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Service-Learning in Undergraduate General Chemistry: A Review

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Abstract

Background: Service-learning is gaining recognition as a valuable pedagogy for students to gain both academic and psychosocial benefits. This high-impact practice allows students to achieve course learning objectives while contributing to their community's needs. A review from 2007 revealed a lack of research focused on the topic in the prior decade, despite the interest that was shown by the American Chemical Society in 2000. **Purpose:** This review of recent case studies on the topic provides future researchers and practitioners with an understanding of the current state of service-learning in undergraduate chemistry courses. **Methodology/Approach:** To create a representative sample of recent literature for a non-exhaustive scoping review, only peer-reviewed articles addressing service-learning in undergraduate chemistry, published in reliable journals in the last two decades were included. These studies were analyzed in terms of course design, research design, and research quality. **Findings/Conclusions:** While the scoping review identified papers with notable contributions to establishing service-learning in undergraduate general chemistry, the review also identified several key gaps in the literature, including small sample size, reliance on subjective and indirect measures, and qualitative measures that exclude correlation analysis. **Implications:** Recommendations for future work for both practitioners and researchers are provided.

Keywords

literature review, North America, higher education, service learning, STEM education

Service-Learning in Undergraduate General Chemistry: A Review

Introduction

Service-learning is an experiential learning pedagogy widely regarded as a high-impact practice, having been researched and validated across many institutions and disciplines for decades. However, it is common to see conflation of service-learning and community service. The defining characteristics of service-learning are integrated learning, high-quality service, collaboration, student voice, civic responsibility, reflection, and evaluation. True service-learning, in most cases, occurs in a credit-bearing course due to these characteristics. Learning occurs through both the service and the reflection, with students achieving real-world objectives within a specific community, demonstrating mastery of course learning objectives, and polishing key transferable skills (Kuh, 2012). In service-learning, the term is often hyphenated to emphasize the connection between service and learning.

There is a notable body of research on the student benefits of service-learning. Psychosocial benefits reported in the literature are improved community service self-efficacy (Weiler et al., 2013), civic attitudes (Weiler et al., 2013), and self-esteem (Celio et al., 2011). Research also demonstrates that students who engage in service-learning benefit through gaining practical experience (Meyer et al., 2016), improved problem-solving skills (Weiler et al., 2013), a stronger understanding of social issues (e.g. diversity) (Benore-Parsons, 2006; Celio et al., 2011; Yorio & Ye, 2012), and stronger academic performance (Celio et al., 2011; Yorio & Ye, 2012). Institutions benefit through improved institutional satisfaction (Celio et al., 2011; Rutti et al., 2016) and increased retention (Celio et al., 2011). Many variables can influence these benefits, though, including the type of reflection used in the course and the mandatory nature of the service-learning experience (Yorio & Ye, 2012). While the research specifically within STEM courses is more limited, studies have reported positive student benefits, including enhanced science literacy (Hayford et al., 2014), improved self-efficacy (Sliker, 2020), as well as a stronger understanding of social issues and the role of science in society (Glover et al., 2013).

In 2000, the American Chemical Society began developing goals to encourage service learning in chemistry (Wiegand & Strait, 2000). Butin (2006) clearly articulated a need for scholars of service-learning to "probe the limits of service-learning in higher education" (Butin, 2006). A 2007 review of service-learning within chemistry reported very few citations and even fewer peer reviewed articles on the topic (Fitch, 2007). Fitch (2007) did note that service-learning may have gained a boost by the NSF's broader impact requirements in grant proposals. Currently, service-learning is widely valued as a high-impact practice in higher education (Kuh & O'Donnell, 2013).

The aim of this scoping review is to undertake a systematic search to identify a narrow section of existing literature on service-learning, focusing specifically on service-learning embedded in undergraduate general chemistry courses. This will contribute a detailed picture, specifically identifying key factors related to the use of this pedagogical practice in general chemistry courses (curriculum design, theoretical perspectives, evidence of effectiveness, etc.) and how research is being conducted on the topic. This scoping review can inform future researchers and practitioners and may serve as a precursor to a systematic review as the breadth of research in this area grows over time.

