Case Study Analysis of Reflective Essays by Chemistry Post-Secondary Students within a Lab-Based Community Service Learning Water Project

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Intentional reflection is a key component of Community Service Learning (CSL) as it guides students to integrate knowledge of theory with experience in practice. A semester-long chemistry curriculum with an integrated CSL intervention was implemented in a Canadian university to investigate how reflection in the laboratory setting enhances post-secondary students' (n=14) conscious awareness of their learning and their attitudes toward having reflection as part of a course. In typical chemistry laboratories, students follow cookbook recipes from the lab manual and are assessed through written lab reports. These lab reports are similar to a technical report with scientific writing where the design aims to communicate scientific information to other scientists. A case study was conducted with reflective essays, focus group interviews, and student observation to analyze qualitatively how students' attitudes changed in their learning over the course of the CSL activity and how they engaged in this type of reflection. The expected audience that may be interested in this study are those involved in teaching chemistry in higher education and those that are interested in Community Service Learning and experiential learning. The results demonstrate that science students are able to articulate their academic growth, civic engagement, and personal growth through reflective pieces. Furthermore, the reflective pieces support self-regulated learning with a positive engagement and attitude over time. The results support the integration of reflective pieces in laboratory settings

Introduction

Experience is one of the most frequently discussed terms when students are seeking employment. Post-secondary science graduates are entering a workforce where business organizations desire their employees to have a firm foundation in scientific knowledge, critical thinking, communication skills, diversity, and professional integrity (Fung and Watts, 2019; Lawrie, 2021). Thus, it is essential for post-secondary institutions to prepare students with the ability to be citizens of the world with lifelong and self-directed learning skills (Ash and Clayton, 2009). One strategy to facilitate the integration of applied learning pedagogies within the curriculum and outside of classrooms is the implementation of Community Service Learning (CSL). Other common terms used interchangeably are Community Based Learning and Community Engaged Learning. CSL projects involve student-community engagement. One of the main aims is to develop genuine partnerships between students and their community partners so that mutual teaching and learning experiences and co-creation of knowledge can take place. CSL constitutes an experiential learning method that integrates community service into student projects to provide diverse and exploratory learning opportunities to reduce interdisciplinary barriers (Smith, 2012; Ho *et al.*, 2021). Over the course of the semester, these collaborative projects provide students with an opportunity to learn independently in an environment that forces them to construct and reconstruct their own knowledge and understanding (Nyachwaya, 2016; Santos-Díaz and Towns, 2021). Students will develop conscious awareness in their learning rather than reproducing what their instructors have taught them.

Traditional laboratory practical

Historically, students in chemistry labs follow cookbook recipes from a lab manual. Because this approach remains common today, we refer to these isolated interactions with natural phenomena as typical laboratory experiences (Clough, 2002). Students are assessed by written lab reports, a technical form of scientific writing designed to communicate scientific information to other scientists. Therefore, students are not often asked to reflect on their feelings, attitudes, and personal experiences in the laboratory setting (McDonnell and Murphy, 2019; Wei *et al.*, 2020; Ho *et al.*, 2021).

Reflection as an Essential Component of CSL

Previous studies have shown that science courses with integrated CSL benefit post-secondary students' favorable engagement and attitude towards learning and higher self-confidence levels after the activity (Ho *et al.*, 2021). Furthermore, it is well-documented that CSL is a high-impact educational practice and there are many associated benefits for learners (Washington, DC: AAC&U, 2013). As part of the CSL process, post-secondary students are expected to reflect upon their experiences. Reflection plays an important role in learning because it provides opportunities to infuse students' subjective experiences, thoughts, and feelings into the content-oriented course work (Molee *et al.*, 2010). A "well-structured, intentional manner with purposeful fidelity reflection" can also improve students' academic performance (Persson and Kvist, 2018, p. 12). During reflection, students can address prompts and feedback from the lab instructor to support students' reflection on what they have done before, during, and after the CSL activity (Lin *et al.*, 1999). The reflection piece can be delivered in different writing formats, such as summaries, journals, and interviews (Roskos, Vukelich and Risko, 2001; Chang, 2019). These reflection pieces are rich sources for students to document what they have learned in connection to the course material (Molee *et al.*, 2010). One advantage of having course-

embedded reflection is that it is generally less time consuming for both instructors and students than having separate interviews or portfolios (Ash and Clayton, 2009). Another advantage of this design is that it allows data to be collected at different intervals throughout the CSL activity, resulting in documentation of deep exploration on participants' reflective and emotional thought.

Having an experience does not directly lead to learning (Rubin, 2002). Kolb proposes a holistic model of the learning process called "experiential learning" that constitutes three components. They are experience, reflection based on prior knowledge, and learned experience (Kolb, 1984). Over time, current experience may or may not encode into a part of long-term memory. It is only becoming part of long-term memory when students are able to repeatedly retrieve the memory through recall, recognize, and relearn to improve their learning and strengthening their memory (Chang, 2019).

