Journal of Cleaner Production 119 (2016) 229–235

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Educational initiatives

Systematic student-driven literature reviews in sustainability science – an effective way to merge research and teaching

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ARTICLE INFO

Article history:
Received 31 October 2015
Received in revised form
8 January 2016
Accepted 1 February 2016
Available online 6 February 2016

Keywords:
Sustainability research
Systematic literature review
Qualitative literature analysis
Systematic document review
Research-based teaching
Student researcher

ABSTRACT

Sustainability science has gained momentum in recent years, with a rising number of publications and degree programs focusing on sustainability. However, sustainability research and sustainability education are often considered as two independent activities within Universities. In this paper we present an educational research approach for integrating teaching and learning settings into academic research. Based on our experience in international research education projects, we present a detailed description of how to empower students to conduct student-driven cutting-edge research that contributes to sustainability science. We established international research education projects with students to jointly conduct, draft and publish systematic literature reviews in sustainability science. Here we present an iterative review procedure for examining qualitative and quantitative data and organizing student-driven research projects. We discuss the demands and limitations of systematic literature reviews in sustainability science and elaborate on the benefits and key challenges from student-driven education research projects. Thus, the paper offers comprehensive guidance to the research community for actively engaging students and junior researchers in collaborative projects to effectively merge research and teaching. In conclusion, we call for stronger integration of students into sustainability research including jointly framing of research projects and collaboratively publishing of research findings in peer-reviewed journals.

1. Introduction

Sustainability science has evolved into a vibrant branch of science, focusing on understanding human–environment interactions and developing practical solutions to sustainability problems (Bettencourt and Kaur, 2011; Spangenberg, 2011). Sustainability science is consolidating as a unique scientific field, with focal research programs (Yarime et al., 2012, 2009), a growing body of scientific literature (Buter and Raan, 2012; Kajikawa et al., 2007) dedicated journals (Buter and Raan, 2012) and hundreds of sustainability degree programs around the world (Van De Keere, 2012; Vincent et al., 2012).

The solution-oriented agenda of sustainability science demands transformational change in current academic institutions, including research practices as well as teaching and learning settings (König, 2015; Lozano et al., 2013; Mochizuki and Yarime, 2016). Implementing sustainability research in education demands a fundamental change in existing paradigms (Barth and Michelsen, 2012) and requires sustainability to become "researchable, teachable, and learnable" (Martens et al., 2010, p. 294). A close link between research and education is beneficial for (i) providing joined knowledge generation of students and researchers, and (ii) allowing students to develop key competencies in sustainability science (Reid et al., 2010; Wiek et al., 2011). However, academia is generally dominated by a dualistic approach, where research activities and education remain separate endeavors (Elkana et al., 2010; Lozano et al., 2015; Smith and Rust, 2011). While curricula are designed to introduce students to scientific practice, learning experiences are often limited to the classroom, reducing students

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http://dx.doi.org/10.1016/j.jclepro.2016.02.005
0959-6526/

to consumers, instead of enabling them as producers of science (Rowe, 2007). As a result of this dualistic approach, sustainability science curricula not only fail to involve students into university sustainability efforts (Krasny and Delia, 2015) but also fall short in integrating students into concrete research endeavors. Therefore, graduated students often lack scientific literacy essential for conducting rigorous, peer-reviewed research (Correia et al., 2010).

Research projects can provide an active learning-teaching-research environment for engaging and educating students (Trencher et al., 2015; Wiek et al., 2014a). In recent years programs that apply problem-based or project-based learning approaches have increasingly been established (Brundiers and Wiek, 2013; Rosenberg Daneri et al., 2015). These learner-centered approaches change the traditional role of teachers to coaches and facilitators, empowering students to decide themselves what and how to learn (Brundiers and Wiek, 2011; Stauffacher et al., 2006). Research on such learning approaches commonly focus on integrating research into conventional study programs and individual curricular courses (Knutson et al., 2010; Smith and Rust, 2011). However, research projects that involve student sustainability learning and education are largely under examined (Trencher et al., 2015). We suggest that student-driven research projects that empower students to actively engage with sustainability science can complement existing sustainability courses, building scientific literacy and educating students in real-world research processes.