Methods

Search Strategy

The systematic search was performed by identifying relevant research literature using the following strategies: database search, targeted journal search, internet search, and reference mining from preliminarily identified articles. The following databases were used: Eric, SAGE, Science Direct, Scopus, Web of Science, and Wiley Online Library. Articles to consider for this review were also identified in an internet search using Google Scholar. The targeted journals for this study included experiential learning journals, scholarship of teaching and learning journals, and disciplinary-based educational journals. Examples of specific journals searched were Chemistry Education Research and Practice, International Journal of Research on Service-Learning and Community Engagement, Journal of Chemical Education, Journal of College Science Teaching, Journal of Higher Education Outreach and Engagement, Journal of Science Education and Technology, Journal of Service-Learning in Higher Education, Partnerships, and Science Education. Boolean operators were used with combinations of the following search terms of ("service-learning", "service learning", "community-engaged learning"), ("undergraduate", "post-secondary", "university", "college") and "chemistry".

Selection Criteria

From the articles identified through application of the search criteria, systematic selection was performed to identify a representative sample of recent literature on the topic of service-learning in undergraduate chemistry. The following criteria were applied for selection of research papers into this study:

- Peer-reviewed articles (verified through Cabell's database or Ulrich's database)
- Reliable journals (absent from Cabell's Predatory Reports)
- Undergraduate level
- Credit-bearing experience in a general chemistry course
- Published between January 2001 and August 2021
- Meets the criteria of service-learning (Service-Learning - NYLC, n.d.)

In retrieving articles to screen, the following were excluded: book chapters, dissertations and theses, and co-curricular service-learning (i.e. service-learning that took place outside of an undergraduate course such as student clubs or extra-curricular programs), and academic service-learning outside of a general chemistry course. Service-learning in both lecture and lab general chemistry courses were included for first and second semester general chemistry courses. For the purposes of this study, service-learning was defined to align with the National Service-Learning Clearinghouse, as an experiential learning pedagogy where learning occurs while students address a community need. Key components include structured reflection to connect the experience to the learning as well as a true collaboration with the community partner. Volunteerism, community service, and internships were excluded, even if course-based. The aim of this scoping review was to be representative, not exhaustive; pre-prints were not considered.

First, titles and abstracts of retrieved articles were screened by the researchers for inclusion criteria to develop a list of tentatively selected articles. Next, a full-text review was performed to make a final inclusion determination (Moher et al., 2009). From the 55 articles identified through title and abstract screening, full-text review resulted in the retention of 7 papers. The most common reason for exclusion (26 scholarly works) was that the credit-bearing course the service-learning was embedded in was not a general chemistry course. No articles were rejected due to a lack of access to full texts.

Other exclusion reasons included graduate-level courses or miscategorization of community service as service-learning (e.g., project did not incorporate reflection and/or course connection). For example, one 2013 study (Theall & Bond, 2013) was eliminated as it was described as “science service learning”, using a definition from Cartwright (2010) (Cartwright, 2010) that does not include formal reflective or evaluative components. Sutheimer (2008) described projects and strategies for implementation but did not describe reflection, assessment, or any data related to the implementation of projects described (Sutheimer, 2008). After careful consideration, one study was removed from this study because service-learning was a minor component of a larger program focused on nanoscience

(Furlan, 2009). The paper's methodology presented evaluation of the overall program; service-learning was not independently considered. While reflection was mentioned briefly as a component of the program, it was not clear how reflection related to service-learning was integrated into the program nor how it was evaluated. It was also not clear how student performance related to the service activity itself was evaluated.

The articles selected for this review were published in Journal of Chemical Education (n=5), Journal of Science Education and Technology (n=1), and Transformative Dialogues: Teaching and Learning Journal (n=1). Publication dates ranged from 2002 to 2013. Interestingly, all publications fell in disciplinary-based education journals or scholarship of teaching and learning journals; no included papers were published in journals specific to service-learning.

Analysis

From the studies that met the inclusion criteria, an inductive content analysis was performed to identify themes on the service-learning implementation, including the nature of the course (e.g. online vs. in person, lecture vs. lab, etc.), course design (e.g. mandatory vs. optional participation), and pedagogical choices for reflection and assessment. Additionally, thematic analysis of the service-learning research was performed to identify themes on the theoretical frameworks applied, research methods used, and outcomes reported.