Assessing learning through reflection

Ash and Clayton have developed a three-step sequential process called the DEAL Model to understand and assess student learning through reflection based on the theoretical frameworks of *Bloom's Taxonomy of Educational Objectives* (1956) and *Critical thinking: Tools for Taking Charge for Your Professional and Personal life* by Paul and Elder (2002) (Ash and Clayton, 2009). Within the DEAL model, students engage in a) **D**escription of their CSL experience, b) **E**xamination of their experience based on specific learning objectives for *academic enhancement*, *personal growth*, and *civic engagement,* and c) **A**rticulation of the **L**earning through reflection (Ash and Clayton, 2009). This model has been widely used in different formal education settings, from K-12 to post-secondary to graduate courses, as well as in professional training settings (Ash and Clayton, 2009).

According to Ash and Clayton (2009), the goal for students who participate in a CSL activity is to enhance their academic enhancement, personal growth, and civic engagement. Academic enhancement is defined as the understanding of concepts or theory presented in the class and through class discussion. Personal growth is an on-going process where an individual develops understanding of his or her strengths and weakness, sense of identity, assumptions, beliefs, and conviction as well as other traits (Molee *et al.*, 2010). Depending on the discipline where the CSL activity occurs, civic engagement can be defined in various ways, such as change agency, leadership, and public problem-solving (Ash and Clayton, 2009). Students should identify the mutual objective they are working toward with the community partners and examine the approach for achieving this objective. If the approach has a negative effect, potential suggestions for enacting long-term and sustainable service should be provided in order to improve other individuals' well-being (Obradović and Masten, 2007; Molee *et al.*, 2010).

The current study is the second part of a multi-year study. The first study focused on post-secondary and K-12 student attitudes in a CSL chemistry laboratory setting with the integration of the different instructional methods that were involved in a mid-sized Canadian post-secondary institution and collaborating K-12 schools (Ho *et al.*, 2021). The current study investigates how reflection in the laboratory setting affects the awareness of post-secondary students in their learning and investigates their attitudes toward having reflection as part of a course. The current study was conducted in the lab component of the second-year course Analytical Chemistry II (CHEM 2302). This is the first in a sequence of three required courses with integrated CSL projects at the university. Chemistry degree students at the university must complete three courses that employ CSL in their curricula (minimum of nine credits) in order to receive a CSL citation on their transcripts. Types of projects that other CSL-integrating courses conduct include a qualitative study on chemistry education research with College Chemistry Canada as a community partner. Each course is associated with 3 credits and the learning hours per course are 20-25 hours. Students have the option to earn CSL citations. The current study's semester-long CSL project involves a mutual partnership among post-secondary and K-12 students to work collaboratively to determine the physical and chemical properties and total dissolved solids in water fountains from the K-12 schools (Ho *et al.*, 2021). The intervention of this water project is intended to empower post-secondary students to be in charge of their own learning while developing a deep, meaningful, and lasting understanding (Gupte *et al.*, 2021). In addition, the interaction with K-12 students allows post-secondary students to think beyond the classroom within a social context.

There is a very limited number of existing studies that include analysis of student reflective writing in their CSL project. Sewry and Paphitis have examined students' reflection journals in thinking about broadening their education goals within chemistry education (Sewry and Paphitis, 2018). Reflection helps develop student subject-specific knowledge and understanding. In chemistry education, various reflection approaches have been introduced when seeking to develop a student's metacognition. For example, the use of photos, to enhance practical skills development, and talking mark schemes in a self-assessed exercise (Read *et al*., 2019). The reflection associated approaches, however, are a one-time activity. There is no continuous reflection on student progress that could be captured. Thus, it is important to further study and explore how reflection impacts students' learning over a course consisting of constructivist epistemology with a naturalistic research approach and a relativist perspective (Baxter and Jack, 2008; Merriam, 1988; Yin, 2009).

Reflection in the content of this CSL project

The goal of the current study is to evaluate how post-secondary students engage in reflective thinking over the course of the CSL activity in a chemistry laboratory setting. Using case study as a methodology with reflective essays, focus group interview, and direct observation as method, the research questions are follows:

1. How do science students demonstrate their articulation of any individual learning, academic enhancement, personal growth, and civic engagement through writing reflective essays?

2. How do students' attitudes change over the course of CSL activity?
3. How do science students demonstrate their articulation of learning progression and experiences through writing their reflective essays?
4. What are students' opinions about the use of reflective writing on learning in a laboratory setting?

Methodology and Methods

A case study is "an empirical method that investigates the contemporary phenomenon in depth and within its real-world content, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2009, p. 15). The epistemological commitment of the current study comprises a relativist perspective with a constructivist approach as post-secondary students construct or create their own knowledge while integrating new ideas into existing knowledge through interaction with others (Ho *et al*., 2021). The research was conducted as an exploratory case study (Yin, 2009). The research questions focusing mainly on "how" align with Yin (2009) in the way that they explore "real-world phenomenon that has concrete manifestation" (p. 32). The "what" question is exploratory, with the goal of developing propositions for further inquiry (Yin, 2009).

Participants

Convenience selected samples were taken from students who were registered in Analytical Chemistry II winter 2020-21 semester in a mid-sized Canadian institution (Lavrakas, 2008). A total of 20 students were enrolled in the course, divided into two lab sections. From these, 14 students participated in this research project, giving a response rate of 70.0%.

