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Susan E Ramlo (University of Akron)
Carrie Salmon (College of Wooster)
Yuan Xue (Oberlin College and Conservatory)

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ABSTRACT

Several traditional chemistry lab experiences were replaced with a problem-based learning (PBL) experience in a university general education, conceptual chemistry course. Students worked in small groups on an authentic chemistry problem in which each student played a different role (Scientist, Engineering, Marketing Manager, Safety Officer, or Secretary). Mid-semester, the pandemic forced the course online. Q methodology [Q] was used to determine the divergent viewpoints that existed amongst the students regarding their PBL experience. Each student provided their view by sorting related statements into a grid. Three divergent viewpoints emerged from the analyses: two viewpoints were positive about the PBL experience (Motivated learners and Committed to my group) and one was negative (Negative experience due to group dynamics). Descriptions of these views and implications are discussed.

Keywords: chemistry, general education, conceptual, methodology, mixed method, PBL

Introduction

Chemistry for Everyone (CFE) is a general education science course offered at a large, public Midwestern university. The purpose of this study was to ascertain and describe the divergent student perspectives about a problem-based learning (PBL) laboratory experience within this course. Because most of the traditional laboratory experiences were maintained, students experienced both typical college-chemistry lab experiences and the PBL experience. Additionally, the coronavirus pandemic meant that although some of the traditional laboratory experiences were eliminated, much of the PBL experience could continue as planned. Student views of the PBL experience were determined using Q methodology (Q), a mixed research methodology created to study subjectivity (Brown, 1980; Newman & Ramlo, 2010).

CFE is a conceptual chemistry course designed for nonmajors, with a three-hour lecture and a three-hour laboratory each week. The course description is as follows: “Integrated, hands-on, laboratory instruction in the fundamental concepts of chemistry for general education and middle-level licensure for pre-service and in-service teachers.” As a general education natural science course, CFE must meet a set of learning outcomes. Within this study, the lecture portion of the course remained unchanged and a PBL experience replaced a portion of the traditional laboratory experience.

General education

General education coursework is required for bachelor’s degree attainment within the United States. These general education courses are part of the typical curriculum within American universities and often target learning outcomes such as critical thinking and scientific literacy (Rowe et al., 2015). General education course work is often categorized such as natural science, humanities, and mathematics. Although these courses are required, Miller and Sundre (2008) found that many college students do not value these general education classes. Overall, students are often disinterested in their general education coursework because they feel these courses are disconnected from their undergraduate majors. Therefore, motivating students in general education courses is often problematic.

A brief review of chemistry education in higher education

Students often struggle to learn college-level chemistry and feel disinterested in this type of general education coursework (Miller & Sundre, 2008). Additionally, natural science general education coursework such as CFE tends to lack authentic experiences. Instead, this type of coursework typically takes place in traditional settings and consists of didactic lectures and verification experiments (DeVos et al., 2003). When learning tasks are disassociated with a student's interests, those tasks can lack a sense of intrinsic value for that student (Kim et al., 2015). Chinn and Malhotra (2002) suggested that authentic inquiry experiences should become a priority in every science course. Authentic experiences offer greater relevance to the course material (Miller & Sundre, 2008). Additionally, prior negative science course experiences can create a level of anxiety associated with taking college science courses, especially for female students (Udo et al., 2004).

Fortunately, a new era of science education reform started in the early 1980's (Hofstein & Lunetta, 2004). These reforms include the use of inquiry, discovery, and PBL. These changes are a result of current models of how students construct knowledge and information about how teachers and students engage in science laboratory activities. Additionally, the National Science Education Standards (National Research Council [NRC], 1996) recommends these contemporary goals for science learning and pedagogical strategies. However, for college science courses, didactic lectures and verification experience remain the norm (Miller & Sundre, 2008).

Problem-based learning (PBL)

Hmelo-Silver (2004) described PBL as a pedagogical strategy. PBL encourages student-directed learning that is focused on solving a meaningful, authentic, open-ended problem with no set solution. With its beginnings in medical education, PBL has expanded into K-20 education (An, 2013; Barrows, 1996). The problem design facilitates students' deeper learning of the content (Jonassen, 2000, 2011) and uses Vygotsky's (1986) social construction of knowledge. In PBL, social construction of knowledge is a byproduct of students working effectively in small groups to address the problem (Jonassen, 2011). The student group must collaborate to determine the information to collect, the design of data collection, and the problem solution. This type of collaboration has beneficial effects such as improved intrinsic motivation, persistence when faced with adversity, and transferability of the knowledge (Pfaff & Huddleston, 2003). Kapp (2009) found that establishing a collaborative environment and creating shared expectations improves the ability for student teams to work together effectively with minimal issues.

