Scholarship of Teaching and Learning in Civil and Structural Engineering: A Systematic Literature Review

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ABSTRACT

The Scholarship of Teaching and Learning (SoTL) pertains to scholarly endeavors centered on the pedagogical aspects of teaching and learning, with its principal objective being the enhancement of students' educational experiences. The present systematic literature review addresses the following questions: (i) In what capacity do educators within the field of Civil and Structural Engineering (CaSE) engage with SoTL? and (ii) What are the benefits of implementing a SoTL for CaSE educators?. The scope of the review encompasses SoTL studies specifically developed by CaSE educators and implemented within CaSE teaching and learning environments. Findings are synthesized and disseminated via a bibliometric analysis and a narrative synthesis. The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses

(PRISMA) methodology. It has been found that CaSE educators participate in SoTL endeavors through diverse approaches; however, such involvement remains more of an exception than a common practice. The insufficiency of existing benefits and incentives, if any, serves as a barrier hindering broader engagement and participation in SoTL activities.

INTRODUCTION

An attempt to provide a straightforward and concise definition of the Scholarship of Teaching and Learning (SoTL) involves understanding it as educational research conducted not by educational researchers, but by educators within their specific disciplines during their teaching practice. However, its nature is considerably more complex and dynamic, having undergone significant evolution since its inception over three decades ago.

First introduced in 1990 (Boyer 1990) and within the context of a holistic scholarship perspective, SoTL was initially delineated as one of four interrelated faculty functions: (i) the scholarship of discovery, (ii) the scholarship of integration, (iii) the scholarship of application, and (iv) the scholarship of teaching. According to Boyer, the scholarship of discovery is closely related to research, the scholarship of integration accounts for interdisciplinary approaches, the scholarship of application is related to knowledge application and creation at and from the professional activity at the service of the general society, and finally, the scholarship of teaching involves all kinds of pedagogical procedures (i.e., planning, assessment, teaching, etc.). Furthermore, this seminal book also identified the clear undermining of teaching rewards against other faculty's competing obligations and the paramount importance of scholarship of teaching for the service of students, the creativity of faculty, and the definition of institutional goals.

In 2009, the "systematic reflection" and "study of teaching and learning made public" descriptors were added to the concept (McKinney and Jarvis 2009). Moreover, McKinney and Jarvis (2009) discussed how SoTL can benefit teaching at multiple levels. Namely, they highlighted the improvement of class design and redesign at the classroom level, better informed curricular changes at the program level, clear justification of budget requests at the department level, enhanced decision-making at the institutional level in terms of strategic planning, program reviews, and assessment processes, and as evidence-based creation of teaching and learning best practice guidance at discipline level.

In 2012 (Bishop-Clark and Dietz-Uhler 2012) confered to SoTL the aim of establishing a body of knowledge through the communication of findings obtained by not specialized educational scholars through their teaching practices in their respective subjects. These authors delineated the SoTL process within a structured framework consisting of five distinct steps:

- Formulating a research inquiry
- Crafting the study's framework
- Gathering the necessary data
- Analyzing the collected data
- Publishing and disseminating the SoTL discoveries

In 2013, the imperative for a more comprehensive understanding of student learning was advocated by Felten (2013) as one of the fundamental principles of good practice within SoTL. Furthermore, several key components deemed essential for the cultivation of effective SoTL practices included grounding it within a specific contextual framework, conducting it with adherence to rigorous methodological standards in collaboration with students, and ensuring the dissemination of results to the wider public. In 2017, Swart et al. (2017) presented an expanded 8-axes (or "spokes", as per the authors analogy to the spokes of a wheel) SoTL framework definition. According to their model, the practice of SoTL is underpinned by the following elements: awareness, reflection, discernment, development, application, evaluation, sharing, and crystallization.

More recently, Cox et al. (2023) deliberated upon an extended 11-step approach to SoTL, positioning it as an integral element within the broader construct of educational research. Although all presented definitions primarily centered around the activities undertaken by educators engaged in SoTL and their potential for enhancing teaching practices, it is imperative to emphasize that the ultimate objective of SoTL remains the provision of superior learning experiences for students.

One challenge confronted by educators in the field of Engineering when they initially engage with SoTL lies in the fundamental disparity between the research demands within their discipline and those inherent to SoTL. Engineering research typically adheres to an objective paradigm, while SoTL is characterized by subjectivity. As outlined by Wankat et al. (2002), Engineering educators often grapple with skepticism when attempting to assess the influence of input parameters—such as inherited traits, home environments, prior educational experiences, current knowledge and skill levels, learning styles, personality types, and present life circumstances—on the desired output, which is student learning. Most of these effects are not readily observable or quantifiable. Moreover, as posited by Tight (2018), the impact of the SoTL has been limited as it has not significantly contributed to the generation of novel lines or research.

Several studies have contributed to the body of literature concerning SoTL, spanning a spectrum of educational contexts. These studies have encompassed general educational contexts (Healey and Healey 2023; How 2020; Tight 2018), the realm of Science, Technology, Engineering and Mathematics (STEM) (Faulconer and Griffith 2023), as well as inquiries into multi/interdisciplinary (Kahn et al. 2013) and distinct engineering disciplines (Michelson 2016; Prince 2008). While some of the overarching findings and discussions articulated in these studies possess the potential for extrapolation to the practice of SoTL within Civil and Structural Engineering (CaSE), it is imperative to acknowledge that the discourse surrounding SoTL has experienced subtle variations across diverse disciplines. For instance, Stephanie A. Garcia and Browning (2022) analyzed the experiences, views, and needs of two engineering (chemical engineering) faculty members who have recently moved from industry to academia throug a SoTL framework, and Maisiri and Hattingh (2022) explored the impact of game-based learning on improving a deep understanding of technical knowledge and acquiring non-technical skills in a third-year engineering (industrial engineering) module. These distinctions have had consequential implications for the nature, inquiry, and role of SoTL within each discipline (Huber and Morreale 2002). In light of these considerations, a systematic review of SoTL within the specific domain of CaSE appears to be a justifiable endeavor.