Ethics considerations

This study was approved by the two universities' Research Ethics Boards. In addition, a permission letter was obtained from the area director from a local school district. The letter is required for purposes of contacting school-based principals to inform them of the opportunity to have classrooms participate in the CSL water project and for receiving permission to work with school staff and partner about water analysis. All post-secondary students were informed of the purpose of the research and the voluntary and anonymous nature of their participation after the CSL activity is completed. Their informed consent to participate was obtained after data collection because all the reflective essays and focus group interviews were completed as part of the coursework. For focus group interview, students were graded based on their active participation in answering the interview questions.

Design and procedures of the intervention

The reflection assignments were designed to meet the academic and emotional needs of the learners. These reflective essay assignments and a group interview were embedded in the course. The lab component of the Analytical Chemistry II course has a 45% weighting that includes reflection pieces and the quantitative analysis of organic and inorganic materials using different instrumental methods.

Analytical Chemistry II focuses mainly on critical thinking and development of analytical skills. Students are guided to think critically and to develop problem-solving skills through logical approaches. The laboratory component is given special attention as it is oriented to give students the opportunity to develop practical analytical skills in handling samples and analysis techniques. The CSL component provides the students opportunity to work with a community partner on the water project that aligns with the learning objective. 21.5% was allocated for the reflection work and 23.5% was assigned for the rest of the practical lab work and oral presentation.

As noted by the National Research Council (2001), students can maximize their learning if prompts and instructions are provided during reflection with assessment integrated in the course. A workshop was hosted by the laboratory instructor in Week 4 to introduce science students to the importance of reflective practice and guide them on how to become better independent learners. The workshop explored the topic of reflective practice through self, peers, and instructor. Examples from past students' reflective writing work were provided to create space for diverse viewpoints and to demonstrate how to give effective feedback from peers. Interested parties may contact the corresponding author for further information about the workshop. Instructor feedback can be used as a guide to help students improve their reasoning and the quality of their future work. The approach for instructor feedback is developmental, encouraging, thoughtful, and beneficial as a learning experience for all parties (Piccinin, 2012). The main notion students need to apply is receiving peer and instructor feedback, which is essential to development and continued improvement. Feedback was provided to students specifically when particular articulation was missing and suggested improvement for future work. To maintain consistency among all students, the lead researcher was also the lab instructor for all of the lab sections.

Students wrote five reflective essays following structured prompts based on the concepts in the DEAL model during the 10-week period of the laboratory component in which the post-secondary students participated in the CSL activity (Ash and Clayton, 2009). The reflective essays were assigned before, during, and after the oral presentation to the community partner. The lab schedule for the post-secondary students is shown in Table 1. All reflective essays were assigned during lab hours and students were given one week to complete each assignment. Students were required to individually reflect on the highlights, feelings, and lessons that they gained during each phase of the CSL activity. Each reflective essay was submitted online. Written feedback from

the lab instructor was returned within 24 hours to challenge students to think more deeply and broadly about their learning in the reflective essay. To encourage students' honest reflection, grades were allocated based on accuracy, clarity, depth, and relevance of the reflective writing.

To promote group reflection, an online focus group interview was held between reflective essays 2 and 3 to examine students' opinions about reflection on learning in a lab setting. The interview was hosted online due to the coronavirus pandemic. In group interviews, the difference among students' perspectives can be highlighted, which allows researchers "to surface the views of each person in a group" (Yin, 2009, p. 120). The interview is semi-structured in a manner that resembles guided conversations, consisting of open-ended questions for one-hour. There were three interview questions probing students' learning experiences in the lab setting. These questions were provided to students one week prior due to the unfamiliarity of learning in this type of setting for science students. Each interview was facilitated by trained undergraduate research assistants and was recorded for transcription. The undergraduate research assistants were co-authors of this study and were trained by the lead researcher.

Table 1 Lab schedule for post-secondary students

Week	Activity	Reflective Essay
1	Check in & Introduction of CSL	
2	In-person lab	
3	In-person lab	
4	Introduction: How to write reflective essays?	Reflective essay 1
5	Ion chromatography – open inquiry	
6	Ion chromatography	Reflective essay 2
7	Focus group interview	
8	Atomic absorption spectrophotometry	Reflective essay 3
9	Mapping & web conference preparation	Reflective essay 4
10	Oral presentation	Reflective essay 5

In an effort to capture the knowledge that students gained through reflection, direct observation of students was recorded as additional information throughout the CSL activity. Haslam and Gunstone have reported an increase in content learning when teachers observe their students (1998). This involves recording observations from the dialogue among post-secondary and K-12 students after the oral presentation and group interviews. K-12 students were involved in the collection of water samples and conducted some of the water testing in the beginning of the CSL activity. These preliminary results were provided to the post-secondary students to compile the water analysis data for the oral presentation. Post-secondary students used web-conferencing to present their results to the K-12 students and the larger community (Ho *et al*., 2021). Time was given after the oral presentation for both groups of students to ask each other questions if needed. This data is extremely valuable to complement the primary and secondary sources of data to document how reflection enhances the student learning journey during the semester.

Data collection

Diverse forms of information were obtained in an attempt to collectively capture a picture of how post-secondary students articulate their learning processes and attitude changes through reflection. Reflective essays, student interviews, and student observations were collected.

