in this increasingly technical and global economy.[4] As a result, back in the 1990s, scientific organizations set the goal to increase the scientific literacy of the general population.[5]

Undergraduate science education has an instrumental role in improving scientific literacy of everyday Americans.[2a] The author was encouraged to read that even small changes to how science is taught at the college level can result in significant changes in students' understanding of science.[6] As a result, the author came up with a simple assignment that was incorporated into two undergraduate biochemistry courses. One course was designed for STEM majors and had medium enrollment (30−40) whereas the other was designed for non-STEM majors and had large enrollment (100). Students in both courses were asked to find a popular science topic that is related to material taught in their respective biochemistry courses. The topic chosen had to be related to material covered in class, and the connection to class material had to be clearly illustrated. Students had to research the scientific literature by reading three to five articles and present a review of their chosen topic during the last lecture of their respective biochemistry course. The presentation mimicked a conference poster session. Surveys conducted before and after the assignment aimed to assess how students' perception of science changed after they were required to connect material learned in lecture to real-life scientific problems. Grading of the assignment was entirely based on peer evaluation. The assignment was performed in groups of 2 or 3 students. Having students work in groups made this assignment manageable even in a large classroom. Moreover, group projects

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gave students invaluable lessons on how to be a productive team member and how to share responsibilities, debate, and reach consensus in a professional manner.

Poster presentations have been used as a teaching tool in chemistry classes since the beginning of the 20th century.[7] Poster sessions have been incorporated in chemistry lecture courses as a means to visually present the result of a one-time project[8] or in place of a written exam.[9] Poster presentations have been used to replace written laboratory reports in introductory undergraduate chemistry courses.[10] Poster sessions held in courses that are designed for non-STEM majors carry the benefit of introducing students to online search engines (SciFinder or PubMed) and placing the chemistry they learn in lecture in the context of their professions.[8b] Evaluating poster presentation via peer review instead of instructor review makes these types of assignments manageable in courses with large enrollments.[11] The numerous educational benefits of poster sessions are extensively documented. They promote collaborative learning and communication skills,[12] engage students who are visual learners,[13] and increase students' enthusiasm toward learning chemistry resulting in increased passing rates for a notoriously difficult organic chemistry course.[8c] Holding poster sessions as part of the undergraduate course work has the obvious benefit of introducing students to this important presentation module.[14] A recently published clever idea of conducting poster sessions online demonstrated that poster assignments are doable in courses with very large enrollments without taking up lecture time.[8d]

Poster assignments require different skills than excelling on a written exam. Creativity and computer skills are required to make a poster, and presenting a poster improves communication skills. Therefore, assessment of knowledge using poster sessions is a great way to provide a channel to students with different learning styles. Visual learners tend to appreciate posters, because they contain graphic imagery to illustrate a topic. Bodily kinesthetic learners excel in this assignment, because they are good at making things with their hands. Finally, interpersonal learners enjoy interacting with others during the poster session and linguistic learners shine when they explain the topic presented on the poster to their peers. According to Gardner "The broad spectrum of students...would be better served if disciplines could be presented in a numbers of ways and learning could be assessed through a variety of means".[15] Furthermore, it has been demonstrated that using a combination of assessment tools helps retain a student body that is traditionally underrepresented in science.[16]

The seminal works listed above represent a collection of assignments that use poster sessions in innovative ways. What is missing from the literature is an objective evaluation of how these assignments affect students. The work presented herein aims at filling in this gap. The novelty of the work is 3-fold. First and foremost, surveys conducted before and after the poster session permit the author to assess how students' attitudes toward science were changed by the assignment. Second, since the poster session was graded by peer evaluation, students' views of peer evaluation could also be assessed. Third, data collected from STEM-major and non-STEM-major courses permits a comparison of how different students were affected by the assignment. The author has used the poster assignment for 3 years in her undergraduate biochemistry course. The assignment was improved throughout the years; work presented here represents the poster assignment in its most recent form. Surveys assessing the benefits of the assignment were added during the last year of the study.