The purpose of this paper is to present a systematic literature review focusing on the SoTL within the scope of CaSE. The objective is to comprehensively and rigorously identify all pertinent works pertaining to this subject matter. Specifically, this review delves into the various methodologies and approaches adopted by CaSE educators and explores the underlying motivations driving their engagement in SoTL activities. In particular, the principal aim of this work is to address the following research questions:

- How do CaSE educators (including Professors, Lecturers, Teaching Assistants, etc.) participate in the SoTL?
- What are the benefits, encompassing economic, professional, and personal aspects, associated with the implementation of SoTL practices for CaSE educators?

The remaining sections of this paper are structured as follows: the Methodology section outlines the systematic review methodology employed and describes in detail the protocol, search strategy, bibliographic mapping, and narrative synthesis work performed. Subsequently, the outcomes and discussions stemming from the bibliometric and narrative synthesis procedures conducted are presented. Finally, the Conclusions section deals with the insights and implications drawn from this research.

METHODOLOGY

Protocol and Search Strategy

The systematic review presented in this paper adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Page et al. 2021). These guidelines are underpinned by the development of a systematic review protocol, as elucidated by Shamseer et al. (2015) where the administrative information, introduction, and methods of the systematic review are recorded and reported. The complete protocol of this systematic review can be found in (Jiménez Rios et al. 2023b).

Given the paramount significance of transparently reporting the information retrieval process to uphold the quality of this systematic review, we elected to adhere to the PRISMA-S (Rethlefsen et al. 2021) checklist for documenting the executed search strategy. In summary, the electronic databases that underwent scrutiny encompassed Scopus, Web of Science, Google Scholar, and the OsloMet

Library database. Moreover, we consulted OSF Registries to forestall the inclusion of works still in progress and avoid duplication. Relevant initial keywords (i.e., "civil engineering", "structural engineering", "scholarship of teaching and learning", "SoTL") and similar terms of interest were used to form the search queries presented in Table 1, whereas the full title of the systematic review was searched in OSF Registries. Both searches were executed on 01/09/2023. Elaborate details of the search strategy are available in a companion publication authored by Jiménez Rios et al. (2023c). To ensure the exclusion of duplicate records, deduplication was executed employing an automatic detection tool during the import of RIS files into EndNote (2023). Notably, RIS-formatted records from Scopus, Web of Science, and OsloMet Library were exclusively subjected to this process. Further scrutiny was conducted through manual assessment, involving the organization of all records by title. The first 50 pages of results, amounting to 500 of the most pertinent records from Google Scholar, were manually inspected. After the deduplication of records identified during the manual screening of Scopus, Web of Science, and OsloMet Library records, in conjunction with the manual curation of records from Google Scholar, a total of 156 records were retained for further analysis.

Following deduplication, all retained records underwent a comprehensive evaluation, encompassing scrutiny of both their titles and abstracts. After the first round of screening, only 29 relevant records were preserved for a second round of screening. During the subsequent screening stage, all shortlisted records underwent a rigorous examination, including a thorough assessment of their full content, to determine their ultimate inclusion or exclusion from the systematic review. Only records directly pertinent to the realm of civil and structural engineering education were considered for inclusion. In the culmination of this meticulous screening process, a mere 17 records successfully navigated through all screening criteria and eligibility filters, rendering them eligible for inclusion in this comprehensive systematic literature review (as depicted in Fig. 1).

Bibliographic Mapping

The bibliographic data obtained after performing the search strategy has been made available in open source and published in Zenodo (Jiménez Rios et al. 2023a). This database contains all the bibliographic information found after applying the search strategy used for the SoTL in CaSE. It contains information presented in .ris, .bib, and .csv format from the searched electronic databases which allow to download such information (namely, Scopus, Web of Science, and OsloMet Library).

Subsequent to the deduplication phase, the bibliographic data derived from the retained records underwent comprehensive analysis through a bibliographic mapping approach executed within the software VOSviewer, as outlined by van Eck and Waltman (2018). The whole deduplicated set of records (the 156 records screened as presented in the Screening stage of the PRISMA flow diagram shown in Fig. 1) was used as it could give a better hint of the work and attention paid to the topic by the broad educational research community. The co-occurrence of all keywords (both author and index keywords), as well as the co-authorship of authors relationships are mapped and discussed. This scientific mapping process, commonly referred to as science mapping, enables the visualization of the intricate interconnections among fundamental concepts and ideas within the chosen research topic. Furthermore, our analysis extended to various aspects of the bibliographic data, including the determination of papers with the highest citation counts, the quantification of publications per year, the identification of prevalent keywords, and the evaluation of the distribution of papers among different countries. This comprehensive assessment provides a holistic portrayal of the research topic's performance, effectively capturing the outcomes achieved through our meticulously devised search strategy.