Reflective essays. To capture individual voices during the CSL activity, five reflective essays were assigned at different time intervals. The reflections include "reflection on past," "reflection in action," and "reflection on future actions" (Chang, 2019). The reflective essays embedded at the end of every weekly session were included for the purpose of conceptualizing students' learning and providing a space for students to express their feelings and concerns. Each reflective essay was assigned to be 400-600 words in length and prompts were provided based on the concepts of the DEAL model to guide students in reflecting on what they learned from the activity and their emotional thoughts about the experience (Ash and Clayton, 2009). A marking rubric was also provided to students from *The Miniature Guide to Critical Thinking* by Paul and Elder for grading (Paul and Elder, 2019). Examples of textual prompts guiding the students include:

- How can you explain this CSL water project and your Atomic Absorption Spectrometry result to the community members that are not involved but can understand the content?
- Discuss what you have learned from the Atomic Absorption Spectrometry experiment. Please reflect on what you have learned in regard to your experimental data that is important as a Calgarian.
- During the group work, how can you identify the errors that you have made and re-construct proper adequate understanding through this error-identification process? Please provide a direct example in this lab course.

Students submitted their reflective essays through an online education platform. Through formative and summative assessments, the lab instructor provided feedback to each reflective essay to deepen students' learning and improve students' writing and reasoning skills for future reflective essays.

Focus Group Interview. To promote group reflection, an online group interview was conducted as a secondary source of data in Week 7. Students were divided into groups of 3-4 for a total of six group interviews. Each interview was scheduled for one hour. The three open-ended questions to prompt a reflective dialogue on their learning experience were provided to students one week prior. This type of reflective dialogue aims to help students explore whether reflection can support their life-long learning in a laboratory setting. The transcript was manually checked by the lead researcher during the data analysis to ensure that students who opted not to participate in the study were removed. The interview questions were:

- How does learning through *reflection* help you understand your own strengths and weaknesses in this course?
- During this CSL activity, does *reflection* provide you the opportunity to become a self-directed learner? If not, what other aspect(s) do you think should be used to promote your self-directed learning?
- Should *reflection* pieces (could be delivered in various formats) be used for other chemistry and biochemistry laboratory settings as well and why?

This type of social group dynamics led discussion supports students emotionally and creates a sense of community, especially during the coronavirus pandemic (Dugas, 2017).

Student observation. Student observations were employed as a tertiary source of data to triangulate with the reflective essays and group interview to establish construct validity (Yin, 2009). The student observation was recorded as field notes from the group interviews and during the questions and answer period after post-secondary students presented their dissemination. The data were used as means to provide context for the narrative.

Data analysis

Interested students participating in this project received an alphanumeric code to ensure confidentiality. First, selected quotations from 14 students were used to demonstrate their articulation of academic enhancement, civic learning, and personal growth at different phases during the course of the CSL activity. Secondly, students' attitudes about this CSL water activity were also documented. Thirdly, a student vignette was used to provide a more holistic perspective of a student's learning process over the course of this CSL activity through reflective essays. Lastly, students' comments and opinions from focus group interviews about their experiences in reflection on learning in a lab setting were collected. A total of 70 reflective essays were downloaded from Blackboard for analysis. Group interviews were transcribed using Meet Chat Transcribe, an extension from Google Meet. A total of 6 hours of interview data were manually checked for errors and corrected if required by the research team. Reflective essays, interview transcripts, and student observations were uploaded for qualitative data analysis using Microsoft Excel for coding. Field notes were used to verify speaker identification and ensure accuracy. A constant comparative analysis among methods was used throughout the coding process as a means to increase the validity of this interpretative research (Lewis-Beck, Bryman, and Futing Liao, 2004). This process builds trustworthiness with the meaning of data and provides an audit trail (Bloomberg and Volpe, 2018). A time-series analysis was used to illustrate students' learning processes over the course of the semester (Yin, 2009).

Analysis procedure

Lincoln and Guba state that trustworthiness is one way researchers can persuade themselves and readers that their findings are worthy of attention (Lincoln and Guba, 1985). Using the consensus coding approach, the data were read and analysed independently by three researchers in the team. The lead researcher first randomly selected five reflective essays and one interview transcript to individually code. Then, the researcher team went through subsequent meetings to discuss the interpretation of the analysed data and areas of overlap and discrepancy until consensus was reached and appropriate refinements were made to the coding categories and descriptions. The research team involved the lead researcher and two undergraduate research assistants. The lead researcher was responsible for the codebook editor that created, updated, revised, and maintained the master list for the group. Different members in the research team brought multiple ways of analysing and interpreting the data (Saldaña, 2021). Once all coders came to an agreement, the shared definition was used and applied consistently for all the reflective essays and interview transcripts.

Results

Our analyses explored how each strategy for intentional reflection (reflective essays, focus group interviews, and student observations) supported student learning in this CSL water project. Each strategy reveals a portion of the story that contributes to the complete understanding of this multifaceted case. The quotations and observation notes provided were selected based on clear examples of the findings being presented, and the data showing these findings applied to a majority of the participants. The majority of the quotations was taken from reflective essays with some quotations from the focus group interviews. The

observation notes recorded the researcher's first-hand experience with the participants. Weaving all the data together leads to a more definitive claim about this case study.