METHODS AND FRAMEWORKS

Enrollment and Course Description

Non-STEM-Major Course. This one-semester 300-level biochemistry course is designed for applied science majors (dietetics majors, exercise science majors, and chemistry minors). Enrollment in this course was 70–100 each year during the course of this study. This course combines functional group organic chemistry with an introduction to biomolecules and metabolism. Each of these topics takes up approximately one-third of the semester. The instructor used a personal response system (iClicker) to engage students in the learning process and routinely pointed out the relevance of the material learned in class to everyday life.

STEM-Major Course. This 400-level biochemistry course is a two-semester sequence designed for (bio)chemistry and prehealth professional majors. The first semester gives students a solid background on the structure, function, and catalytic activity of macromolecules. The second semester reviews the most important energy producing metabolic cycles and teaches the basics of nucleic acid biochemistry. Enrollment in this course was lower than in the other (30–40 students per semester during the course of the study). During both semesters the instructor routinely pointed out the relevance of the material learned in class to everyday life. Students were actively engaged in the learning process by completing in-class worksheets in a group setting and answering questions posed by the instructor.

Project Description

At the beginning of the semester, students were introduced to the assignment. This introduction used no more than 10–15 min of lecture time. A poster from a previous year was presented to students at this time. A summary of the assignment was also posted on Blackboard, the university's course management system (the description is available as Supporting Information). Peer evaluation and group member evaluation questionnaires are shown below (boxes 1 and 2).

Box 1. Peer Evaluation Questions

- I found the presentation interesting.
- I found the introduction adequate.
- The presentation was easy to follow.
- I think the abstract is well written.

Students were asked to rank each presentation by answering four Likert-style questions using a 1 to 5 scale (1 strongly agree; 5 strongly disagree).

Box 2. Group-Member Evaluation Questions

- Attendance of team meetings.
- Active contribution to project completion.
- Respectful of team members.
- Willingness to help other team members.
- Level of contribution to the team project.
- Attitude toward team.
- Acceptance and sharing of responsibilities.

Students were asked to rank each member of their team by answering seven Likert-style questions using a 4 to 1 scale (4, great; 1, poor).

Weekly office hours were sufficient to provide additional guidance on completing this assignment. When asked, the

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instructor helped students to choose a topic and proofread the abstract and explained to students how a conference poster is made. Hence conducting this assignment did not require significant time commitment from the instructor. About 10 weeks into the 15 week semester, students were asked to submit the title and abstract of their presentation. This small task appeared to be crucial in making sure students are on track with the assignment. Otherwise about one-third of the students did not start working on the assignment until a week before the presentation.

Peer Review Process

The poster presentation and peer review were conducted using the lecture time, 50−90 min, depending on the course. Each student reviewed as many posters as they could within the time frame provided; typically 10−15 posters. Peer evaluation was carried out on the spot using the questions listed in Box 1 and scores had to be entered into a Qualtrics form within 24 h. The instructor used these average scores from the Qualtrics form to rank the poster presentations and assign a grade in the 0−20 points range. Typical grade distribution was between 15 and 20 points.

Survey and Data Analysis

In the first 3 years of this study a 28-question survey was administered to students a month before the presentation. Within a week of the posters being presented, students were asked to complete a postpresentation survey. This 31-question survey contained, in addition to the 28-prepresentation questions, three questions that focused on students' experience regarding peer evaluation (Supporting Information Table S1; IRB no. 786530-1). Survey questions were written by the author but were inspired by previous survey questions on the attitudes of students toward biology[17] and students' views on science.[18] During the final year of the study the postpresentation survey was augmented with eight additional questions to gauge student opinion of the assignment and the peer review process. These questions were directly taken from a published manuscript.[19] The goal the surveys was to assess how students' views changed about science in general, funding of science, their attitude toward conference presentations, and peer evaluation. Participation in the survey was entirely voluntary and anonymous. The surveys were generated and administered with Blackboard and Qualtrics (last year only). The complete survey is available in the Supporting Information. The questions were presented in random order to minimize student response bias. Data shown are the result of surveys generated during the course of the study (Supporting Information Tables S2 and S3). Numbers presented represent the percentof the student population who answered a question in a certain way. For presentation and analysis purposes, questions were grouped into five categories: "students' views on science",[17,19] "the relevance of science to students' career", "funding of science", "attitude about conferences", and "students' thoughts about peer evaluation". Pre- and postpresentation surveys were conducted within no more than 3 weeks of each other to ensure that a change of opinion about the topics assessed is mainly an effect of the assignment and is not the result of other factors.