This type of collaborative environment is important within PBL because students must explain and justify their positions, which, in turn, results in reflective social discourse (Land & Zembal-Saul, 2003). These PBL groups must consistently work to improve their ideas through discourse. This discourse must focus on knowledge-building (Hmelo-Silver & Barrows, 2008). Ryan and Deci (2000) describe what is necessary for students to be motivated to participate in a collaborative learning process such as PBL. These characteristics include a sense of autonomy and a feeling of belonging within the group. The latter can determine if participants feel engaged or alienated within their groups. Overall, students should take responsibility for advancing the group's understanding about the situation (Hmelo-Silver & Barrows, 2008).

Motivation is also an important component to PBL—specifically, intrinsic and extrinsic motivation. Intrinsic motivation represents an inherent tendency to seek out challenges, to explore, and to learn for the sake of personal improvement and mastery. However, extrinsic rewards can undermine an individual's intrinsic motivation (Ryan and Deci, 2000). An example of extrinsic motivation is in the social pressures to perform in a group on a topic that is not of interest to the individual (Ryan & La Guardia, 2000). Hmelo-Silver and Barrows (2008) suggest that the instructors and facilitators of PBL must find ways to help orchestrate the knowledge-building discourse within the student groups.

Involvement in the PBL process can help students develop the attitudes and attributes expected of a reflective practitioner, such as a chemist (Bate et al., 2014). In this way, students must determine how to apply knowledge rather than remembering information (Bodner & Herron, 2003). Applying knowledge is cognitively more complex than fact retrieval, based on Bloom's taxonomy, and leads to improved retention of information and concepts (Agarwal, 2019). Thus, PBL offers a student experience much more aligned with how a scientist works and enhances learning (Jonassen, 2000).

Chemistry Laboratory PBL Design

The laboratory instructors, who are current graduate teaching assistants within the Department of Chemistry, created the format for the PBL. Students were introduced to the company presidents (the laboratory instructors) and given instructions to form groups with five students each (one group had six students). Once in their groups, students selected roles with defined duties: Scientist, Engineer, Safety

Officer, Marketing Manager, and Secretary. The group of six students had two Scientists. Students then received a packet of information and a list of possible products to select for their group. The students also shared contact information and signed a contract regarding their roles, the timeline, and product selection.

Products

For PBL, Jonassen (2011) suggested that it is important to provide problem cases that are fitting to the levels of the students. Because CFE is a conceptual chemistry course, the PBL product choices were relatively simple, such as making soap. The laboratory instructors provided students with basic information regarding the product choices so students could make informed decisions during the selection process. The products did not require specialized laboratory equipment, such as fume hoods, so that students could work on a variety of experiments both inside and outside the laboratory. The initial laboratory packet included a brief description of each lab product, including materials. The goal was to have student groups, with each student in their company role, produce procedures that were more detailed, including an expanded chemical list, safety requirements, etc.

Student groups chose from the following lab products:

- Milk-rainbow (using milk, dye, and dish soap)
- Creating designer soaps
- Slime
- Fire-snake (using burning sugar and baking soda)

Contracts and Presentation

Throughout the semester, students agreed to four distinct contracts that dealt with effective communication, criteria for the project (including providing citations), and written and oral assessments. The fourth contract was used to stress to students that they were each responsible for being prepared to answer any question pertaining to the chemistry within the project during the oral presentation. Prior to the pandemic moving all courses online, the oral presentation required students to run the experiment associated with their selected product. However, the pandemic interruption to face-to-face instruction created a situation such that the students still had to plan the experiment and create the associated processes. One of the instructors ran the actual experiments using the procedures provided by each student group. Although the structure was not optimal, the instructors intended to promote social distancing and laboratory safety as much as possible. Students presented as a group via WebEx but in different physical locations because of restrictions related to the pandemic. Students shared their screens during their parts of the virtual presentation. Each student's part of the presentation was based on his or her company role. Students watched videos of the instructor and her family running their group's experiment using the stated procedures, and the students were able to gather data. The instructor also provided feedback within these videos. When they created their group presentations, students were required to include this data and address any concerns provided by the instructor in the video.