We consider collaborative systematic literature review projects as particularly suitable to introduce students to the scientific practice of sustainability science. Systematic literature review projects investigate topics according to the available scientific literature, assess the quality of research and summarize the state of research by following a well-defined procedure (e.g. Bettencourt and Kaur, 2011; Brandt et al., 2013). They are widely acknowledged in science in general and have become an established approach to summarize the current state of research in various branches of science (Garrard, 2013; Khan et al., 2011). Such reviews can be developed as collaborative student-driven projects, introducing students to the full project cycle of research, from problem framing through to peer-reviewed publication. Organized as a problem-based-learning approach systematic literature reviews support students to develop effective problem-solving, self-directed learning skills and intrinsic motivation (Hmelo-silver, 2004). Drawing on our experience from over 5 years of conducting systematic reviews, we observed that the review process enables students to acquire in-depth sustainability related knowledge. For example, in areas such as transdisciplinary sustainability research, urban ecosystem services, ecosystem-based adaptation, transformational change, and education for sustainable development. Moreover, they encourage students to critically reflect on the scientific process of knowledge production advancing their scientific literacy. In addition, such collaborative projects support the development of academic skills and interpersonal competencies in students. Review formats are also beneficial to researchers since the volume of literature for many sustainability related topics might exceed the capacity of single researchers to conduct comprehensive and multi-dimensional reviews.

Against this background the purpose of this paper is to provide detailed guidance for researchers interested in organizing and conducting student-driven, systematic review projects (Section 2). We describe six essential phases of student-driven literature reviews and provide a systematic review protocol for such endeavors. Finally, we elaborate on the demands of systematic literature reviews within the field of sustainability science, using our experience from three different projects to illustrate our procedure and reflect on the process and dynamics of student-driven research projects (Section 3).

2. Student-driven research in sustainability science: guidelines for conducting systematic literature reviews

In the following sections we provide an overview of student-driven literature review projects. We elaborate how sustainability research becomes learnable and teachable by enabling students to become full members of the research team. Detailed guidance is provided for each of the key phases of a student-driven literature review.

2.1. Step-by-step guide to organize student-driven literature review projects

The presented project design builds on established review guidelines from peer-reviewed literature (Cooper, 1982; Newig and Fritsch, 2009; Stewart, 2006). In addition, we build on our experiences from three student-driven review projects (see Brandt et al. (2013) for a review on transdisciplinarity in sustainability science, Luederitz et al. (2015) for a review on urban ecosystem services, and Brink et al. (2016) for a review on ecosystem-based adaptation). In Fig. 1 we present the six phases for conducting and planning such projects, including project initiation (A), initial project meeting (B), review procedure (C), data analysis (D), results framing and presentation (E), and article finalization (F). While this structure is based on our experience in extracurricular projects, it might need fine-tuning to fit specific demands of future projects, institutional settings and learning objectives. In the following sections we elaborate on each phase.

2.1.1. Phase A – project initiation

This phase includes the defining of the research area, engaging faculty and motivating and organizing students (see faculty's and students' responsibility in Fig. 1). A potential starting point for defining a research topic is the expertise of the faculty members overseeing the project. This ensures topical relevance and can be used to align the research project to the study programs from which students will be recruited. Note here that we use the term ‘faculty’ to refer to PhD scholars, post doctoral researchers and more senior scientists. Ideally the project should include faculty members from across this experience range. Doing so gives the students involved in the project the opportunity to interact with and learn from a researchers at different stages in their scientific careers. Communication with students needs to start as early as possible to allow for a seamless planning of all later steps. Here, it is vital to clearly communicate the workload to potential participants in order to allow for realistic project planning.