Narrative Synthesis

Given that the data collected for this study is qualitative in nature and not amenable to a meta-analysis, the principal findings of this systematic review are presented via a narrative synthesis. This methodological choice has enabled us to integrate the diverse types of evidence and qualitative data found, thus addressing the posed research questions. In adherence to the PRISMA guidelines, we have registered this systematic review (Jiménez Rios 2023), and we have also made both the protocol and search strategy publicly accessible. This transparency facilitates peer review and enhances the overall credibility and replicability of our study.

BIBLIOMETRIC ANALYSIS RESULTS AND DISCUSSION

Performance Analysis

Fig. 2 depicts the annual distribution of publications of the total number of records identified (those which were screened as indicated in the PRISMA flow diagram presented in Fig. 1) after conducting the search strategy described in the protocol of this systematic literature review, which uses keywords such as SoTL and CaSE. The graphical representation illustrates a discernible trend of incremental growth over the past two decades, except for the year 2018, which recorded an exceptionally high number of more than 30 publications on the topic. Specifically, there were a mere 14 publications between 2003 and 2007, a figure that nearly doubled during the subsequent period of 2008-2012, resulting in 23 records. The trend then showed a stabilized growth between 2013 and 2017, culminating in a pick of publications per year in 2018, yielding a total of 61 publications for this five-year period. Notably, the period spanning 2018 to 2023 witnessed a substantial surge in publications, averaging more than 11 publications per year. As of the time of our search (01/09/2023), a limited total of 9 records were identified for the year 2023, which may have increased in the remaining months of the year. This observation underscores the heightened interest exhibited by scholars in the field of CaSE in the domain of SoTL during recent years.

Among the various sources examined in the context of this systematic literature review, only Scopus, Web of Science, and Google Scholar furnish information regarding the number of citations attributed to each record. Within the subset of records that got through the deduplication process previously detailed, Table 2 presents the top ten most frequently cited papers. Notably, the paper boasting the highest citation count, 57 citations in total, is “Improving teamwork skills and enhancing deep learning via development of board game using cooperative learning method in Reaction Engineering course” authored by Azizan, M. T.; Mellon, N.; Ramli, R. M.; and Yusup, S. (Azizan et al. 2018). It is important to mention that this particular work, although noteworthy for its citation count, has not been included in the present systematic review as it does not directly pertain to the domain of CaSE. The paper with the highest citation count among those included in this systematic review is “Homework Methods in Engineering Mechanics” by Lura, D. J.; O.Neill, R. J.; and Badir, A. (Lura et al. 2015), which has accumulated a total of 17 citations. The aim of including highly cited papers obtained during the screening stage, even if they are not ultimately included in the systematic review (the full list of included papers can be seen in Table 3), is to provide a point of comparison. Thus, examples of work done in the SoTL that may not necessarily focus on CaSE, are also incluede in Table 2.

Both Scopus and Web of Science furnish comprehensive bibliographic data about the authors' affiliations for most of the records retrieved from these databases. Fig. 3 illustrates the distribution of authors by country based on the affiliations documented in the deduplicated records within the scope of this systematic literature review. The dataset encompasses contributions from authors representing a total of 20 different countries. Prominent among these nations, the United States stands out with the highest number of authors, accounting for a total of 125 researchers. Canada follows with 40 authors, while both Malasya and the United Kingdom feature 13 authors each. Additionally, South Africa is represented by 12 authors within the dataset. 54 more authors were identified in the remaining countries color-coded in Fig. 3.

Bibliography Mapping

Fig. 4 illustrates a co-authorship map containing information pertaining to the top 50 authors engaged in the publication of works identified in the search strategy. In Fig. 4 (a) the various clusters emerging from distinct author groups are discernible, each delineated by a distinct color. Meanwhile, in Fig. 4 (b) the color scale serves to represent the average publication year of the corresponding works within each cluster. A qualitative analysis of these clusters reveals a diverse landscape concerning the nature of educators' involvement in the SoTL. For instance, it is evident that Bedewy et al. and Brooks et al. are part of collaborative clusters characterized by robust interconnections. In contrast, certain authors, such as Samah, Adams, and Nesbit, tend to work predominantly in isolation. Additionally, it is noteworthy that there exists a noticeable lack of interconnectivity between these various clusters. This underscores the potential for future improvement through the fostering of collaboration among authors hailing from distinct research groups and/or educational institutions. Such collaborative endeavors could serve to enhance the cohesion and interdisciplinary exchange within the field of SoTL.

On the other hand, Fig. 5 provides a comprehensive bibliometric map illustrating the co-occurrence of the top 50 keywords. This map is constructed based on data derived from the Scopus database. It is worth noting that while Web of Science also offers bibliographic information, including keywords, its database structure differs significantly from that of Scopus. This divergence in structure precludes the amalgamation of both datasets for co-occurrence analysis within a single map. Fig. 5 (a) delineates the formation of seven distinct clusters. A central cluster is prominently centered on the keywords "SoTL" and "students". Additionally, two relatively central yet smaller clusters emerge, each associated with the keywords "intelligent manufacturing" and "practitioner research", respectively. The remaining four peripheral clusters encompass concepts such as: (i) "iterative methods" and "creativity", (ii) "educational environment" and "distance e-learning", (iii) "learning strategy", and (iv) "cumulative learning" and "communities of practice". Fig. 5 (b) captures the evolving trends within these clusters over time. Notably, recent publications demonstrate a pronounced concentration within the latter two peripheral clusters previously delineated. These publications exhibit a heightened focus on "educational" oriented concepts. This observed trend may signify a shift in the interests of educators actively engaged in the SoTL towards a more scholarly-oriented approach. This orientation is characterized by a concerted effort to enhance teaching practices, with the potential to yield improved learning experiences for students as an ultimate outcome.