Finding 1. Science students were able to articulate their learning goals through structured prompts and instructor feedback in reflective essays.

Articulating goals for students learning is valuable as students are trying to accomplish and achieve them (Kadioglu-Akbulut and Uzuntiryaki-Kondakci, 2021). Many science students lack experience in writing reflection pieces because most laboratory courses focus on teaching technical skills when writing proper formal lab reports. Through writing reflective essays, science students demonstrate their articulation of any individual learning. Focusing on the contexts of academic enhancement, civic learning, and personal growth, five reflective essays were assigned to examine how science students express and explore their individual learning. All students (100.0%) were able to identify and describe concepts in academic enhancement, civic learning, and personal growth to some extent. They were able to apply those concepts using the rubrics. The quotations in the following sections illustrate how science students communicated effectively in terms of these three learning outcomes during different phases of the activity.

Academic enhancement: Students examined what they have learned in class in relation to the CSL activity. They analysed the similarities and differences between theory and practice to generate their understanding of the academic concepts. The aim of academic enhancement focused on getting students to learn, construct, and reconstruct knowledge together to form new meaning.

> 005: *It was interesting to see that calcium has the highest concentration in value... I have noticed that calcium tends to build up on faucets much more quickly in Calgary than faucets in other places in Alberta (for example, Ponoka).*

Civic engagement: Students indicated in their reflective essays that this CSL activity helps them to build personal connections between the theories and the community with which they were familiar. Collaboratively, there is a shared objective between post-secondary and K-12 students of having clean drinking water.

> 007: *I think the most important aspect about this CSL water project is to teach K-12 students why these service learning projects are so crucial. Although the city treatment plant does an amazing job to provide a safe, drinkable supply to local citizens, there are other factors that could influence these decisions, such as budget. Community members have the responsibility to evaluate and make awareness if there is an issue. I believe this project encourages youth to be more involved in their communities.*

Personal growth: Students indicated that this CSL activity has provided them with a skill set to develop continuously to reach their full potential. This indicates changes they are adapting to their own growth as revealed through this CSL experience. These lifetime skills are important even after formal education has been completed.

> 002: *I have not had an opportunity to interact, specifically give a presentation for people whom I have never met before. Although I stuttered a little during the presentation, it went quite well overall. Because of this experience, I am more confident to present to other people that are not chemists.*

During the final presentation, students demonstrated their understanding and articulation of the CSL activity by presenting for 20 minutes on their experimental data, followed by a 20-minute question and answer period. For example, when K-12 students were interested to learn additional information about safe drinking water quality guidelines, the post-secondary students provided a website link that directed them to look up specific information from the World Health Organization on national drinking water policy. This demonstrates that post-secondary students have increased their understanding of sophisticated content areas through independent reading and their participation in meaningful conversations during group work. Proficiency in both these skills is critical for overall academic success.

Finding 2. Students developed a positive attitude and engagement toward learning chemistry throughout the course of the CSL activity.

Over the course of the CSL activity, students developed a positive attitude and engagement toward learning chemistry. At the beginning of the course, students reported that they were looking forward to participating in this CSL activity. All students expected that the CSL activity could help them increase awareness of the world around them and improve their critical thinking skills. It is interesting to mention that some science students (8 of 14 [57.1%]) indicated that they felt the structure of the lab design was unique compared to their previous lab course experiences.

017: *This learning environment is unique as we will spend a semester-long process to learn various techniques to conduct experiments and prepare for a well-polished oral presentation.*

018: *I think this type of learning environment puts us [as] students in control which could be an odd experience at first. There's a sense of both independence and co-dependency among my group members because we will all share the same responsibilities in understanding the material.*

020: *I have never been experienced into this type of large group project. It provides an opportunity to challenge myself to work with a group of students with different personalities.*

The students' support for the lab design became more evident in Week 9, as students transitioned from merely being participants to being proactive collaborators. All students (100.0%) indicated in their reflective essays that they supported this type of collaborative learning design.

018: *I personally enjoyed this type of learning environment because I was able to meet so many other students, learn, and understand the content [through discussion], which deepened my understanding of the chemistry knowledge.*

011: *I am glad that I was able to be a part of this complex and interesting project.*

016: *I really liked the idea of working and providing services for my own city.*

Furthermore, it is important to highlight that many students were experiencing remote learning due to the coronavirus pandemic. Therefore, this CSL activity engaged students to be more connected and have a more positive attitude.

005: *It's easy to feel lonely and apathetic sitting at a desk and working on individual tasks all day. I really enjoyed being able to participate in the group interview and work on the final presentation with 2 other students.*

The results parallel the findings from the survey after the CSL activity in the previous study, where students expressed favorable enjoyment, attitudes, and interests towards learning chemistry after the CSL water activity (Ho *et al.*, 2021).

While most were positive on this point, one student presented a contrasting view saying, "a challenge that I encountered involves my group members willingness to do their work within the timeframe." This statement shows that the student was challenged in handling the interpersonal conflict effectively. To help the student overcome their interpersonal and emotional relationship with their peers, the lab instructor played active listener by reaching out to the student to facilitate a two-way, interactive dialogue and to provide supportive feedback (Harkins *et al.*, 2020).