Written Report

Students also coproduced a written report; however, this written report represented the type of document students would receive as part of the laboratory instruction. The formal lab report included pre-lab questions (with answers), a theory section concerning the product chemistry, laboratory objectives, equipment, chemical list, and lab safety requirements. This report also included a section with all relevant data (including observations, graphs, and tables–with data collected by the instructor rather than the group, because of the campus hiatus), calculations, and results. Finally, the report included a conclusion in which findings had to be supported with evidence (data and/or calculations) as well as post-lab questions (with answers). The conclusion also included modifications to procedures or other aspects of the PBL experience that would improve the product, safety, or other aspect of the lab product. Students also included a subsection related to the potential scaling of the product for production and information related to marketing and testing (e.g., FDA). The various aspects of the PBL design were used within the methodology to determine divergent viewpoints about this PBL chemistry laboratory experience.

Method

William Stephenson created Q methodology (referred to as Q throughout this manuscript) over 80 years ago to study and differentiate the subjective views of groups of people. Q blends qualitative and quantitative offers a hybrid of qualitative and quantitative research methodologies in a form that can be called a qualitative-quantitative hybrid (Ramlo, 2021). Each Q study consists of a set of procedures that accompany an epistemological and ontological framework (Brown, 1980). Every Q study begins with the collection of items, typically statements, concerning the topic.

Q-sample

This collection of items, called the concourse, should represent the myriad of communications about this topic and, therefore, often involves using multiple sources. The Q-sample is a subset of the concourse and is most often purposefully selected using Fisher's Design of Experiments

(Brown, 1980). In this way, the researcher can ensure a balance among the various themes within the concourse and that the Q-sample, like the concourse, represents the types of communications regarding the subject at hand.

In this study, the lead researcher collected statements from various sources. Some statements came directly from the design of this PBL (e.g., written report, working in groups, and presentation). Other statements came from a literature review of problem-based learning (Barrows, 1996; Jonassen, 2000, 2011; Land & Zembal-Saul, 2003) and attitudes about science (Miller & Sundre, 2008; Tobin, 1990). However, other statements came from the university's learning outcomes for all natural-science general education coursework. Because the students thought of this PBL as a project, the word project was used, rather than PBL or problem, within the statements of the concourse. The concourse consisted of 56 statements. Five themes were identified within the concourse: attitudes about science/chemistry, the laboratory experience (e.g., laboratory versus lecture), university learning outcomes, PBL in general, and the student PBL tasks (e.g., written report, working in their groups, and the presentation). Fisher's Design of Experiments (Brown, 1980; Ramlo et al., 2019) was used to reduce the concourse to 36 statements. The latter represented the Q-sample. Although the Q-sorting stage is often done face-to-face with a researcher, the pandemic created a situation such that the Q-sorts were done online via HtmlQ.

Q-sort

Students received a link to the online Q-sort along with an overview of the sorting process. The software presented each statement randomly to the participant. Participants placed the statements into one of three piles—Agree, Neutral, and Disagree—based on their views of the CFE laboratory project experience. Students then took each of these piles and distributed them into a grid provided by the researchers. They were able to rearrange these statements in the grid until they were satisfied that their sort represented a snapshot of their view concerning their experience. Because each sort represents a student's subjective viewpoint, there are no right or wrong answers (Brown, 1980; McKeown & Thomas, 2013).

After the sort, students were asked to answer several questions about their sorting experience. They were asked to comment on those statements placed at +5 and -5 (most agree, most disagree, respectively). These statements are those that are most salient for the participant. During the post-sort, students were also asked to indicate some demographic information such as their college year (freshman, sophomore, junior, senior), role within the PBL experience, and major (e.g., education, health professions).

All data entered, including the Q-sorts, were downloaded from the web application in the form of a JSON (JavaScript Object Notation) file. JSON is a standard data interchange format primarily used for transmitting data a web application to a server. Twenty-eight sorts were successfully submitted.