■ FINDINGS

Presentation Topics

The author permitted student groups to choose similar presentation topics as long as they were aware that their peers might compare those presentations to each other. Popular presentation topics were related to hot-button science issues but did not cover controversial subjects such as genetically modified crops. On average, there were no more than two presentations on the same or similar topic per year. Popular topics included artificial sweeteners, the impact of high-fructose corn syrup on weight gain, renewable energy sources such as E85 ethanol, and neurodegenerative diseases.

Non-STEM-Major Survey Data

The project appeared to have a significant positive impact on how non-STEM majors view science. Significantly fewer students thought that science was "not cool" after they got to research a topic that captured their interest (Figure 1.). This apparent increase in students' appreciation of science did not, however, translate to a commitment to read scientific literature or watch scientific shows. Only 10% more students vowed to follow popular science in the future and the number of students who planned to keep up with scientific literature actually decreased from 63% to 52%. Intriguingly, the number of students who would consider becoming a researcher in academia or industry increased significantly, from 17% before the assignment to 46% after. The overwhelming majority of students' realized that academic research is relevant to their career; the number of students who considered academic research relevant increased from 56% to 84%.

Even though students' interest in science and appreciation of basic research appeared to increase, the number of students who considered becoming an educator at a university actually went down from 35% to 18%. Thankfully, students' appreciation of science and basic research meant that they would desire to see more funding for research and science education. Students became more familiar with how to prepare a poster since the presentation part of the assignment followed the format of a conference poster session. The author found it encouraging that students considered the conference poster session a fun and great way to learn about science. Students' opinion of peer evaluations was most interesting. The majority of students appeared to know that science is judged by peer evaluation even before the mini-conference. Even though about 90% of students said that they took the peer evaluation seriously, they admitted that they learned a lot from evaluating their peers and stated that their appreciation of their peers increased as a result of peer evaluation. Still, the majority of students thought that peer evaluation was subjective. Even after conducting the peer evaluation, only a slight majority of students disagreed with the statement that "peer evaluation cannot be trusted because people will always say good things of each other" and 53% of students still agreed that peer evaluation was subjective (Figure 1.).

STEM-Major Survey Data

STEM majors were affected differently by the mini-conference than non-STEM majors. STEM majors came to the class thinking that science was cool, that academic research is useful and had the habit of following science by watching shows and/or reading papers (Figure 2). Participation in the mini-conference did not appear to change students' career plans significantly. These students were chemistry or biochemistry majors; hence, they were already preparing for a position in academia or industry. Participation in the mini-conference had a significant positive effect on students' views of scientific conferences. A clear majority thought that conferences were a great way to learn about science and were wonderful opportunities to