Finding 3. With the implementation of reflective essays, students articulated their learning progressions and experiences across the three phases of the CSL activity.

Ash and Clayton suggest that reflection is more valuable when the reflective essays are implemented throughout the CSL activity by providing students prompts, feedback, and reporting outcomes (Ash and Clayton, 2009). A series of reflective essays were assigned at the beginning, during, and after the CSL water activity to document students' development of their own emergent learning processes and experiences through writing over the course. The vignette of one exemplary post-secondary chemistry student (005) illustrates the arc of students' reflections on their learning experiences across the CSL activity.

Phase 1: Connection with and contribution to their world

In the beginning of the course, post-secondary students expected that the real-world experience of this CSL activity could motivate them to learn independently and advance their scientific knowledge. Through mutual partnership and shared learning with community partners, students learning become more self-directed. The ability to explain chemistry phenomena and share their experimental findings with community partners is rewarding because they could use the knowledge learned in class to support both students and community partners in learning.

005: *Labs with a CSL component are a great way to connect post-secondary students to "real science." I believe it's beneficial to have someone [community partners] care about the data you collect. However, this means that you have to take measures to do a good job.*

Phase 2: Identifying the areas which are missing and develop reasoning abilities

During reflection, students reviewed from their assigned weekly session in an attempt to make sense of what occurred and to identify the unclear areas in learning. Reflection promoted self-regulated learning through individual performance or progress.

> 005: *The purpose of this weekly session is to determine the difference in concentration of selected ions from the experimental data to the water treatment plant report. When presenting this information to our community partners, I could do some research on the toxicity of each selected ion and determine if the concentration we found in our experimental data is harmful to people. Additionally, I could suggest relevant reasons as to why the variance occurs.*

A similar comment was made after this student completed another lab weekly session while they reflected back on and identified an area in the calculation where they were not certain. They reflected on how the work could be improved using a collective approach for future lab experiments.

> 005: *For last week's weekly session, initially I was working independently on the assignment. Then, I was a bit confused about the calculation. So I reached out to my group (I wished I had connected earlier) to see what their thoughts on it was. We were all able to come to a reasonable conclusion after discussion.*

During Week 9 presentation preparation, students began to develop a better understanding of the overall CSL activity.

> 005: *I think my understanding of this project has evolved. A lot of the focus is learning to collaborate with both my peers and the community partner to enhance my knowledge. Learning from others includes processing experimental data and applying active reflection during group interviews.*

Phase 3: Integration in learning

The students have demonstrated how their learning progression about this CSL activity has intertwined to form their personal meaning.

> 005: *Over the course of the semester, I have gained a better understanding of the project. This project provides me an opportunity to share my experimental findings to broader audiences that utilize my scientist skills. I think it's important for scientists to value communication skills with non-scientist as it promotes wider relevance to society.*

All 14 students progressed through the same three phases of learning, although at different rates, because each student learned at a different pace.

Finding 4. Students like and support the intervention of having reflection pieces in laboratory settings because they feel it will guide them to be self-directed learners. Furthermore, students think reflection helps them to retain what they have learned.

Reflection enables students to look back and rethink their experiences in order to improve, practice, and further refine their learning (Freed, n.d.). During this course, a focus group interview was conducted to ask students about their opinions about having reflections on learning in a lab setting. All students (100.0%) supported the intervention of including reflective pieces as part of the laboratory assessment because they feel it guides them to be self-directed learners.

> 012: *The prompts questions in the reflective pieces guided me to what I should be thinking about. It eases me into what to expect from this lab and what I should get out of it.*
> 002: *The reflective pieces help me to understand the chemistry content, and what I can improve on.*

It is interesting to note that 2 of the 14 students (14.28 %) held differing opinions about which year reflection pieces should be introduced in a post-secondary lab. The student below reasoned why reflection should be implemented as early as a first year introductory chemistry lab.

> 005: *Courses that could benefit from reflection the most is first and second year chemistry lab as it helps to guide students the progress of learning independently.*

The majority (12 of 14 [85.7%]) of the students, however, felt introducing reflection in an introductory course might be overwhelming as students need to adapt to many changes in their first year of post-secondary education.

> 007: *I think this reflective piece is a very helpful exercise, but you have to really sit down and be like, "okay, I want this to help me". However, if your mindset is, "oh, what a drag, I have to do this", then you're not going to get anything out of it. I think reflection pieces will be more helpful for advanced laboratories because students are about to enter the real world and they are going to need these skills.*

006: *The reflection pieces should be implemented starting in advanced lab courses as it will be better to prepare students for graduate school because graduate students need to write a lot of reflective writings.*

Furthermore, all of the students articulated that the reflective pieces promoted the ability to retain information and apply it in a new situation.

016: *Reflection helps me retain what I've learnt. It helps me understand what I've learnt in a different perspective.*
018: *Reflection not only helps me organize my thoughts, but it also helps me stimulate a lot of more thoughts.*
017: *Reflection helps me to tie my thought process and understand the concepts more.*

To further understand whether students' opinions changed two weeks after the focus group interview, the same question about their thoughts of having reflection in a lab setting was asked again in Reflective Essay 4 along with the other prompting questions. This stability in students' perspectives supports the internal validity of the finding. It is evident that all students held the same convergent opinion that learning through reflection is helpful in their lab studies.