Analyses

Data analysis in Q requires specialized software that provides the statistical analyses but also the descriptive outputs required to interpret the factors, each of which represents a unique viewpoint. In this study, the data was analyzed by uploading the JSON file, along with a text file containing the 36 statements, into KenQ (Banasick, 2019). Q best practices, as described by Brown (1980) and Ramlo (2021), were used for the statistical analyses. Two factors emerged with the first factor bipolar (such that some sorts were negatively correlated with the factor while others were positively correlated). This factor (Factor 1) was split into two parts (Factor 1a and Factor 1b) for improved analysis and interpretation. Splitting the factor simply provides two factors each with positive correlations on the factors, 1a and 1b, rather than one with sorts positively correlated with Factor 1a and the other with sorts negatively correlated with Factor 1b.

Results

The course consisted of 46 students and 28 participant Q-sorts. Thirteen participants were male, 13 were female, and two did not provide a response. The majority (18, 64%) of participants were freshmen, six were sophomores, and four were juniors. Regarding categories for majors, 12 were in the fine arts, eight were in education, four were in STEM, three were in health professions, and one was in humanities. The average student age was 20 years-old. This course is most often used as a science general education course.

Again, two factors emerged from the analyses, one of which was bipolar. For each factor, the analyses include the production of a factor array; the factor array provides a representative sort that reflects the factor/viewpoint. Distinguishing statements help differentiate each view from the others. Finally, written comments about those statements placed in the most salient locations of the grid (+5 and -5 in this study) help clarify these views. Each viewpoint will be described in the next section. Table 1 contains the factor arrays for each of the views (factors) that emerged.

Statement Number	Statement	Factor 1a	Factor 1b	Factor 2
1	I disliked my role on this project.	-3	3	-5
2	Science classes usually make me anxious.	-2	-2	3
3	I think science is relevant to my field of study.	-2	-3	-2
4	I had to do too much of the heavy lifting for this project.	-3	4	-4
5	I feel more confident about my understanding of chemistry because of this lab project.	2	-1	-2
6	I better understand the role of ethics in science after this laboratory experience.	1	-2	2
7	The lab experience helped me do better in the lecture part of this course.	-1	0	-4
8	I wish we hadn't done this project in chemistry lab.	-4	5	1
9	Some people on my team weren't helpful enough on this project.	-4	5	2
10	I understand chemistry better now.	3	-4	-2
11	The project was fun.	3	-4	0
12	Everyone needs to understand science.	1	1	-1
13	I enjoyed seeing the other presentations.	0	2	0
14	I felt motivated to do well on this chemistry lab project.	5	1	5
15	Learning science is a waste of time.	-5	3	-2
16	I enjoyed the problem-solving aspects of this lab experience.	0	-1	1
17	I feel like I am better at giving presentations after this lab project.	-1	2	0
18	Collecting the data for this project was my favorite part.	0	0	-3
19	The authentic nature of this laboratory was important for my learning.	1	-3	1
20	I think science is interesting.	4	1	-1
21	The timeline for this project was too demanding.	-3	0	-1
22	I disliked giving the presentation.	-2	3	1
23	Doing lab project helped me feel less anxious about chemistry.	1	-3	-5
24	My group role was important for this lab experience.	-1	2	3
25	The contracts (1-4) were a silly idea.	-3	3	-3
26	The lab instructors were a key part of this chemistry project.	2	0	4
27	I am more confident that I can solve problems in chemistry after this type of laboratory experience.	3	-2	-1
28	I enjoyed working in a group for this project.	3	-5	2
29	The lab project made me appreciate science more.	0	-1	-3

Table 1. Factor arrays for each of the viewpoints

30	I wish I didn't have to take this course.	-5	4	3
31	I feel like I better understand the processes of scientific research because of this lab project.	2	1	3
32	I feel more like a real science problem-solver now.	-1	-1	-3
33	The members of my group helped me understand their roles and the project.	4	-5	4
34	This project helped me become a better communicator.	2	-3	2
35	The writing for this lab project was difficult.	-2	-2	0
36	I am glad my group picked the project we did instead of another project.	5	2	5

Note: Each factor array contains the grid positions for the factor's representative sort; these factor arrays are shown in Figures 1, 2, and 3.

Table 1 cont. Factor arrays for each of the viewpoints

Factor 1a – Motivated learners

The nine participants are represented by this viewpoint. Explanations for most salient statement placement correspond to the representative sort for Factor 1a, shown in Figure 1. For instance, participant #13 wrote, "Learning from others is interesting." Participant #5 explained, "Good grades are always a priority in any class. You need to be able to motivate yourself to be able to strive for good grades all the time." Written comments provide insight, but the representative sort for this factor helps us to further this factor.