NARRATIVE SYNTHESIS RESULTS AND DISCUSSION

The 17 studies incorporated into this review are systematically presented and deliberated upon through a narrative synthesis. They are categorized into two primary groups, as delineated by the two core inquiries central to this systematic literature review: (i) how do CaSE educators conduct and/or are involved in the SoTL?, and (ii) what are the benefits/incentives/outcomes stemming from the implementation of SoTL for CaSE educators? It is important to note that studies addressing both facets are appropriately referenced and discussed within the respective subsections dedicated to these questions.

Limitations

It is also worth noticing that the relatively low number of finally included records in this systematic literature review (see a full list and details of the finally included records in Appendix I) is not due to a lack of educational research activity by CaSE academics but might be an indication that authors are not aware of SoTL and therefore do not present it as such. This observation is mainly based on the personal experience of the authors and their knowledge about the existence of literature which could be considered as SoTL, but that has not been identified as such by their authors. Therefore, such records have not complied with the inclusion criteria of this systematic review. Some record examples of this issue are (Binnekamp et al. 2020; Campos et al. 2020; de la Torre et al. 2021). This fact evidences the paramount need of providing training on SoTL to CaSE academics, or at least increase their awareness about the topic by other means, so that future educational research could be correctly identified.

Involvement of CaSE Educators in the SoTL and Methodologies Applied

Bielefeldt (2015) and Bielefeldt et al. (2015) (these studies were included because they presented a comparison on the involvement of civil engineering faculty in SoTL with respect to other engineering areas such as environmental or electrical and computer engineering) studied, based on a bibliometric and statistical analysis of data related to the USA, the demographic and faculty characteristics of CaSE academics involved in the SoTL and the closely related Learning Through Service (LTS) mentoring experiences. LTS encompass traditional classroom learning with hands-on service experiences in the community. LTS programs aim to provide students with practical opportunities to apply their academic knowledge and skills to real-world problems and challenges. This approach is often associated with service-learning and community engagement (Delaine et al. 2023). According to Bielefeldt (2015), about 5.6 % of Civil Engineering faculty is involved with these practices (in comparison, the percentage of electrical and computer engineering and environmental engineering faculty involved in SoTL correspond to 4.6% and 8.9% respectively) and they differ considerably in comparison to the rest of Civil Engineering faculty. Their results showed that engineering educators implementing SoTL practices tend to be (i) a higher percentage of assistant professors, (ii) a lower percentage of full professors, (iii) a higher percentage of women, (iv) higher percentage employed at Baccalaureate or Master's institutions, and (v) a smaller percentage from institutions with very high research activity.

One of the initial instances of implementing a SoTL approach in a CaSE context was documented by Brannan et al. (2004) (this work was considered eligible because the primary interest of one of the co-authors is teaching structural engineering within a SoTL framework, thus being of relevance to answer the posed research questions of this systematic literature review). Their research was undertaken within the CASTLE (The Citadel Academy for the Scholarship of Teaching, Learning, and Evaluation) program, which actively encouraged faculty members to conceive novel teaching practices aimed at measuring learning outcomes. They examined the student performance with respect to immediate and delayed quizzes. Their findings revealed a notable improvement in students' on-task behavior, coupled with significantly higher scores in immediate quizzes as compared to delayed ones. Therefore, contrary to the common belief that students effectively utilize the time between lectures and examinations to bolster their learning, their research suggests that administering immediate quizzes may be more effective in facilitating student learning.

A SoTL approach has been implemented to support the development of beliefs among students about the role of civil engineers in society by Nesbit et al. (2012) (this work was included because it discusses how challenging it is to develop students beliefs while teaching subjects such as calculus, mechanics, and numerical analysis; subjects commonly taught to structural engineering students), who argued that meta-cognition and Self-Regulated Learning (SRL) can be used as enabling activities for such purposes. Meta-cognition refers to the awareness and understanding of one's own cognitive processes and the ability to regulate and control those processes. On the other hand, SRL refers to the ability to manage one's own learning and take responsibility for one's academic success. SRL involves not only thinking about your thinking (meta-cognition) but also actively regulating and controlling your own learning behaviors. SRL is normally associated with students' approach to learning both in and out of the classroom, and motivation constructs (Nelson et al. 2015). The methodology implemented in this study was based on a series of Community

Service Learning (CSL), a teaching and learning strategy that emphasizes active participation in real-world community projects or activities as an integral part of a student's academic curriculum, ultimately leading to the solution of engineering-based problems for charities, schools and other not-for-profit organizations experiences dealing with the type of work performed by civil engineers and the broad impact of their knowledge (Coyle et al. 2006). Through an assessment involving a Likert-scale survey, which gauged students' perceptions of the role of civil engineering in society, they identified enhanced levels of knowledge, skills, attitudes, and identities among the student participants. These outcomes underscore the efficacy of their approach in fostering a deeper understanding of the societal contributions made by civil engineers.