2.1.2. Phase B – first project meeting

The objective of the second phase is to create a cohesive project team and develop the research aim. This includes collaborative development of organizational structures that clarify expectations, responsibilities and competencies as well as decision rules. During the first project meeting individual learning objectives need to be formulated as well as skills and (educational) backgrounds of those involved in the project should be shared. At this stage rules for decision-making, responsibilities of the participants and modes of communication need to be established (see faculty's and students' responsibility in Fig. 1). Defining extended responsibilities for two members (one student and one faculty) provides a meaningful way to enhance and streamline communication. A jointly defined research aim should consolidate the group towards a united goal, which then needs to be broken down into smaller items that form the project agenda. The latter includes identification of key activities, sequence of actions and arranging milestones in relation to a timeline.

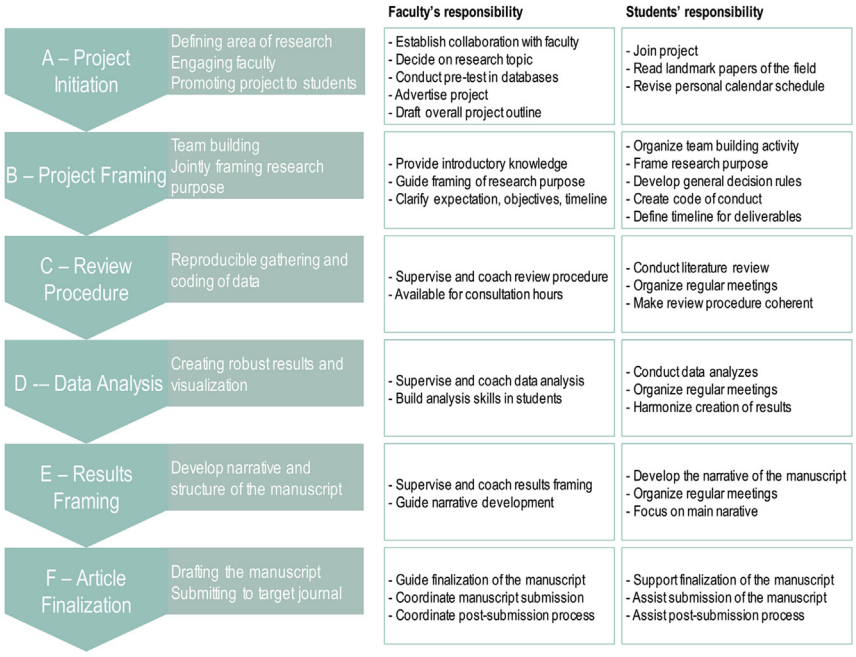

Fig. 1. Six phases for organizing student-driven literature review projects.

2.1.3. Phase C — review procedure

This is the core phase of the project, during which the empirical research is conducted. It involves six consecutive steps: i) definition of selection criteria, ii) data gathering, iii) data screening, iv) data clearing, v) data scoping, and vi) full-text review (see Table 1). Each step is detailed in the following sections.

i) Definition of selection criteria. The research aim and related research questions, hypothesis or narratives are translated into a search string that is applied in the search for the relevant literature. A search string enables the creation of a dataset containing the relevant literature from a particular database. Scholarly databases are usually preferable to access peer-reviewed literature (e.g. Scopus), but full-text driven databases can also be helpful as they include gray literature (e.g. Google Scholar) (Beckmann and von Wehrden, 2012). Depending on the research field that is reviewed the extraction of data from multiple databases is recommended. The search string should be cross-checked whether it includes landmark papers, making sure that it is broad enough to include all potentially relevant papers, often leading to a high rate of false positives. An initial pre-review of a subsection of the database is advisable to ensure a pool of relevant literature that is large enough for a systematic literature review.

ii) Data gathering. The created dataset is imported into a reference management system. In the case that data from multiple databases is combined, duplicates have to be removed from the dataset. A unique identifier (ID) is produced for every paper in the dataset. Paper-IDs ensure consistent use in later process stages and provide a unique reference for communication within the group.