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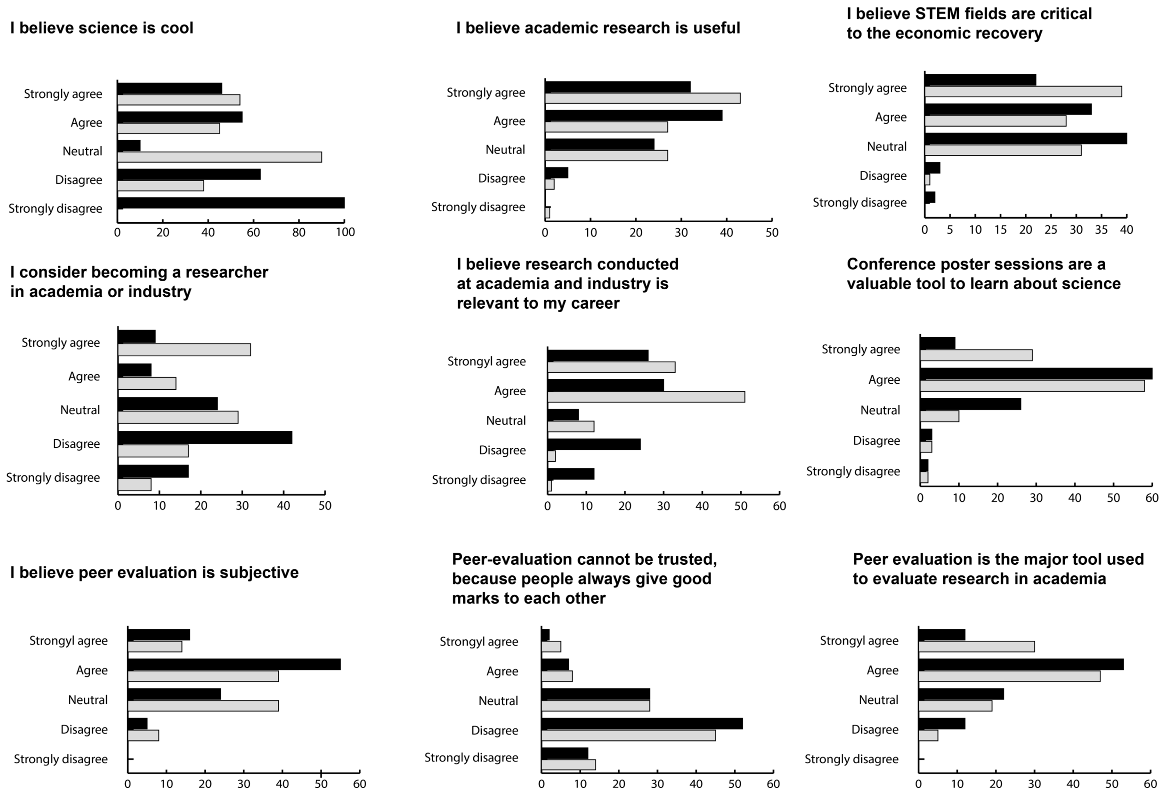

Figure 1. Bar chart representation of survey data illustrating how non-STEM-majors' opinions changed by the mini-conference. Bars represent percent of students who answered a question in a certain way (black, before; gray, after).

network with fellow scientists. The overwhelming majority of students became committed to attend a conference in the future and appeared to be comfortable with preparing a poster presentation (Supporting Information Table S3).

Survey data on peer evaluation were most interesting. The majority of students were already aware that science is judged by peer evaluation and took the peer evaluation part of the assignment seriously. Furthermore, students found the experience rewarding: 85% thought that they learned a lot from evaluating their peers, and 80% grew to appreciate their peers more. Despite these positive results, the majority of students still felt that peer evaluation is subjective and only 39% of students disagreed with the statement that "peer evaluation cannot be trusted" (Figure 2).

Comparison of How the Experience Affected STEM and Non-STEM Majors

To assess the impact of the mini-conference on STEM and non-STEM majors, we calculated the effect size (Cohen's d) for each survey question category (see Supporting Information Table S1). The effect size is defined as the standardized mean difference between the two survey groups (see eq 1; SD is standard deviation). Typically $d < 0.2$ is interpreted as a small effect, and $d > 0.8$ indicates a large effect, whereas $0.3 < d < 0.7$ is a medium effect.[20] "Before" and "after" designates data from surveys conducted before and after the mini-conference, respectively.

$$d = \frac{\mathrm{mean}_{\mathrm{before}} - \mathrm{mean}_{\mathrm{after}}}{\mathrm{SD}_{\mathrm{pooled}}}$$

$$\mathrm{SD}_{\mathrm{pooled}} = \sqrt{\frac{{\mathrm{SD}_{\mathrm{before}}}^2 + {\mathrm{SD}_{\mathrm{after}}}^2}{2}} \tag{1}$$

Despite differences in sample size, analysis of survey data clearly indicates (Table 1) that the mini-conference achieved

Table 1. Comparison of Science-Major and Non-science-Major Survey Data[a]

Comparison	Effect Size STEM Majors (n = 21)	Effect Size Non-STEM Majors (n = 89)
View of science	0.08	0.58
Science as career	0.19	0.27
Science funding	0.24	0.44
Poster presentations and conferences	0.53	0.65
Peer evaluation	0.38	0.19

[a]Effect size was calculated using eq 1. The significant difference in sample size (21 vs 89) is due to a difference in course enrollments.

its primary learning goal. It is apparent that students became comfortable with making and presenting a poster and came to appreciate conference poster sessions. Perhaps the most interesting outcome of the study is the markedly different impact the mini-conference had on STEM and non-STEM majors with respect to their view of science. Non-STEM-majors' view of science significantly improved. This improvement did not translate into a desire to become a STEM major, but it did result in an increase of support for science funding. It is interesting to note that STEM-majors' view of peer evaluations changed for the better, while the opinion of non-STEM majors remained the same.