Results & Discussion

Thematic Analysis of Service-Learning

Nature of the Course

The first focus question aimed at the course design was understanding the nature of the service-learning experience. In light of the recent transition to online learning in the wake of the COVID-19 pandemic, it is important to consider both traditional and virtual service-learning opportunities. Of the 7 papers evaluated, only one was non-traditional. Saitta, Bowden, & Geiger (2011) indicated online service, but the paper did not clearly describe the course so it is not possible to distinguish between Type II (onsite course instruction with online service) and Type IV (online course instruction and online service) eService-Learning at this time, according to Waldner's definitions (Waldner et al., 2010). As noted in Faulconer (2021), STEM disciplines are largely absent in eService-Learning literature.

In this review, lecture and lab courses for the first and second semester of general chemistry were included. Lecture and lab courses for both semesters were represented in the literature (Table 1). Service-learning experiences were most predominant in general chemistry II laboratory courses.

[insert Table 1 here]

Course Design

In some courses, the service-learning component was optional while in other experiences included in this study the service-learning was mandatory. Two papers made optional participation very clear while one paper clearly articulated mandatory participation. Donaghy & Saxton (2012) stated "Reported here is a unique approach to service learning that gives students a choice in the kind of course experience they desire; described is a separate grading scheme created within a traditional general chemistry course called the Service Track." Similarly, Lee (2012) stated "… while strongly encouraged, students participated in the program on a voluntary basis". Esson & Stevens-Truss (2005) stated "All 58 students enrolled in Chem 120 were required to complete the service-learning project as part of the course." While it did not occur late in the paper, Hatcher-Skeers (2002) made optional participation clear by stating "The college students were not required to take part in Chemistry day…". Other articles required readers to make inferences regarding the nature of engagement. Kalivas (2008) stated, "Because the program at this university affects all general chemistry students, it has a greater impact on the educational development of more students than the capstone research experience." Burand & Ogba (2013) stated, "To this end, a laboratory project in which students write a letter in lieu of a traditional laboratory report was created and implemented." Both of these papers suggest a mandatory nature of engagement, though it is not expressly clear. Saitta, Bowdon, & Geiger (2011) did not provide enough information to evaluate the nature of engagement.

Development of Community Partnership

How community partnerships were established was given limited attention in most of the papers in this study. Across the board, it appears that instructors make at least the foundational relationship. In some cases, the students were more directly involved. For instance, Kalivas (2008) described how students were provided with a list of teachers in the area willing to participate in the project.

Types of Projects

Within the surveyed literature, service-learning activities were diverse (Table 2). While clearly the predominant activity includes supporting younger science students, it is clear that there are many other options for service-learning in a general chemistry course. While outside of the scope of this study, other chemistry-related service projects reported in the literature include replacing standard laboratory experiments with faculty research that has connections to the course content (in a research-based service-learning activity) (Norris et al., 2013) and engaging in National Chemistry Week beyond an outreach event through activities like developing chemistry-related posters related to that year's theme (Roberts-Kirchoff, 2014).

[insert Table 2 here]

Reflection

Reflection is the critical link between service and learning (Eyler, 2002). Diverse approaches to reflection were seen in the studies, with some courses using a summative reflection such as a graded paper, post-lab assignment, or lab report (Donaghy & Saxton, 2012; Kalivas, 2008; Saitta et al., 2011) while others chemistry service-learning courses supported written reflection throughout the experience (Esson et al., 2005; Lee, 2012). Donaghy and Saxton (2012) state that students reflect on “where this [the service] connects to their class and, more philosophically, to their career objectives.” Esson and Stevens-Truss (2005) report that students reflected weekly on their experiences, graded on a pass/fail scale. While the focus of the weekly reflections was largely not addressed in the paper, the authors describe the final reflection as focusing on suggestions to improve the service-learning project. Kalivas (2008) simply stated that students perform “reflection on what was learned”, with no further details.

In general, the papers do not address reflection, with little detail about the focus of the reflection, how it was graded (e.g. rubric), and the course weighting. While Hatcher-Skeers (2002) did not articulate a reflective component in their publication, personal communication with the corresponding author revealed that an informal post-experience discussion was performed by the class for reflection but was not graded. Similarly, Burand & Ogba (2013) did not address reflection in their article but personal communication with the corresponding author revealed that an informal summative survey was used for reflection, but it was not detailed.

Assessment of Student Learning Gains

How students were assessed on their learning associated with the service inherently varied across the studies. In the papers studied, authors indicated use of summative deliverables (with rubrics (Burand & Ogba, 2013) or without rubrics (Saitta et al., 2011)) on summative deliverables, the use of summative exams (Donaghy & Saxton, 2012; Lee, 2012), or did not elaborate on how deliverables measuring student learning were evaluated (Esson et al., 2005; Hatcher-Skeers & Aragon, 2002; Saitta et al., 2011). One study specifically excluded a discussion of assessment because assessment of that deliverable was already published elsewhere (Kalivas, 2008), though the inclusion of this information would have helped strengthen the author's argument for the impact of the service-learning project.