iii) Data Screening. For the screening of data, the dataset has to be transferred to a spreadsheet (Review Data Table) that is accessible by all members of the project. Every paper is assigned to a reviewer. To assure reliability between group members it is advisable to have all papers analyzed independently by two reviewers. The inter-rater reliability measure provides a score for the consensus between reviewers and indicates whether a particular criterion or scale is appropriate for evaluating a specific attribute (Gwet, 2014).

iv) Data Cleaning. The inclusion of papers is decided upon by evaluating the title and abstract against defined criteria derived from the research purpose of the literature review. If a decision, whether to include a given paper, is not possible based on this initial check, the full paper should be read. Discrepancies between reviewers should be discussed in the larger group, which builds a shared understanding of the selection criteria, minimizing any systematic bias in the paper selection process. Abstracts can be assessed as relevant, not relevant or unclear. The later categorization demands further scrutiny by other reviewers to decide whether the research purpose is applicable to the paper in question.

v) Data Scoping. The full-text sourcing of relevant papers is based on the finalized Review Data Table. Access to scientific journals and the respective paper might be limited due to university subscriptions. Direct contact to authors of publications in question can alternatively be pursued for receiving the respective publications. Papers for which full-text cannot be accessed need to be identified and reported (see Table 1, row "data scoping"). Often around 10% of the potentially relevant papers cannot be obtained during the data scoping process.

vi) Full-Text Review. A full-text review is conducted for all entries in the Review Data Table. To obtain qualitative data a systematic qualitative content analysis is conducted for each paper (Mayring, 2000; Srnka and Koeszegi, 2007). To do so a coding scheme is developed that comprises all categories that are considered relevant to the research purpose. The development of categories can be informed in advance by the literature or created during the review process. Review categories that are added at later stages require iterative review of the database. Following Srnka and Koeszegi (2007) these categories are initially derived from the literature and subsequently adapted and enriched through iterative procedures. The coding scheme provides the guidelines (rules)

Table 1
Overview of the steps of the systematic literature review.

Review steps	Action	Result	Example: Luederitz et al., 2015
Definition of selection criteria	Joint translation of the broad narrative (or field of research) into the search string defining the research focus.	Comprehensive search string (with correct syntax) that generates a dataset of potentially relevant papers.	Search string for the Scopus database: TITLE-ABS-KEY((“ecosystem servic*” OR “ecosystem functio*” OR (provisioning AND ecosyste*) OR (regulating AND ecosyste*) OR (cultural AND ecosyste*) OR (supporting AND ecosyste*) OR (habitat AND ecosyste*)) AND (urban OR city OR cities OR periurban OR town)) AND (EXCLUDE(PUBYEAR,2013)) AND (LIMIT-TO(DOCTYPE,“ar”) OR LIMIT-TO(DOCTYPE,“re”)) AND (LIMIT-TO(LANGUAGE,“English”))
Data gathering	Extraction of bibliographic data from an appropriate database. Load the data into a reference management program (e.g. Endnote, Papers, Citavi, etc.), merge results if multiple databases are consulted and delete duplicates. Assign paper-IDs to each row of the dataset for future reference (e.g. to reproduce dataset at all process stages).	Initial dataset of papers that match the search string	Database search on Scopus and ISI using jointly defined search string. Bibliographical information of 3266 potentially relevant papers (duplicates excluded).
Data screening	Transfer dataset to data table. Assign abstracts to one, better two reviewers.	Central *Review Data Table* where reviewers can enter results.	A spreadsheet was created on google drive with reading and editing rights assigned to all project members. Division of data load into bundles of 320 papers per reviewer.
Data cleaning	Conducting an abstract analysis, based on jointly developed *paper inclusion criteria*. It is advisable that every abstract is analyzed independently by two people. Joint discussion of unclear abstracts can lead to recursive step; check for consistent abstract analysis (inter-rater reliability).	A *Review Data Table* that contains only papers with abstracts that fit the research purpose.	The screening of abstracts identified 387 potentially relevant case studies, guided by the questions: • “Does the paper conduct a case study” • “Does the case study focus on urban areas” • “Does the case study analyze ecosystem services or benefits provided to humans in an urban area?” • “Explicit use of the term ‘ecosystem services’ or described link between eco-systems and benefits to an urban population”
Data scoping	Full-text sourcing of relevant articles.	Accessible folder containing all PDFs of papers with relevant abstracts. Paper PDFs are named according to their paper-ID.	Download of all papers classified as potentially relevant. Download of 352 potentially relevant case studies (35 papers with no full-text access).
Full-text review	Assign PDF to reviewers. Developing a coding scheme for obtaining coded data from full-text analysis. Coding of Papers into *Review Data Table*	A *Review Data Table* containing information given by full texts.	Analysis of papers classified as case studies that serve the study focus using 23 jointly defined review categories. Through the full-text review additional papers were identified as not relevant leaving a coherent dataset of N = 201 case study.