006: *I find that reflection is very useful in organizing my thoughts. Most of the time my thoughts are rather convoluted, and reflection aligns my thoughts in a more succinct fashion. Writing these reflective essays makes my thinking process more organized.*
017: *Reflection has helped me a lot more than I thought of. Reflection helps me think back, and the prompt questions guided me to organize my thinking, learning, and understanding of the content.*
018: *Reflection is really important. It gives me the opportunity to assess my strengths and weaknesses, and to learn how to overcome those weaknesses and enhance those strengths. It's something that we, as science students, don't usually emphasize on.*

Discussion

In the Analytical Chemistry II laboratory, post-secondary students were provided a lab manual that introduced background information on the chemistry principles underlying the activity as well as techniques for conducting the experimental procedure. Students worked in groups of 2 or 3 in student-selected friend groups with the goal of enhancing peer learning (Cooper and Slavin, 2001; Takeuchi, 2016; Ho *et al.*, 2021). In this CSL activity, post-secondary students worked in groups for the water quality experimentation and web conference oral presentations. Within the groups, students were required to utilize their thinking, discussion, and reasoning abilities to make sense of the data. For example, during conflict resolution in group experiments, students needed to identify the error and re-construct their understanding through this disequilibrating experience (Sherif, 2015). During the service experience in the community, the interaction and discussion among both groups of students challenged post-secondary students' thinking and knowing, questioned their preconceived notions, invited controversy, and presented multiple pathways to draw conclusions (Petritis, Kelley and Talanquer, 2021). This dialogue among students can generate new, more nuanced understanding of their academic learning.

The CSL activity provided opportunities for students to explore how they learned to be the way they are. Bowen conducted a study on a group of post-secondary students and found evidence that students' values, attitudes, and life choices change through self-discovery after they join university (1977). The DEAL model facilitates students' learning by examining personal characteristics through the process of the CSL activity (Ash and Clayton, 2009; Molee *et al.*, 2010).

In this CSL water project, the post-secondary and K-12 groups of students identified the importance of having clean drinking water and what clean drinking water signifies. Post-secondary students analysed their water quality testing results in comparison with the city water treatment plant statistics. A difference in statistics could identify potential environmental or health related issues with the water at the K-12 schools. Post-secondary students then offered possible improvements to facilitate short-term as well as long-term change (Ash and Clayton, 2009).

Summary of the results and answers to the research questions

RQ 1: Science students were able to articulate the learning goals of the CSL activity in their reflective essays through structured prompts and instructor's feedback. Through reflection, students came to understand their role in the CSL activity, gained insights into their own personal attributes, as well as interrogated their role as citizens (Sewry and Paphitis, 2018). In this study, the reflective pieces were embedded into a structured lab setting that was facilitated, supported, and assessed by the lab instructor and research assistants. Over the course of a semester, students could identify, describe, and apply their individual learning through documentation.

RQ 2: A series of reflective essays were assigned as an evidence-based approach for monitoring student attitudes toward learning chemistry during the CSL activity. Many first-year students typically experience a teacher-centred pedagogy with technical reports as assessments in their laboratory program. Results indicated that students expressed a positive attitude and engagement from the beginning of the CSL activity that they maintained to the end of the CSL activity. This conclusion aligns to other literature that reported student reflection in the lab helps students' learning and increases their confidence level (Read *et* al., 2019). As a result, this lab design supported students' motivation and engagement in chemistry.

RQ 3: Applying experiential knowledge through reflection can develop students' continuous, life-long learning (Wain, 2017). The reflective essay captured students' learning progression across the CSL activity. Monitoring the learning process is helpful for post-secondary education because students can adjust their thinking based on new information in order to become self-directed learners (Tashiro *et al.*, 2021). This process involves collaborative learning where learners construct knowledge with richer meaning through negotiating consensus with others (Boyer, Maher and Kirkman, 2006).

RQ 4: Students reported that the implementation of reflective pieces in a laboratory setting enabled them to step back to review the whole process of learning and recognize the value of learning in a holistic way. This outcome aligns with the students' articulation and exploration of their learning in their reflective pieces as suggested by Ash and Clayton (2009). Furthermore, students reported that reflection promotes the ability to retain information and apply it in new situations.

Limitations and recommendation to the study

General limitations for case study research as a methodology are that it is time consuming, and its findings are not easily generalizable to the larger population (Yin, 2009). This study was conducted within a single extended CSL project in one course. Therefore, this study is an incomplete snapshot of the potential spectrum of experiences that students might have in this type of activity. Furthermore, there was minimal information on the incoming level of knowledge of participating students or on their ability to write a reflective piece, particularly for the international students for whom English is not a first language. Another limitation is that the ethical guidelines meant that students had to opt in to allow their data to be used. Students who are motivated to opt in tend to be more motivated learners.