Through the implementation of a SoTL study on a "Statics and Dynamics" course, Lura et al. (2015) (this paper was deemed eligible for inclusion because the case study of a "Statics and Dynamics" course presented on it, corresponds to a typically taught course in CaSE programs) realized the negative effects that short in-class quizzes used to assess students' understanding of homework assignments had in both students and educators. The delayed quizzes consisted of one of the assigned homework problems being re-phrased and/or with different numbers, were administered at the start of class, and students were given 15 to 20 minutes to complete them. From most students' point of view, this activity represented a source of anxiety and stress, whereas only a few students saw it as a beneficial approach to reviewing the learning material. From the instructor's perspective, this course modification did not alter students' behavior, who continued attempting to memorize homework solutions to solve newly presented problems on quizzes. These authors used quantitative data directly from students' performance in exams, quizzes, and homework to draw their conclusions, along with a qualitative perceptions survey completed by the students involved in the study.

Awange et al. (2017) (although this work mainly discusses the case study of a surveying course in civil engineering, it has been included in this systematic literature review because one of its main learning outcomes is that students *"interpret civil engineering drawings, including the use of plans, elevations, and sections and details for structures..."*, which is of relevance for CaSE educators) implemented a SoTL approach through a collaborative learning environment method to enhance industry-based skill acquisition and overall learning among students of a surveying course in Australia. A distinctive characteristic of such learning environments is the fact that through sharing and group-based discussion knowledge is generated and reinforced (Rojas 2002). The authors collected qualitative data from validated anonymous questionnaires to find out that face-to-face discussions, project-based learning, and workshop-based learning, contributed to the development of the learning attributes that CaSE students need to acquire.

An alternative application of SoTL in CaSE was exemplified by Beier et al. (2018) (clearly relevant work for this systematic literature review as it presents a SoTL project for the enhancement of the learning experience of students in structural dynamics, a significant CaSE subject). They conceived an e-learning concept tailored to afford students studying structural dynamics an opportunity for active engagement in research endeavors. The efficacy of this e-learning concept was assessed across several dimensions, including: (i) the achievement motivation of the students, (ii) the degree of acceptance of the concept and (iii) its effectiveness showing overall positive results during the first year of implementation. Students who interacted with the e-learning tool displayed notably elevated levels of motivation and exhibited a strong grasp of the subject matter. From the perspective of educators, this e-learning approach facilitated the supervision of a greater number of student projects, thus enhancing its pedagogical utility.

A pedagogical methodology that has been recently popularized is the flipped classroom (Lo and Hew 2019). In a standard flipped classroom model, students acquire a portion of the course material in advance of the class through instructional media like videos or written materials. As a result, classroom time is no longer devoted to traditional lectures and instead focuses on promoting more interactive learning experiences, including group discussions. Cleary (2020) (clearly relevant work for this systematic literature review as it presents a SoTL project for to enhancement of the learning experience of students in structural analysis, a significant CaSE subject) applied this model to the junior level “Structural Analysis” engineering course aiming at increasing student success rates and learning quality. This researcher observed mixed results. Although the flipped classroom allowed faculty staff to identify problematic topics for students earlier in the learning process and address them before exams, a lack of student preparation before lectures was observed, which hindered the effectiveness of the approach. Nevertheless, the author argued that the model serves to improve student engagement and learning experience and should be further investigated and adopted.

Another study case of a SoTL methodology put in practice is related to Experiential Learning (EL), which is based on a process of learning through doing and has been deemed as particularly suitable for engineering education as engineering is an experiential field of science (Abdulwahed and Nagy 2009). Jamison et al. (2022) (this systematic literature review has been considered suitable for inclusion in this paper as it includes two references to case studies of SoTL projects implemented within a CaSE contex, which may be of interest for CaSE educators) examined through a systematic and critical review how EL has been implemented and evaluated in previous undergraduate engineering education works. Their results highlight a close relationship between SoTL and the implementation of EL practices. The impact of Problem-Based Learning (PBL) pedagogy on teaching critical methodology concepts in a civil engineering course is used as an example in this work. This pedagogical methodology is normally perceived as a more learner-centered teaching approach in comparison to the traditional lecture-based teaching methods pervasive in engineering education (Yadav et al. 2011).

A Massive Open Online Course (MOOC) is an online course designed to be accessible to a large number of participants over the internet, typically open to anyone who wants to enroll, and which often offers course materials in the form of video lectures, reading materials, quizzes, and assignments (Joksimović et al. 2017). Al-Mekhlafi et al. (2022) (included on the basis that it was funded under a SoTL grant and presents a case study of relevance for CaSE education) observed with a SoTL study a significant impact on the continuation intention after a MOOC methodology was implemented to deliver the course "Engineer in Society" to CaSE students. They evaluated the choice's greatness or superiority of the online experience through a six-variable model questionnaire which assessed student attitude, course quality, information quality, service quality, system quality, and finally, students' intention to continue learning through MOOCs. The study's findings ultimately concluded that MOOC-based online learning can effectively promote active learning among students by fostering increased course participation and enhancing the overall educational process.

Benefits, Incentives and Outcomes of Implementing SoTL for CaSE Educators

The role of SoTL in the current academic system has been discussed in detail by Wankat and Oreovicz (2003) (included due to the insightful discussion presented on the role of SoTL in faculty promotion, among which CaSE educators). They argued that although different stakeholders (students, parents, legislators, universities) claim the importance of teaching in engineering departments, other factors (research output and attracted funding) are prioritized by decision makers while granting faculty promotion. Although this situation has started to change slightly in recent years and now the role of teaching has been increased in the tenure decision process, this has occurred as a complementary requirement, not as a balancing one (i.e., teaching duties have not substituted other roles aspects, rather they have only been accumulated to the already heavy burden placed on Engineering scholars). Moreover, these authors argued that faculty promotion mainly based on teaching and the scholarship of teaching is further hampered by the lack of importance given to and the lack of actual understanding of the SoTL by engineering departments, as well as the lack of proper metrics that allow the measurement of teaching quality in general. They suggested promoting the adoption of the SoTL among engineering educators by including teaching as an important component in the tenure promotion criteria and by granting the necessary resources not only for the sake of doing SoTL, but because of the inherent benefits this would bring to the learning experience of engineering students based on the pedagogical content knowledge possessed by engineering educators.