Thematic Analysis of the Research

Theoretical and Conceptual Frameworks

Theoretical frameworks present the theory that explains the rationale for a study and is the anchor of the literature review. A theoretical framework is derived from existing theories and is used to frame the work. A conceptual framework, distinct from a theoretical framework, presents how the research problem was explored by visually illustrating what researchers expected to find through their work, defining relevant variables and explaining how they might relate to each other.

In 2007, Fitch noted a prevalence of focus on active learning and scientific literacy (Fitch, 2007). Four papers included in this study provided a theoretical framework to justify the use of service-learning. Esson & Stevens-Truss (2005) identified Kolb's Experiential Learning as a foundational theory. Kalivas (2008) grounded their work in process-oriented guided inquiry learning (POGIL) and connected this to active learning. Saitta, Bowdon, & Geiger (2011) mentioned "…students were involved in active learning for each part of the project …" but no further elaboration is provided to be able to consider this a theoretical foundation for the work. Hatcher-Skeers (2002) clearly grounded their work in active learning. Lee (2012) was the only researcher to connect multiple theories, incorporating cooperative learning, active learning, and problem-based learning as foundational theories to support service-learning in a general chemistry classroom. While it appears that Fitch's trend of the connection between service-learning and active learning has held true within the chemistry discipline, it does not appear that scientific literacy has persisted in the theoretical frameworks put forth by the authors.

None of the articles included in this study provided readers with a conceptual framework.

Research Methods Used

All of the included studies were descriptive case studies. For this reason, there were no research questions, hypotheses, or variables tested. Focus was predominantly on the course design and implementation strategies rather than assessment of outcomes, though all studies did report positive student outcomes. Most used self-developed (unvalidated) surveys to collect student perspectives. Only two studies used quantitative data regarding student outcomes; both were in the form of student performance on summative assessment items. While most studies used a LIKERT-scale survey instrument, some also included open-ended responses. However, none of the studies performed coding for thematic analysis.

The sample sizes in the studies were relatively small, ranging from 21 to 97. However, surprisingly, two studies, (Hatcher-Skeers & Aragon, 2002; Kalivas, 2008) did not present a sample size and this information was not discernible from the results presented.

Outcomes

All of the included studies reported positive student benefits. Table 3 presents an overview of the reported benefits. It is clear that students tend to perceive the service-learning project as helpful for refining content knowledge as well as transferable skills.

[insert Table 3 here]

Only two studies reported direct measures of the impact of the service-learning on student performance in the course. Donaghy & Saxton (2012) reported a modest boost to student course grades, with the average student seeing an increase of 4-6 points on their final course grade (out of 100). Lee (2012) reported that the service-learning experience improved student performance on some summative assessment items studied, but not all. It would be interesting to compare student perceptions of knowledge gains to independent measures of learning gains. It is difficult to evaluate learning gains due to service-learning in general chemistry at this juncture because the measures have been subjective, with one study even reporting that students did not feel the experience deepened their understanding of the content, and objective measures are significantly limited. Similarly, while the majority of general chemistry students engaged in service-learning report gains in transferable skills, introspection, and the real world, these are subjective measures using unvalidated instruments, limiting conclusions that can be drawn.

The benefits to community partners were notably underrepresented in these papers. While several made anecdotal mention of community partner benefits, only Lee (2012) reported specific data to support the claim. In a tutoring service-learning experience, the tutored secondary students reported a 23% increase on exam scores as a result of tutoring as well as an increase in the number of assignments successfully submitted for grading.

As with service-learning in any discipline, there are problems and hurdles to overcome. Two studies reported modifications between academic years based on feedback from students and community partners. Esson & Stevens-Truss (2005) reported that students felt they should have had more course workload allocated for the project despite having 10% of the overall course grade associated with the project.

Research Quality and Reach

Impact and Influence

This study also explored the impact of the existing research. Of the studies included in this review, there were 14 authors, with no authors appearing on multiple papers. The authors included emerging researchers (weak author-level metrics) and experts (strong author-level) within both educational research and chemistry. H-indices for authors, obtained via Scopus, ranged from 1 to 30. Three authors were not able to be in the database.