Implication for Practice and Research

If reflective essays in a lab setting are to be utilized, several recommendations can be used to support student learning. First, science students who are new to the reflection process might find it challenging to demonstrate critical thinking in their writing. We recommend instructors facilitate a workshop where students are introduced to and explore the topic of reflective practice. Secondly, instructors need to provide constructive feedback for students to improve their future reflective essays. Lastly, the use of different types of reflection strategies, such as a focus group interview, can diversify student learning needs.

Further investigation is recommended on how the perceptions of students change through their personal reflections in learning within an advanced chemistry CSL course. The second of three required courses with integrated CSL projects in our program is Research Methods in Chemistry (CHEM 3200). Chemistry students take this mandatory course one year after Analytical Chemistry II. The learning goal for this course is to understand the processes and skills of qualitative human-based research associated with the field of chemistry, which is a very different setting than the current study's water-quality activity. The outcomes of this future work could provide longitudinal data on science students' learning using reflections linked across courses that use a similar framework.

Conclusions

Intentional reflection is a critical component of Community Service Learning. Students review and revisit the information and ideas that they have learned and explored in order to make new information meaningful and thus easier to remember (Chang, 2019). This study provides data demonstrating that reflection can also promote significant learning from students' perspectives in a post-secondary chemistry laboratory setting (Ash and Clayton, 2009). The findings demonstrate that science students are able to articulate their ideas and concepts in the DEAL model if structured prompts and instructor's feedback are provided (Ash and Clayton, 2009). Furthermore, the findings demonstrate that students exhibit a positive attitude towards adding reflective pieces as part of their laboratory component because, from their perspective, it enhances their abilities to develop self-competency in learning. Through this CSL activity, science students articulate that they are able to use their self-knowledge from reflection to develop professional expertise and to engage in lifelong and independent learning.

Conflicts of interest

There are no conflicts to declare.

Appendices

Appendix 1: Textual prompts used for reflective essays.

Reflective Essay 1:

- What is your weakness and what is your strength? Discuss two things that you think you will need to develop further before this CSL water project?
- How do you envision this volunteering opportunity in this CSL water project help you to grow or learn, and improve your individual's well-being?
- Identify what CSL means to you, what knowledge do you think you will need to have that will help you in this lab course?

Reflective Essay 2:

- Based on your Reflective essay 1, what personal characteristic are you coming to understand better as a result of reflection on your applied learning experience? Please provide an example that directly reflects in this lab course.
- Discuss what you have learned from the Ion Chromatography experiment. Please reflect on what you have learn in regard to your experimental data that is important as a Calgarian.
- How can you explain this CSL water project and your Ion Chromatography result to the community members that are not involved but can understand the content?

Reflective Essay 3:

- How can you explain this CSL water project and your Atomic Absorption Spectrometry result to the community members that are not involved but can understand the content?
- Discuss what you have learned from the Atomic Absorption Spectrometry experiment. Please reflect on what you have learned in regard to your experimental data that is important as a Calgarian.
- During the group, how can you identify the errors that you have made and re-construct proper adequate understanding through this error-identification process? Please provide a direct example in this lab course.

Reflective Essay 4:

- During this project, are there any obstacles you have encountered and how were issues resolved?
- What is the most important aspect that you have shared with the K-12 students about citizenship in this CSL water project? Why do you think this is the most important aspect?
- The collective objective of this project allows you, peers, and community partners to assess the progress of the experiment and impact the changemaking process as a whole. How do you feel about this type of learning environment?

Reflective Essay 5:

- Are your values, attitudes, or life choices changed through self-discovery after this CSL water project? Please provide details about what has been changed.
- How does this project as a whole changed your perspective about volunteering and being an active citizen?
- Can you evaluate the completeness of your understanding of this project and its use in the community?

Appendix 2: Example coding procedure

The following is an example of how the coding procedure was applied for academic enhancement.

Theme	Codes	Description
Academic Enhancement	1A	Dialogue amongst students can generate new, more nuanced understanding of academic contextual learning bringing their own thoughts or work to a group discussion Show more creative ways of understanding the project or course content after group discussion
	1B	Within group work, students challenge each other's thinking and knowing "Through discussion we learned…" "Came to an understanding" after group work, things became more clear "We initially assumed, but…"
	1C	Students must utilize their thoughts and reasoning "because…"

	"We learned this class…" (making connections) support valid conclusions with explanation or evidence
1D	Improved understanding of concepts or theory "I now understand this more thoroughly…" "I used to think…. but now…" "After doing …"

Discuss what you have learned from the Ion Chromatography experiment. Please reflect on what you have learn in regard to your experimental data that is important as a Calgarian.

002: *I was surprised that our experimental data that we deduced was much lower than the data from Water Treatment plant, except fluoride. The difference in values can be explained by the fact that the Water Treatment plant annual report usually was released a year after.* (1C) *In this case, we would not know the exact value of the current anion concentration.*

A thought that I have had is to broaden this study with all the Analytical chemistry II students in post-secondary institution to collaborate and conduct the water quality testing. This will benefit us as Calgarian because a more updated reports can be released frequently. (1C)

Acknowledgements

The authors would like to thank Dr. Christopher C. Lovallo for his coordination and support during the CSL activity. We would like to thank students from Analytical Chemistry II winter 2021 at Mount Royal University for their participation in this research project. Lastly, we would like to thank students from Bishop O' Byrne High School for their partnership in the CSL activity.

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