Within the representative sort, statement #14 is at +5 and is distinguishing (I felt motivated to do well on this chemistry lab project). Distinguishing statements are determined empirically and help differentiate the various viewpoints (factors) that emerge. Those on the Factor 1a view are glad that their group picked the project they selected (#36 at +5). These students think science is interesting (#20 at +4, distinguishing) rather than a waste of time (#15 at -5, distinguishing). These students felt that the members of their groups helped each other understand their roles and the project (#33 at +4; #9 at -4, distinguishing). The Factor 1a students

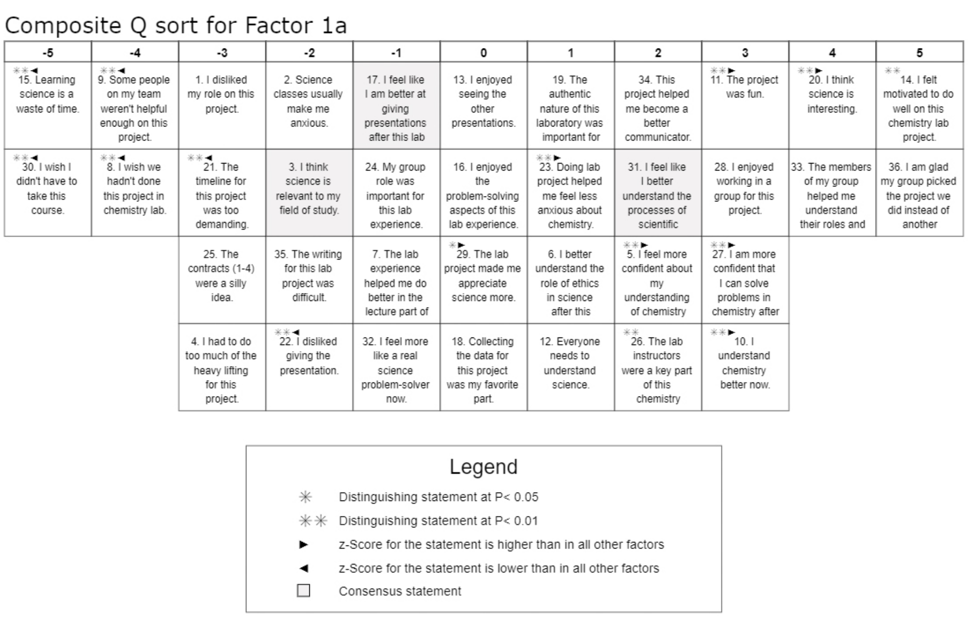

Figure 1. Representative sort for Factor 1a – Motivated learners

are happy about having this project as part of the chemistry lab. Overall, this view displays intrinsic motivation (despite comments regarding good grades) and a genuine interest in understanding science.

Factor 1b – Negative experience due to group dynamics

Factor 1a and Factor 1b are the result of splitting the bipolar factor, Factor 1. However, this result does not mean that Factor 1b is simply the inverse of Factor 1a. Not surprisingly, students on this view are not motivated learners in this lab or course. However, their view is more complicated than simply lacking motivation for the lab, the PBL experience, and/or the course. Written comments by the four students represented by this viewpoint will help frame this view before we discuss the representative sort for Factor 1b.

One of the four participants (participant #27) represented by this view wrote:

> "I had no fun because of group members' name calling and blaming other people…This project was extremely aggravating and stressful because my group did not work professional or together."

Like participant #27's comments, participant #3 had the following to say about their experience:

> "My group made me do an entire part of the project by myself even after I asked them multiple times over the extended break to help me research our project. Then on contract 4 two members helped while one didn't do much and one just ignored everything we asked her to do and didn't even look at the final project before we presented."

These written comments indicate that group dynamics helped create a negative situation for those students on this perspective.