The papers included in this study were not evenly distributed across the period for selection, with none of the included papers being published after 2013.

The papers were published across three journals. However, Journal of Chemical Education published the majority of the papers in this study. This journal has an impact factor of 1.758, CiteScore of 3.4, and Altmetric score of 18. The Journal of Science Education & Technology also has journal level metrics to report, with an impact factor of 2.315, CiteScore of 4.3, and Altmetric of 41. Transformative Dialogues does not have metrics to report. All of the journals were indexed in EBSCOHost. With the exception of Transformational Dialogues, indexing was also achieved through ERIC, OCLC, Ovid, and ProQuest. Individual journals also had further indexing locations not shared by the group. This indexing can help ensure access to practitioners and researchers.

Access to the research can be evaluated through several measures (Table 4). Access by practitioners may be represented by alternative metrics (altmetrics). Access by researchers may be represented by the number of citations. Some papers garnered no attention by either practitioners or researchers. While no papers gained notable altmetrics, some have been used by researchers. The average number of citations across the studies was 33.1. The average number of citations for educational research in that time frame was 44, while disciplinary based educational research averaged 34 citations (Patience et al., 2017). This demonstrates research on this topic has an expected impact and interest within the education community. According to scite.ai, none of the papers presented any controversy. Hatcher-Skeers & Aragon (2002) showed support in the research literature according to this tool.

[insert Table 4 here]

SoTL Best Practices

Through the scholarship of teaching and learning, practices, values, and assumptions are aligned with purpose and practice (Felten & Chick, 2018). The adoption of effective pedagogies and interventions have been slow in STEM courses (Borrego & Henderson, 2014). High-quality papers within STEM disciplines are therefore critical to advancement. Each of the articles included in this review were evaluated for best practices in the Scholarship of Teaching and Learning (SoTL). Standards for SoTL work include inquiry focused on student learning, grounding in context, sound methodology, research in partnership with students, and outcomes made appropriately public (Felten, 2013). Furthermore, SoTL work should present significant results and contain a reflective critique of the work (Glassick et al., 1997).

We conclude that four of the seven papers evaluated in this study, Donaghy & Saxton (2012), Esson & Stevens-Truss (2005), Lee (2012), and Saitta, Bowdon, & Geiger (2011) met most SoTL best practices criteria:

- **Inquiry Focused on Student Learning.** Service-learning is inherently focused on student learning. Donaghy & Saxton (2012) stated, "In an effort to make chemistry relevant and accessible, … [d]uring the second semester, an optional service project is offered …". Esson & Stevens-Truss stated "To more fully engage students enrolled in CHEM 120 while reinforcing class principles, students completed a service-learning project." Lee (2012) stated "This course required them, of course" to understand the material themselves or to see where the gaps in their understanding might be and to articulate that understanding to other students." Saitta, Bowdon, & Geiger (2011) stated "The project allowed UCF students to teach newly acquired content knowledge and build upon course lecture and lab exercises."

- **Grounded in Context.** Esson & Stevens-Truss (2005) grounded their work in Kolb's Experiential Learning Theory while Lee (2012) grounded their work in the theories of cooperative learning, active learning, and problem-based learning. However, neither Donaghy & Saxton (2012) nor Saitta, Bowdon, & Geiger (2011) clearly supported the service-learning pedagogy with a theoretical framework. However, all articles clearly described the general education student climate as well as the culture and climate associated with their community partner. For example, Esson & Stevens-Truss articulated the group sizes for both students and community partners and explained the context of the partnership selection based on proximity, curriculum alignment, and demographic variables (e.g. socioeconomic status of participants).
- **Methodologically Sound.** All studies were descriptive case studies, though the strength could have been improved through the use of validated instruments. Lee measured chemistry attitudes but could have used the validated Chemistry Attitude Scale (CAS) (Tuysuz, 2010), Attitudes toward the subject of Chemistry (ASCI) (Bauer, 2008) or a revised shorter version of ASCI (Xu & Lewis, 2011), the Chemistry Attitudes and Experiences Questionnaire (CAEQ) (Coll et al., 2002), or the Colorado Learning Attitudes about Science Survey (CLASS) applied to general chemistry (Heredia & Lewis, 2012). If these validated instruments were inadequate for measuring attitudes, justification should have been presented along with validation of the developed instrument.