PEER EVALUATION VS INSTRUCTOR EVALUATION

Each year the mini-conference was conducted students appeared enthusiastic about the assignment. An apparent enthusiasm was also documented by a recent study that used online presentations

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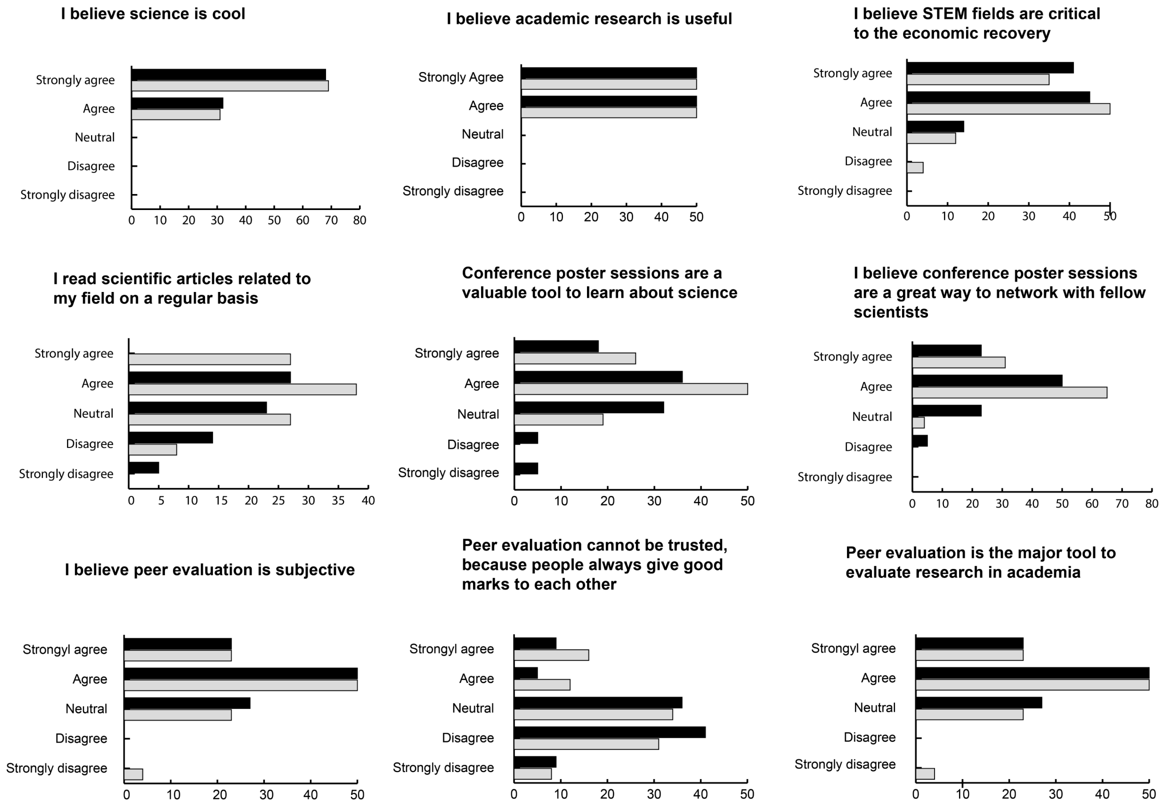

Figure 2. Bar chart representation of survey data illustrating how STEM-majors' opinions changed by the mini-conference. Bars represent percent of students who answered a question in a certain way (black, before; gray, after).