for full-text analysis entailing for every category the name, a definition, an anchor example, and the coding value (number) (Mayring, 2000). Each category should be defined as precisely as possible, to increase validity, and as broadly as necessary to ensure consistent use. The final coding is the “systematic assignment of codes (numbers) to [text] units based on the category scheme” (Srnka and Koeszegi, 2007, p. 37). Where one reviewer is not confident in taking a coding decision ideally two other project members would also code this category for a given paper and discuss their reasoning in the group.

2.1.4. Phase D – data analysis

Methods for data analyses are largely determined by the data format and information content. Diversity between disciplinary backgrounds will foster a wide array of potential data analysis approaches. This phase offers students the opportunity to develop skills in statistical analysis, to familiarize themselves with software tools like R or GIS and to learn visualization of complex data. Through qualitative content analysis students develop in-depth knowledge in the research field that is analyzed while also generating the quantitative data required for the analysis. This will ultimately enable students to discuss and create the narrative framework for interpreting the data in the context of the research field. In most cases a lot of data is available but results have to fit to the explicit storyline.

2.1.5. Phase E – results framing and presentation

The development of the narrative provides the frame for generating results relevant for the broader research community. In order to enable a structured process for framing of the narrative, it is beneficial to develop 2–5 hypotheses/research questions based on the data. The narrative is developed through brainstorming and group discussion activities. Through this procedure, narrative relevant information is collected. Subsequently, the information is reviewed in light of significant results and in the search for a coherent storyline. While in some cases the final manuscript might be restricted to one main hypothesis that builds the narrative, starting with several hypotheses may be beneficial in terms of sharing the work load in the review process and subsequent paper writing. Developing a shared understanding of the paper's contribution, key results and story-line is essential to enable group members to simultaneously draft different, coherent sections of the manuscript. In addition, iterative internal peer-review rounds provide meaningful ways of improving the coherence, quality and accuracy of the manuscript.

2.1.6. Phase F – article finalization

The last step is the finalization of the overall text, and ultimately the submission process. Based on our experience is it crucial to break the concept of the flat hierarchies (used during phases B–E) in order to create a manuscript that is coherent both in style and structure (see faculty's and students' responsibility in Fig. 1). A core team should be responsible for the final improvements formatting

the paper into a submission-ready manuscript as well as managing the peer-review process. Turnover rates of many journals are currently at about three months while the time from submission to publication can take up to a year or more. Therefore it is important that a core team with a long-term perspective manages the further process of the manuscript considering that this might exceed the graduation date of involved students. In addition, not all students follow a long-term academic perspective and, thus, might not be able to actively participate after the submission of the manuscript.