Furthermore, stronger data analysis is warranted to form stronger conclusions. For example, Lee (2012) collected open responses to reflection questions, quoting several in their work, but this qualitative data could have been coded for thematic analysis. Donaghy & Saxton (2012) provided only anecdotal evidence for the influence on career perspective and networking.

- **Conducted in Partnership with Students.** Service-learning has an inherent partnership with students. While service projects may not involve human subjects, the SoTL research of the service-learning experiences likely involves human subjects (e.g. survey or interview data). However, all four papers failed to meet the most basic expectation of conducting work in partnership with students; they did not report approval through the institutional review board, which ensures ethical research involving human subjects. It is unclear if and how students consented to the studies.
- **Appropriately Public.** While the studies are available to practitioners and researchers, they are behind paywalls, which limits access. While the criteria of being "appropriately public" has been met, ideally this research would be available through open access to have a greater reach.
- **Significant Results.** The four studies achieved their stated goals and made contributions to the knowledge base within the implementation of service-learning in general chemistry. The studies also pointed to additional areas for further exploration. In some cases, claims could be strengthened through a stronger analysis of the data (which could also be considered a failure to meet the criteria of being methodologically sound). For example, Saitta, Bowdon, & Geiger (2011) compared groups but did not perform an inferential statistical analysis to see if reported differences were statistically significant.
- **Reflective Critique.** All four studies provided a detailed discussion of their work. Specifically, Saitta, Bowdon, & Geiger (2011) presented a discussion of best practices. However, none included a critical appraisal of limitations of their chosen

design or methodological approach. All studies have limitations. A discussion of limitations should explore how these may have influenced results or may influence the interpretation of the results, thus impacting the generalizability and validity of the presented work. Common limitations in SoTL work are likely sample size, limited prior research on the topic, and data collection or analysis methods.

Implications

Gaps in the Literature

The studies reported here, individually and as a collective, are important for researchers and practitioners because of their insight into service-learning within general chemistry. However, this review highlights several key gaps in the literature.

With such a limited sample (n=7) and low rigor in statistically analysis of data within these studies, there is not enough data to draw conclusions regarding student benefits of service-learning in general chemistry. Quasi-experimental studies that compare service-learning to traditional general chemistry student outcomes are warranted.

The mandatory nature of a service-learning experience could influence learner outcomes (and partner outcomes). Studies outside of the chemistry discipline suggest that students' initial resistance is not a good reason for making the experience optional as most students report positive views after completing the experience (Chan et al., 2021). This is largely mirrored within this study, with both the mandatory and the optional experiences reporting positive student experiences. However, Esson & Stevens-Truss (2005) report some negative student perceptions regarding their mandatory service-learning project, stating that students did not feel their project aided in deeper understanding of the content nor did it develop new personal skills, though the students did tend to agree that the project helped the community. Outside of the chemistry discipline, previous studies have shown that males are less likely to participate than females (Ender et al., 2000). In a more nuanced study, that distinguished mandatory versus optional service-learning, this finding that females participate at higher rates was not supported, though, with more males participating in optional service-learning and more females participating in mandatory service-learning (Haski-Leventhal et al., 2010). While none of the seven studies reported here directly explored gender in participation, Esson & Stevens-Truss (2005) reported that female found service-learning more appealing for reinforcing chemical principles than male students did. A study comparing the outcomes in mandatory versus an opt-in experience in general chemistry would be valuable, particularly if robust participation demographics were presented. Other demographic and background variables that may influence participation include family income and field of study (Haski-Leventhal et al., 2010).

While some studies offered more information than others, much of the work only gave cursory attention to the reflection component of the service-learning experience. Because of this, it is not possible to understand if best practices for reflection have been used or how the nature of reflection may influence learner outcomes. Future work should explore the type, frequency, and assessment of reflection.

Very little attention has been given in the existing literature to the impact of the service-learning on community partners. To underscore the importance of the partnership, future work should also measure and report partner impacts.

As noted by Donaghy & Saxton (2012), the adoption of service-learning in undergraduate chemistry courses will be limited until scalable models are available within the discipline. Service-learning implemented through an existing framework can help navigate challenges and provide this scalable model. For example, the Comprehensive Action Plan for Service Learning (CAPSL) addresses sustainability through structuring the planning, outreach and awareness, resource identification and allocation, piloting, progress monitoring, scaling, recognition, evaluation and research (R. G. Bringle & Hatcher, 1996). The Context, Input, Product, Process Evaluation (CIPP) model is a decision-oriented model that identifies strengths and weaknesses in the course content or delivery to allow for continuous improvements (Zhang et al., 2011). No literature currently applies either of these models (or any other frameworks) to service-learning in general chemistry.