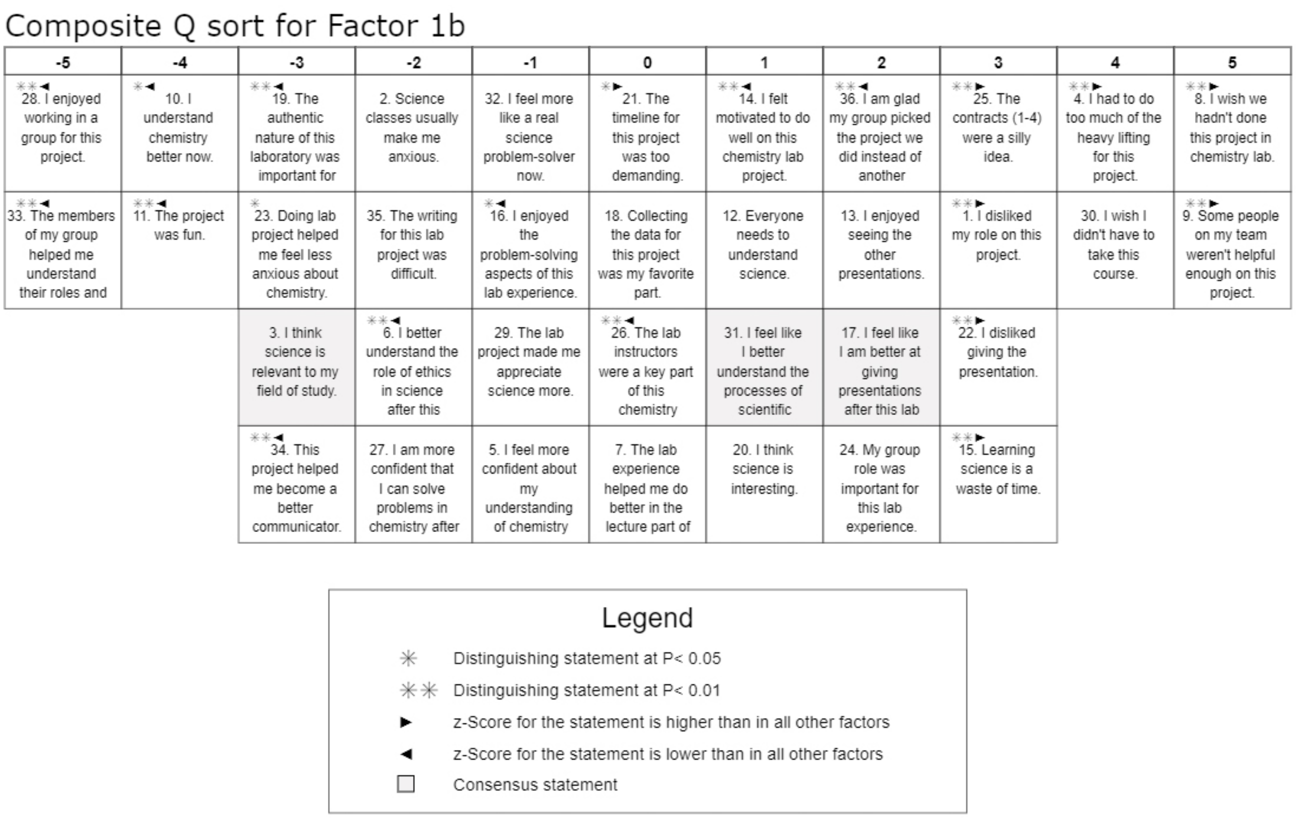

Figure 2. Representative sort for Factor 1b–Negative experience due to group dynamics

Figure 2 represents the factor array for this view. Statement #8 (I wish we hadn't done this project in chemistry lab) and statement #9 (Some people on my team weren't helpful enough on this project) are the two statements at +5, most agree. Both statements are distinguishing for this viewpoint and correspond to the written comments. Likewise, statements 28 (I enjoyed working in a group for this project) and 33 (The members of my group helped me understand their roles and the project) are distinguishing and at -5, most disagree. Statement #4 is at +4 (distinguishing) and reiterates that those on this view feel that they did most of the heavy lifting for the rest of their team on the project. Perhaps most disconcerting is that those on this view feel they do not understand chemistry better now (statement #10 at -4, distinguishing). Notably, those on this viewpoint feel alienated from their group and responsible for completing the project.

Factor 2 – Committed to my group

Factor 2 represents seven student participants. These students are focused on their commitment to their group. They enjoyed their role and they enjoyed working with their peers and did not want to disappoint them. For instance, participant #4 made this statement about her most salient statement placements:

> "I liked the role that I had. Marketing was interesting to look at and see of what went into the experiment and seeing how easily you could get the supplies. I wanted to get a good grade since it's a large part of my grade. I also wanted to do good since it would affect my groups' grade as well, not just my own. Contracts 1-4 were helpful because they are a buildup to the final presentation. It helps students to pace themselves and continuously work on the project without getting too behind and saving it all for the end. The TA's were really helpful with answering any questions we had. And Carrie was super awesome to perform our labs for us!"