Table 2. Student Opinions Regarding the Mini-conference and the Peer Review Process[a]

	Mean (std dev)
Assignment	
This method of learning (the mini-conference) has increased my interest in the course.	2.09 ± 1.15
This method of learning (the mini-conference) has increased my understanding of the material.	2.14 ± 0.94
This method of learning (the mini-conference) has increased my confidence in my understanding.	2.00 ± 0.82
This method of learning (the mini-conference) has increased my ability to communicate.	1.86 ± 0.83
Peer Review	
I took the peer evaluation part of the mini-conference seriously.	1.91 ± 0.92
I prefer peer reviewed over instructor reviewed group projects.	2.50 ± 1.19
I learned from other students during the peer review.	1.82 ± 0.73
I have greater appreciation to the work done by my peers, because I had to evaluate them.	1.73 ± 0.70

[a]This study was only conducted with STEM majors, because the author did not teach the non-STEM course during the past year.

in an organic chemistry course geared toward medical students.[11] To objectively evaluate students' views of the mini-conference and the peer review process as a method of learning, the author conducted exit surveys and assessed how instructor and students' ratings of presentations compared. The exit survey contained eight Likert-style questions where students were asked to rate statements on the scale of 1 (favorable) to 5 (unfavorable) (Table 2). Based on this survey it is apparent that students recognized the educational value of both the peer review process and the assignment itself and did not simply view it as a fun activity at the end of semester. Even though peer review appears to take the burden of grading away from the instructor and place it on the student, students appear to favor this evaluation method over instructor evaluation.

To evaluate whether there was any difference between peer and instructor ratings, the author compared instructor and peer ratings of presentations (Table 3). Instructor ratings represent evaluation by two instructors; peer evaluation is the average of ratings provided by students. Both groups rated the presentations using the questions listed in Box 2 using a Likert scale that went from 1 (good) to 5 (bad). Based on the analysis, we can conclude that instructor and peer ratings are similar; a correlation test conducted in Excel gave a weak positive correlation of 0.21 between the two ratings.

Table 3. Comparison of Instructor and Peer Ratings of Poster Presentations

Presentation	Instructor Ratings	Peer Ratings (N = 29)
1	1.37 ± 0.58	1.28 ± 0.51
2	1.75 ± 0.58	1.19 ± 0.46
3	2.00 ± 1.29	1.25 ± 0.62
4	1.50 ± 0.57	1.21 ± 0.42
5	1.50 ± 0.57	1.32 ± 0.67
6	1.75 ± 0.96	1.49 ± 0.68
7	1.25 ± 0.50	1.17 ± 0.43
8	1.25 ± 0.50	1.17 ± 0.40
9	1.75 ± 0.50	1.18 ± 0.49
10	1.50 ± 0.58	1.19 ± 0.38
11	1.00 ± 0.00	1.27 ± 0.61

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■ LIMITATIONS

The biochemistry mini-conference was used in small (enrollment, 30−40) and medium (enrollment, 70−100) class sizes. A minimum class size of 15 is probably required to ensure a conference-like environment and provide the opportunity for stimulating discussions. Peer evaluations might also be biased in a very small group, because students might guess or think they can guess who is the evaluator, which prevents honest feedback. The project may not be suited for very large classes (>150), due to the logistics of managing poster presentations. The project, the author believes, is suitable for and an excellent addition to chemistry classes from AP high school courses to graduate-level courses. When conducting the assignment in AP or freshmen courses, the instructor may need to allocate a lecture to introduce students to electronic search engines such as PubMed and SciFinder and point out the distinction between popular science sites and peer reviewed scientific manuscripts.

■ IMPLICATIONS

The goal of this project was to evaluate how students' perception of science was changed once they worked on a simple assignment that connected course material to everyday life and presented the result of their research to the class. Even though poster presentations are not uncommon in upper-level classrooms, little is known about the effect these assignments have on students' perception of science. Based on comparing pre- and postpresentation surveys, the author concludes that these assignments have markedly different effect on STEM majors and non-STEM majors. Poster presentations that require connecting course material to real life appear to have a significant positive effect on non-STEM majors as far as their view of science is concerned. According to this survey, non-STEM-majors' views of science are worse than that of the general population: only about half of the student population had a positive view of science and a small minority considered becoming a scientist. A negative view of science is documented to hinder students' ability and motivation to learn science.[21] The author believes that requiring students to critically review scientific literature and connect their findings to everyday life or their future career is the factor that increased students' appreciation of science. Learning about how scientists collect, analyze data, and then report their data in a peer reviewed publication is documented to help students learn about the Nature of Science.[1]