All studies reviewed here took place within the United States. As the literature in this area grows, it will be important to consider international perspectives and experiences with service-learning in general chemistry.

Recommendations for Future Research

Early researchers called for improvements to the rigor in service-learning research (Butin, 2006; Fitch, 2007; Hayford et al., 2014). The expectations and resulting quality of SoTL and discipline-based education research has increased in recent years (Talanquer, 2014). To ensure research on service-learning in general chemistry meets best practices, we recommend the following:

(1) When using subjective measures of learner outcomes, use validated instruments and inventories to improve validity. (This does not address weakened validity due to the use of self-reported, subjective measures, though.) For example, the Situational Motivation Scale (SIMS) (Guay et al., 2000) could be used to measure motivation, external regulation, identified regulation, and intrinsic motivation.

(2) Consider measuring multiple learner outcomes, including cognitive outcomes (both disciplinary and transferable skills) and civic engagement.

(3) Decide if the best data for the study will be subjective or objective and if it will be collected by direct or indirect measures. For example, the Critical Thinking Assessment Test (CAT) (Stein et al., 2007) is a direct, objective measure of student ability to analyze, interpret, and evaluate information, solve problems, apply content, and effectively communicate.

(4) If possible, use a quasi-experimental approach to allow for stronger data analysis and thus stronger conclusions regarding learner and partner outcomes and benefits associated with the service-learning experience.

(5) If collecting qualitative data, use established protocols if available. For example, the Problem-Solving Interview Protocol (Eyler & Giles, 2002) questions students about knowledge application, critical thinking and problem solving, as well as intellectual development, with responses scored, serving as a direct measure.

(6) If collecting qualitative data through reflections, surveys, etc., perform coding for thematic analysis. Overarching themes are more impactful that anecdotal quotes.

These recommendations are not meant to diminish the importance and contributions of the foundational works on service-learning in general chemistry. Aligned with others within the field of SoTL, we do not wish to set standards that privilege certain methodologies over others (Grauerholz & Main, 2013). The case study methodology employed and associated analyses were appropriate and posed key questions to guide future work. However, a different methodological approach can use this prior knowledge to build a schema to understand what service-learning is and does within a general chemistry course. Discipline-based education research in this area is warranted in order to explore context, process, and impact research questions, to test theory, and to produce generalizable results.

Recommendations for General Chemistry Service-Learning Practitioners

(1) Recognize that barriers exist and use a framework to help navigate barriers. Common barriers include defining and communicating the purpose of service-learning to students, establishing a successful community partnership, alignment of service with course learning outcomes, establishing reflection opportunities and an assessment structure (McDonald & Dominguez, 2015). Bringing students into these decisions can

help increase ownership of the project. Students will need ample support in these activities, though.

(2) Understand your community partners, developing a clear picture of their needs, capacity for student work, and interest in the project. Using clearly articulated procedural guidelines (e.g., a service-learning agreement, formal evaluation process for both students and community partners, etc.) can help with this process (R. C. Bringle et al., 2009).

(3) Clearly define the project and roles for all stakeholders, articulating both responsibilities and benefits for all.

(4) Implement the “5 C’s” framework for facilitating reflection in service-learning, which is widely accepted within the educational community (Eyler & Giles, 1999). In summary, these reflection best practices are to form connections between experience and analysis, establish continuity of reflection before, during, and after the service experience, support context by applying subject matter to real life scenarios, challenge students’ perspectives, and coach students to meet their emotional and intellectual needs during the service experience. The combination of formative and summative reflection shows the most student benefit (Hatcher et al., 2004). Structured reflections with clear expectations and instructions are ideal (Hatcher et al., 2004).

(5) Whether the experience is optional or mandatory, adjust the workload for students. In Esson & Stevens-Truss (2005), students were allocated 10% of their overall course grade for the project but still felt that more workload should have been allocated to the project.

(6) Be prepared to modify the project along the way. Over half of the studies reported here discussed modifications to their implementation of service-learning for a variety of reasons.