Similarly, participant #7 said, "I am a naturally motivated person, so that helped. My role also helped me stay motivated. I had a commitment to my group and had to work hard to give them a good grade and not burden them." Although this statement may seem similar to Factor 1a, the motivation is more connected to belonging to a team rather than the individualized motivation expressed by Factor 1a. Additionally, those students on this view are less interested in science than are those on the Factor 1a perspective. Participant #7 continued, "I've never been interested in science. It fails to catch my attention. I have a hard time grasping it." The representative sort for this factor, shown in Figure 3, further clarifies this viewpoint.

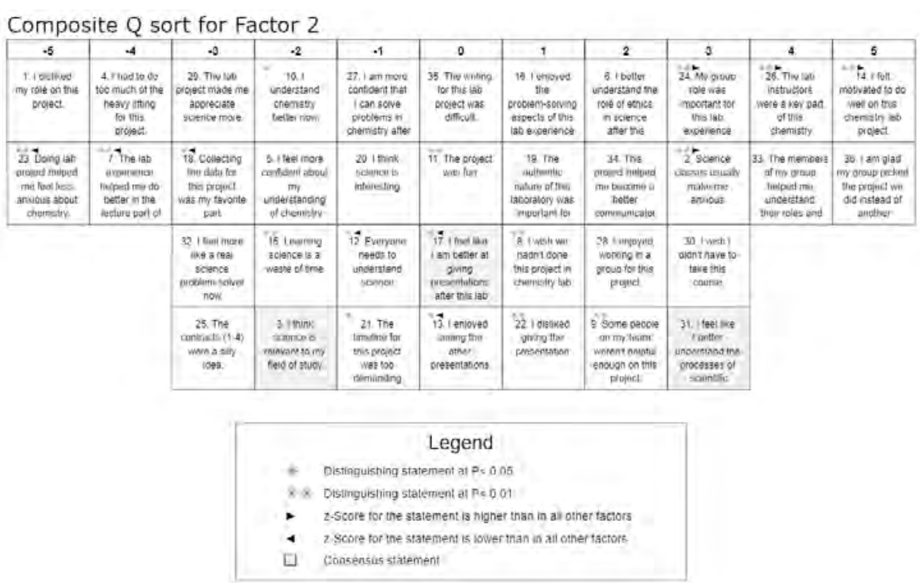

Figure 3. Representative sort for Factor 2 – Committed to my group

Salient statements for this view include "I felt motivated to do well on this chemistry lab project" (#14 at +5, distinguishing, also +5 for Factor 1a) and "I am glad my group picked the project we did instead of another project" (#36 at +5, also +5 for Factor 1a). These students also enjoyed their roles on the project (#1 at -5). For these Factor 2 students, the lab instructors were a key part of their success with this chemistry project (#26 at +4, distinguishing). However, they also had no interest in taking the CFE course (#30, at +3, distinguishing). Science courses typically make these students anxious (#2 at +3, distinguishing), and this PBL experience did not make these students feel less anxious about chemistry (#23 at -5, distinguishing). The Factor 2 students believe that the PBL experience did not help them do better in the CFE course (#7 at -4, distinguishing). Thus, the Factor 2 view motivation seems connected to the idea of working as a team rather than individual, intrinsic motivation. Those students on this view are not motivated to learn science and are disinterested in learning science. In other words, their enjoyment for the PBL experience had to do with working as a team and their desire to support the group members, despite a general lack of interest in science and chemistry.

Consensus

The Q analyses include providing the statements that represent consensus among the divergent viewpoints. Like the distinguishing statements, consensus statements are determined empirically. In this study, three statements represent consensus among the three viewpoints. Students do not think that science is relevant to their fields of study (#3 with grid positions of -3, -2, and -2, respectfully, for factors 1a, 1b, and 2). Additionally, students feel relatively neutral regarding improvement at giving presentations after the lab project (#17 at -1, 2, and 0). Students do agree that they better understand the processes of scientific research because of this lab project (#31, at 2, 1, and 3).