The author, like others,[8a,c] noticed an increase in students' confidence and enthusiasm toward (bio)chemistry after the assignment, regardless of the grade the student received in the class. This surge in enthusiasm is perhaps due to the fact that students got a chance to connect knowledge learned in lecture to everyday life by extensively researching a subject, which in turn made them feel like experts of that particular topic. In the process of conducting the literature survey and making and presenting the poster, students became active participants of the learning process. Making students responsible for their learning process is encouraged[8a,22] and has been demonstrated to increase content retention.[23] Holding poster sessions as part of the undergraduate course work has the obvious benefit of introducing students to this important presentation module.[14] Even though the gold standard of scientific work is publishing scientific data as a written manuscript, undergraduate students present their scientific data at a conference poster session much before they have the chance to write a scientific article. As a result, students benefit from learning how to make and present scientific data as a poster early in their educational career.

Using peer evaluation instead of grading by the instructor proved to be a useful tool to evaluate this assignment for several reasons. Foremost, peer evaluation is the major tool to evaluate scientific research. As a result, students interested in science are well served by being introduced to this evaluation method. Second, peer review has been cited "to enhance the students' ownership of the material".[10a] A majority of students stated that they learned a lot by evaluating their peers. This finding resonates with other studies, demonstrating that students retain material better when they play an active role in the learning process. According to Bloom's taxonomy, evaluating requires higher-order thinking skills.[24] When students are able to critically evaluate each other's work, it is a sign that they achieved high-level understanding of the material covered in class. Likewise, without peer evaluation, this assignment is not practical to use in courses with large enrollments, because most universities do not have enough expert evaluators available and willing to grade it. Comparison of instructor and student ratings revealed similar scores (Table 3).

In the study reported here the mini-conference assignment was performed in groups of 2−3 students. Larger group sizes may accommodate courses with large enrollments. The author does not recommend that students perform the assignment alone, unless there is a compelling reason (commuter student or if the student cannot spend much time on campus due to a valid personal reason). Science is done as a team effort; hence, students must learn how to form a team, share responsibilities, and manage conflicts. Students exposed to cooperative learning formats such as group projects are documented to get better grades and enjoy the course more.[25] When the project was first introduced, the author used a peer review questionnaire as a channel for students to evaluate their team members (Box 2). The goal of this questionnaire was to identify students who do not do their fair share of the work. Using the questionnaire for two consecutive years convinced the author that it was not necessary, since every student appeared to work very hard for his or her respective team.

■ CONCLUDING REMARKS

Leading scientific organizations recognize the importance of teaching nonscientists to understand scientific concepts so that ordinary people can become informed citizens. An educated public is able to relate the achievements of science and technology to everyday life and, as a result, make informed decisions about personal and public life. An informed public is much less likely to be swayed by sources that appear to be scientific, but in reality spread information that is not based on peer reviewed publication by authors with strong credentials on the subject matter. Science educators in colleges have a strong responsibility to educate undergraduate students in this respect. Creating an informed citizenry is a big job that requires significant funding and further studies of the effectiveness of alternative teaching tools. The present study, among many others, shows that even small changes to the curriculum such as a poster presentation on a topic that captures students' interest can sway non-STEM-majors' views of science significantly. The assignment described here only uses one lecture and if it is performed in groups, is manageable in classes with large enrollments. If peer evaluation is used for the assessment, the grading burden on the instructor is minimal. The author believes that assignments such as the one presented here are effective,

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because they transform students from passive observers to active participants of the learning process.

■ ASSOCIATED CONTENT

Supporting Information

Survey questions are summarized in Supporting Table 1. Survey data is listed in Supporting Table 2 for the non-STEM course and in Supporting Table 3 for the STEM course. A project description that the author used in these courses is also included. The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00612.

Group project presentation guidelines (PDF, DOCX)
List of survey questions (Table S1) (PDF)
Non-STEM-major survey data (Table S2) (PDF)
STEM-major survey data (Table S3) (PDF)

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Notes

The authors declare no competing financial interest.

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