Limitations of This Study

The purpose of this scoping review was to address the broad research questions. As such, a detailed assessment of the methodological limitations of this scoping review are not necessary (Munn et al., 2018) Due to the nature of a scoping review, the implications for practice are limited. Due to the breadth of the available literature and the narrow scope of the selection criteria, the resulting n for this study was notably small, which could limit the strength of findings. However, the paucity in the literature is worth noting as a call to research.

Conclusions

Service-learning is a viable and valuable pedagogical approach in undergraduate general chemistry. This review provides an outline of the current use of service-learning in undergraduate chemistry, both from the practitioner and researcher perspective. The findings from the thematic analysis of the service-learning implementation indicate most of the existing papers took place as traditional in-person service-learning within second-semester general chemistry laboratory courses. The mandatory nature of the service-learning varied. Limited description of the formation and maintenance of community partnerships was provided in the papers evaluated. Similarly, the nature of reflection and assessment was often cursory. Thematic analysis of the service-learning research show that case study research has been the preferred approach. Learner outcomes measured varied by study, but often relied on subjective, indirect measures (e.g., asking students to report perceived learning gains rather than directly measuring and reporting learning gains). The published studies have noted impact and reach to both practitioners and researchers. More than half of the papers included in the study met SoTL best practices. However, notable gaps in the literature should be addressed in future research.

Recommendations for future work include the use of validated instruments and protocols and to design a quasi-experimental approach that would allow researchers to explore correlations between service-learning experiences and outcomes for both learners and community partners.

While there is a notable lack of research in this area, the studies evaluated here showed promise that there are positive benefits to undergraduate students through the adoption of service-learning in general chemistry. When more work has been published in this area, another review will be warranted to establish the learner outcomes that are most impacted by the experience and to establish a scalable framework for implementing this high-impact practice within the general chemistry classroom.

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Table 1

Nature of general chemistry course with service-learning component.

	General Chemistry I	General Chemistry II
Lecture	(Hatcher-Skeers & Aragon, 2002; Lee, 2012; Saitta et al., 2011)	(Hatcher-Skeers & Aragon, 2002; Lee, 2012; Saitta et al., 2011)
Lab	(Hatcher-Skeers & Aragon, 2002; Saitta et al., 2011)	(Burand & Ogba, 2013; Donaghy & Saxton, 2012; Esson et al., 2005; Hatcher-Skeers & Aragon, 2002; Kalivas, 2008; Saitta et al., 2011)

Table 2

Types of service-learning activities in general chemistry.

Type of Activity	Reference
Elementary or Secondary School Activities (including tutoring)	(Esson et al., 2005; Hatcher-Skeers & Aragon, 2002; Kalivas, 2008; Lee, 2012; Saitta et al., 2011)
Environmental Testing (Soil, Water, Air; Field or Lab)	(Burand & Ogba, 2013)
Museum Activities or Displays	(Donaghy & Saxton, 2012)
Science-based Internship or Volunteerism	(Donaghy & Saxton, 2012)
Science Fair Coordination or Judging	(Donaghy & Saxton, 2012)
Science Student Support (peers)	(Saitta et al., 2011)

Table 3

Self-reported student benefits in general chemistry service-learning courses.

Study	Benefit
Burand & Ogba (2013)(Patience et al., 2017)	94% reported the project caused them to think about chemistry differently than a regular assignment would 64% reported working harder because the deliverable was provided to an external stakeholder
Donaghy & Saxton (2012)	79% agreed the project had a positive influence on their attitudes towards chemistry 86% reported an increase in their confidence of success in the course
Esson & Stevens-Truss (2005)	Reported improved ability to design and troubleshoot an experiment (data to support the claim were not reported)
Hatcher-Skeers & Aragon (2002)	87% reported a positive experience Reported improved confidence in laboratory skills (data to support the claim were not reported)
Kalivas (2008)	*None Reported*
Lee (2012)	96% agreed that the project had improved their understanding of the subject 92% reported that the project improved their communication skills
Saitta et al. (2011)	85% agreed that the project increased their ability to understand and apply course content

Table 4

Paper-level metrics as of September 23, 2021.

Study	Altmetric	Citation Count (#)
Burand & Ogba (2013)	4	16
Donaghy & Saxton (2012)	1	32
Esson & Stevens-Truss (2005)	-	53
Hatcher-Skeers & Aragon (2002)	-	53
Kalivas (2008)	-	43
Lee (2012)	-	7
Saitta, et al. (2011)	-	28