Conclusions

Consensus among the three views provides insight, as do the descriptions of the three divergent viewpoints regarding the PBL experience within the CFE laboratory. Regarding consensus, an important agreement among the views was that students feel they did learn more about the processes of scientific research, a learning outcome desired for the CFE course and general education science courses more generally. Overall, two of the three views that emerged from the analyses represent a positive view of the PBL experience although for different reasons. The third view was negative about the experience.

A key aspect of PBL is the social construction of knowledge as students work effectively in small groups to address the problem (Jonassen, 2011). Within this study, the negative view is strongly connected to a negative experience working within the student group as part of the PBL experience. In an effective student group, participants must collaborate to determine the information to collect, the design of data collection, and the problem solution (Jonassen, 2011). Factor 1a and Factor 2 participants demonstrated the benefits of collaboration described by Pfaff and Huddleston (2003), including improved intrinsic motivation and persistence when faced with adversity, although these characteristics were expressed differently for these two views. Also, for these two views, but not the Factor 1b view, the setting for the PBL helped establish the type of collaborative environment described by Kapp (2009). Thus, these two groups demonstrated shared expectations and, as suggested by Kapp (2009), experienced effective teamwork. Alternatively, Factor 1b did not effectively work together and demonstrated some major issues related to collaboration and shared workload.

Without this collaborative framework, PBL becomes ineffective, as shown with participants represented by the Factor 1b viewpoint. These students' groups lacked the reflective social discourse described by Land and Zembal-Saul (2003). Students within the groups on the Factor 1b view, lack the type of motivation to participate in collaborative learning processes necessary in PBL (Ryan & Deci, 2000). Overall, students on Factor 1b did not express a sense of belonging to the group. These students did not feel supported by their teammates. Instead, participants on this view felt they were left in a position that obligated them to do most of the work related to the PBL.

Alternatively, Factor 2 students belonged to groups that embraced reflective social discourse as described by Land and Zembal-Saul (2003). These students feel engaged within their groups—a characteristic described as important within PBL (Ryan & Deci, 2000). The group framework motivated the Factor 2 students to work not only for their own success but also for the success of their teammates. The Factor 2 *Committed to my group* view embraces the group dynamic of PBL even if they do not embrace science learning.

The *Motivated learners*, Factor 1a, represent what science faculty would like to see: these students enjoy science and are interested in improving their understanding of science, despite believing that science is not well connected to their desired career choices. No indication is apparent that students on this viewpoint became more interested in science because of the PBL chemistry experience. Although both Factor 1a and Factor 2 demonstrate motivation within the PBL experience, the source of that motivation is quite different for these two viewpoints. The *Motivated learners* are driven by their personal success in the course and their interest in science. Alternatively, the motivation of those represented by the Factor 2 view is based on students not wanting to disappoint their teammates and wanting success for the group more than just individual success.

In summary, PBL is a pedagogical strategy that encourages student-directed learning that is focused on solving a meaningful, authentic, open-ended problem with no set solution (Hmelo-Silver, 2004). The importance of the student group's ability to collaborate is demonstrated within the results of this study. A negative PBL experience is strongly related to problems regarding group dynamics and the balanced workload across the multiple members of the team (Factor 1b). When the group dynamics are positive and the workload is more equitably shared, students have a more positive experience even when they lack an overall interest in science, as demonstrated by the Factor 2 viewpoint. The opportunity to have different roles within the student team was important to these students and allowed them to draw on their non-science interests. Those students, who are typically interested in science and learning, embrace PBL as well (Factor 1a). Without the pandemic, the laboratory instructors may have been more effective in defusing student group issues. The instructors did find that the need to use WebEx to meet with student groups during the pandemic facilitated private meetings with individuals as well as a group to discuss group-dynamics. Finally, in the future, the laboratory instructors may need to find ways to help orchestrate knowledge-building discourse within the student groups, as described by Hmelo-Silver and Barrows (2008), as well as finding additional ways to assist students in equitable workload sharing within their teams.

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Susan E. Ramlo, PhD is president of SueZ Q, LLC and a senior lecturer at The University of Akron. Her research focuses on STEM education and Q methodology.

Carrie Salmon, PhD is Visiting Assistant Professor at the College of Wooster. She was previously with the Department of Chemistry, the University of Akron, where this research was conducted.

Yuan Xue, PhD is Visiting Assistant Professor at Oberlin College and Conservatory. He was previously with the Department of Chemistry, the University of Akron, where this research was conducted.