Drawing from their experiences within the CASTLE program, Brannan et al. (2004) arrived at the conclusion that SoTL is commonly met with skepticism among CaSE educators. This skepticism stems from the perception that SoTL offers limited opportunities for professional development within their domain. Furthermore, the formidable demands currently placed on CaSE faculty, coupled with the perceived lack of influence or significance of SoTL activities in the context of promotion and tenure processes, act as deterrents to the widespread adoption of SoTL within this academic setting. To address these challenges, they suggest further administrative support in terms of conference funding, physical space to conduct SoTL activities, administrative task assistance, teaching load reduction, and support in tenure and promotion decisions. These measures are proposed as essential components in fostering a more receptive attitude towards the integration of SoTL practices among CaSE educators.

Through the narrative testimonia of three engineering educators, among whom a CaSE faculty, Adams et al. (2007) (this work was included as one of the case studies presented on it corresponds to the SoTL experience of a civil engineering educator, while put in perspective with respect to the experiences of educators from a more general engineering education and educational phsycology field) explored the different pathways, opportunities, and challenges of SoTL. One of the main factors hindering the implementation of SoTL in the CaSE context (and mostly also among STEM in general) is the fact that it was perceived as “pseudo research” due to its qualitative character and misperceived lack of rigor. On the other hand, the positive lessons learned from the implementation of SoTL included the opportunity of using research for reflective teaching practice, building of community and personal satisfaction.

Smith et al. (2008) (record deemed relevant for this systematic literature review as it discusses the impact of a SoTL approach in several case studies, among which, a course on *"Introduction to Civil Engineering"*, attended by CaSE students) explored the implementation of Faculty Learning Communities (FLC) as a way of enhancing SoTL practices in STEM disciplines, including the CaSE field. Their expectation was that the FLC would begin to institutionalize the use of new pedagogies to support STEM instruction and enhance the achievement of underrepresented and disadvantaged students. Their approach was based, among other activities, on a classroom innovation case study on the “Introduction to Civil Engineering” course through peer teaching. The incentives put in place to motivate CaSE faculty to join the FLC initiative consisted of (i) appropriate acknowledgement for promotion, (ii) a small stipend (ranging from $500 to $1000), and (iii) the subjective satisfaction of enhanced student interest, retention, and achievement. Overall, their results suggest that FLCs are an effective mechanism for positively impacting teaching and learning in STEM disciplines.

Shrivastava (2013) (relevant work due to the emphais given to the structural engineering component of the undergraduate civil engineering capstone design project presented as case study following a SoTL approach) has as well identified the need for research in the SoTL to support and adequately conduct civil engineering curriculum updating while accounting for global and specific geographical and cultural context factors. Following Wankat and Oreovicz (2003), this researcher also identified the lack of recognition of SoTL in faculty assessment and promotion processes as the main challenge for its adoption in engineering education. The author concluded that the required curriculum improvements in civil engineering would not be achieved in time until the SoTL is formally acknowledged as an equal study field within civil engineering.

Bielefeldt (2015) and Bielefeldt et al. (2015) argued that younger faculty are more interested in SoTL and that with time, SoTL value could be increased "naturally" due to a generational change. On the other hand, this may also mean that people who dedicate time to the SoTL struggle more to achieve seniority and progress to higher ranks as other competing priorities (research outputs and amount of attracted funding) have a heavier weight towards achieving seniority in academia.

Swart et al. (2017) (work included as it surveyed two CaSe educators and presents their experiences implementing SoTL) sought to enhance and redefine the concept of the SoTL using the analogy of a unicycle and delineating it into eight foundational principles: (i) awareness, (ii) reflection, (iii) discernment, (iv) development, (v) application, (vi) evaluation, (vii) sharing and (viii) crystallization. Their proposition emphasizes the importance of encouraging engineering scholars to actively engage in the practice of SoTL. However, Swart et al. (2017) also uncovered that factors such as the fear of change or potential discrimination could act as barriers to participation in SoTL activities. Drawing insights from a focus group interview involving four academics representing diverse engineering disciplines (two from the CaSE field) these authors concluded that newcomers to SoTL principles may require additional effort to acquaint themselves with these principles. Meanwhile, seasoned scholars must remain committed to actively embracing the eight principles, as failure to do so may result in a loss of balance, akin to falling from a unicycle.

Ultimately, Swart et al. (2017) argued that a proficient mastery of SoTL practices can yield profound personal satisfaction, particularly through the achievement of the ultimate SoTL objective, which is the enhancement of student learning outcomes.

A comprehensive examination of the implementation of the SoTL within the context of a Dutch university has been documented by Poortman et al. (2020) (relevant record for this systematic literature review as it discusses the role of SoTL within the Senior University Teaching Qualification in the Netherlands, a topic of interest for university educators in this country, among which CaSE faculty). At the University of Twente, the Senior University Teaching Qualification (SUTQ) program is offered to seasoned educators who harbor a keen interest in educational innovation and the design of pedagogical practices within their teaching milieu. The primary objective of this program is to cultivate an environment that encourages collaborative reflection, the exchange of knowledge, and the pursuit of practice-based research among its participants. To facilitate these goals, enrolled educators are provided with comprehensive support mechanisms, including guidance from a dedicated coach, constructive peer feedback from colleagues, and participation in seminars focusing on educational research and design. Noteworthy among the observed outcomes among SUTQ participants were their reports of feeling inspired and appreciative of the lucidity, utility, and feedback derived from SUTQ sessions. On the other hand, the authors reported an insufficient community-building activity and further support requirements in terms of teaching rewards and recognition in career advancement, as well as allocation of both time and monetary resources to participate in the program. Addressing these challenges is imperative to realize the overarching objective of implementing a genuinely student-centered engineering education.

As supporting evidence to what is suggested by Smith et al. (2008), Wolff et al. (2021) (included as it presents a relevant SoTL implementation, and a case study focused on a civil engineering integrated cognitive-affective-systemic model, which may be of interest for CaSE educators) identified a series of disciplinary, discursive, and contextual challenges for the implementation of the SoTL in STEM. Thus, they proposed the implementation of a Community of Practice (CoP) approach to overpass such challenges and enhance a SoTL development in engineering education. They justify such a proposal since without proper systemic support, academics consider the extra effort required for the involvement of the SoTL as a heavy burden with marginal benefits, being the intrinsic motivation of few individuals the only reason to engage in it. Their CoP proposal was founded upon a peer learning environment, which foster collaborative practice-sharing of scholarly theories and a more holistic development of academics in their teaching role. Their concept was put to test through a novel EL approach applied in an introductory transport science course (part of a Civil Engineering curriculum). They concluded that the CoP approach enabled "a deeper sense of being part of a whole", with opportunities to strengthen individuals' "sense of identity and belonging". Finally, Jamison et al. (2022) concluded that faculty requires complementary support performing research on EL opportunities such as training, funding, and facilitation of research collaborations, which could be operationalized through the creation of Centres for Research on Learning and Teaching (CRLTs) at educational institutions.

Conclusions

In contemporary academia, scholarship encompasses a multifaceted spectrum, comprising teaching, service, and research endeavors. However, within the context of academic career progression, these facets do not receive uniform consideration, nor are they assessed with equal weight. This paper presents the findings of a systematic literature review focused on the SoTL within the realm of CaSE. The primary objectives of this study were to delineate the various methodologies and approaches adopted by educators in the CaSE field and to illuminate the challenges and incentives that may either foster or impede engagement in SoTL activities. The results of this investigation are presented through both bibliometric analysis and narrative synthesis methodologies.

It can be inferred that the interest of the community of CaSE educators in SoTL has shown a notable uptrend in recent years, as evidenced by the increasing number of publications within the searched databases. However, it is apparent that the academic output in this domain could be further enhanced by fostering greater collaboration among individuals and research groups involved in SoTL endeavors. Additionally, the predominant focus of the identified SoTL records seems closely aligned with a student-centered vision as these two keywords were the ones with more counts. This trend is particularly prominent in recent publications, as revealed through the bibliometric analysis.

The implementation of SoTL within CaSE contexts exhibits considerable diversity. It spans a spectrum from innovative e-learning and experiential learning methodologies to more conventional problem-based learning and peer learning environments. A noteworthy approach within this field is the incorporation of service-learning contexts, which underscore the pivotal role that engineers play in society. This addresses the first question of the systematic literature review.

Nevertheless, the integration of SoTL in CaSE contexts is accompanied by a set of challenges. These challenges encompass a dearth of adequate training, funding, and support for research collaborations, as well as a prevailing perception among engineering educators that their substantial efforts yield marginal benefits. Moreover, apprehension about change and potential discrimination, coupled with a lack of comprehension of SoTL within engineering departments, presents formidable obstacles. However, it is unequivocal that the most significant challenge hindering the successful implementation of SoTL in CaSE contexts is the absence of recognition for teaching activities in faculty promotions.

Despite the introduction of several incentives, such as modest stipends and the establishment of research centers dedicated to learning and teaching, faculty learning communities, and community of practice groups, to encourage SoTL among CaSE educators, this systematic review reveals that the pivotal factor required to attain this objective is the proper acknowledgment of teaching activities in faculty promotions. This recognition should be integrated as an equitable component alongside the existing criteria of teaching, learning, and service requirements, rather than imposing an additional burden on the already demanding responsibilities of CaSE educators. The expected benefits identified through this systematic literature review that could be observed if these challenges were overcome and if more CaSE educators adopted a SoTL approach include (i) enhanced teaching practices as educators using SoTL rely on research and evidence to guide their teaching practices, ultimately leading to the adoption of methods that have been proven to be effective, resulting in better student comprehension and retention; (ii) improved student engagement as SoTL promotes active learning techniques, such as problem-based learning and collaborative projects, which are particularly beneficial in engineering education; and (iii) strengthened curriculum design as SoTL encourages the integration of interdisciplinary knowledge and perspectives, enriching the curriculum and broadening student learning. This addresses the second question of the systematic literature review.

The limited number of records included in this systematic literature review is not due to a lack of educational research conducted by CaSE academics. Instead, it may indicate that authors are not familiar with the concept of SoTL and thus do not label their work as such. This observation is primarily based on the authors' personal experiences and their knowledge of existing literature that could be categorized as SoTL but has not been recognized as such by the original authors. This underscores the importance of offering training on SoTL to CaSE academics or increasing their awareness through other means, so that future educational research can be correctly identified.

The significant insights presented in this paper that can help advance engineering education research and practice are: (i) the identification of teaching methods implemented and tested by CaSE educators, (ii) the presentation of implications for faculty development, informing about areas where professional development opportunities are needed, (iii) fostering a culture of research in engineering education by encouraging CaSE educators to engage in scholarship related to their teaching practices, contributing to a more evidence-based and research-informed educational environment, and (iv) the synthesized presentation of primary sources that can inform educational policies and institutional practices by highlighting successful approaches and identifying areas where improvement is needed.

APPENDIX I. FULL LIST AND DETAILS OF THE INCLUDED RECORDS IN THIS SYSTEMATIC LITERATURE REVIEW

This appendix includes a full list and details of the finally included records in the presented systematic literature review. Table 3 provides details about the source, title, and reference of the records.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available in a repository online in accordance with funder data retention policies (Jiménez Rios et al. 2023a).

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Disclaimer

The content of the manuscript has previously appeared online in the form of a preprint (Jiménez Rios et al. 2024).

Supplemental Materials

Figs. 1–5 are available online in the ASCE Library (www.ascelibrary.org).

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TABLE 1. Search queries and number of records found in every source.

Source	Query	# Records Found
Scopus	TITLE-ABS-KEY (("engineer*" OR "civil engineer*" OR "structural engineer*") AND ("scholarship of teaching and learning" OR sotl))	84
Web of Science	ALL=(("engineer*" OR "civil engineer*" OR "structural engineer*") AND ("scholarship of teaching and learning" OR sotl))	43
Google Scholar	("engineer*" OR "civil engineer*" OR "structural engineer*") AND ("scholarship of teaching and learning" OR sotl)	34000
OsloMet Library	Any field contains "engineer*" OR "civil engineer*" OR "structural engineer*" AND Any field contains "scholarship of teaching and learning" OR sotl	55
Total		34182

TABLE 2. Top ten most cited papers found among the deduplicated records of this systematic literature review.

#	Title	Reference	# Citations
1	Improving teamwork skills and enhancing deep learning via development of board game using cooperative learning method in Reaction Engineering course	(Azizan et al. 2018)	57
2	Challenges in learning communication skills in chemical engineering	(Dannels et al. 2003)	47
3	Constructive Controversy and Reflexivity Training Promotes Effective Conflict Profiles and Team Functioning in Student Learning Teams	(O'Neill et al. 2017)	35
4	Modeling and simulation practices in engineering education	(Magana and de Jong 2018)	26
5	A (Updated) review of empiricism at the SIGCSE technical symposium	(Al-Zubidy et al. 2016)	19
6	Teaching and learning styles in engineering education	(Kapadia 2008)	19
7	Poly(lactic acid) and its composites as functional materials for 3-D scaffolds in biomedical applications: A mini-review of recent trends	(Sikhosana et al. 2021)	17
8	Homework Methods in Engineering Mechanics	(Lura et al. 2015)	17
9	Flipped university classrooms: Using technology to enable sound pedagogy	(Sankey and Hunt 2014)	16
10	The birth of a notion: The windfalls and pitfalls of tailoring an SoTL-like concept to scientists, mathematicians, and engineers	(Connolly et al. 2007)	16

TABLE 3. Full list and details of the finally included records in the presented systematic literature review.

#	Source	Title	Reference
1	Scopus	An e-learning-concept for research-based learning in structural dynamics	(Beier et al. 2018)
2	Scopus	Characteristics of engineering faculty engaged in the scholarship of teaching and learning	(Bielefeldt 2015)
3	Scopus	Evaluating the impact of a faculty learning community on STEM teaching and learning	(Smith et al. 2008)
4	Scopus	Experiential learning implementation in undergraduate engineering education: a systematic search and review	(Jamison et al. 2022)
5	Scopus	Learning through service engineering faculty: characteristics and changes over time	(Bielefeldt et al. 2015)
6	Scopus	Tenure and teaching	(Wankat and Oreovicz 2003)
7	Scopus	The senior university teaching qualification: engaging in research, design and building community in engineering education	(Poortman et al. 2020)
8	Scopus	Scholarship of teaching and learning: 'what the hell' are we getting ourselves into?	(Swart et al. 2017)
9	Scopus	ASCE Vision 2025 and the capstone design project	(Shrivastava 2013)
10	Scopus	A cumulative learning approach to developing scholarship of teaching and learning in an engineering community of practice	(Wolff et al. 2021)
11	Web of Science	Enhancing civil engineering surveying learning through workshops	(Awange et al. 2017)
12	Web of Science	Modeling the impact of massive open online courses (MOOC) implementation factors on continuance intention of students: PLS-SEM approach	(Al-Mekhlafi et al. 2022)
13	Web of Science	Using the flipped classroom model in a junior level course to increase student learning and success	(Cleary 2020)
14	Google Scholar	Becoming an engineering education researcher: intersections, extensions, and lessons learned among three researchers' stories becoming an engineering education researcher: intersections, extensions, and lessons learned among three researchers' stories	(Adams et al. 2007)
15	Google Scholar	Facilitating cross-disciplinary scholarship of teaching and learning at The Citadel	(Brannan et al. 2004)
16	Google Scholar	Homework methods in engineering mechanics	(Lura et al. 2015)
17	OsloMet Library	Influencing student beliefs about the role of the civil engineer in society	(Nesbit et al. 2012)

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