2.2. Student-driven literature reviews as learning endeavors

In order to empower students to actively take part in the full research cycle from orienting the research, to peer-reviewed publishing we identified essentials to guide the research process (see Box 1). The structure of the process enables students to adopt responsibilities and step into the roles of researchers over time, a development that needs to be considered in the project framing. Accordingly, the project is not initially framed by the students but enables them to take leadership as it progresses (see phase A–F). Experienced researchers provide the general setting, predefine goals and suggest milestones to empower students to steer the course of research. Students identify issues of interest within the predefined topic. They determine the specific review categories as well as set and adjust the timeline and milestones of the project. A core requirement is that the topic provides enough scientific publications as a data basis, with the ultimate goal of submitting a manuscript to a peer-reviewed journal, with all participants listed as co-authors. Researchers from different levels (BSc, MSc, PhD, Post-Doc, Prof), and ideally different scientific disciplines, engage collaboratively in structuring and framing the research as well as jointly write the manuscript in order to publish the results.

We have designed systematic literature review projects as extracurricular education courses located at two international universities as well as hosted by a single university. International settings add a certain degree of complexity to the project (e.g. different semester schedules, distant communication, etc.) but also provide benefits to students (e.g. short-term exchange, expanding networks, dynamic learning environments, acquiring soft and hard skills etc.) (McMahon and Bhamra, 2012). Here we present a short overview of the general structure of an international review project: Students enrolled in a sustainability science related degree program at the Master or PhD level were invited to engage in the project, while one professor from each institution agreed to provide supervision and assistance. Two 2–3 day workshops were hosted, one at each university, the first to start the project, narrow down the research focus and introduce the systematic literature review process (Phase B). The second workshop focused on synthesizing the reviewed literature and framing the manuscript (Phase D–E). Between the first workshop and submission of the manuscript to a peer-reviewed scientific journal, open and repeated communication involving all participating students as well as the interactive process of reviewing and synthesizing the literature are required.

Box 1
Essentials of student driven research projects

- The project topic and research questions are of relevance to the scientific community.
- Students adopt responsibilities of and step into the roles of researchers which requires thorough supervision and flexible project structures to allow for this development.
- Experienced researchers facilitate the general structure and identify potential milestones and goals to empower students to conduct independent research.
- Researchers from different levels (BSc, MSc, PhD, Post-Doc, Prof) engage collaboratively in orienting, framing and doing the research, jointly writing the manuscript and publishing the findings with all collaborators listed as co-authors.

3. Discussion

Why use student driven systematic literature reviews in sustainability science? The number of publications in academia is rapidly increasing and systematic literature reviews are on the rise, creating opportunities for student-driven review projects. Such projects allow students to get both in-depth insights into a research fields and develop their academic skills. However, problem-based learning that focuses on real-world issues provides an alternative path to enable students in more practical research approaches (Trencher et al., 2015; Vilsmaier and Lang, 2015; Wiek and Kay, 2015). Such problem-based research projects are clearly beneficial for training students in field methods such as conducting interviews and sampling ecological patterns as well as engaging students in participatory research settings. In addition, problem-based learning provides meaningful educational environments for building sustainability competences and expertise in students. We suggest that student-driven literature reviews provide a complementary approach to such problem-based approaches for empowering students as researchers. The demands on, and the capacity built in students differ significantly between the two approaches. Similar the resources required vary substantially. While real-world problem-based leaning projects often lack sufficient resources and faculty capacity (Wiek and Kay, 2015), student-driven literature reviews do not rely on funding (besides travel cost for international projects) and faculty engagement is bounded. We therefore argue that systematic literature reviews are efficient and effective means for integrating students into research. Specifically, because the research design is less complex than in real-world problem-based learning approaches and can be more readily applied in a student-driven approach.

Most of published research in sustainability science is undertaken by either PhD students or more senior researchers. While many approaches try to link Bachelor and Master students to active research, we argue that ideally students should engage in actual research projects creating actual publications. While there is a long tradition in creating student-driven learning formats, most teaching approaches do not create actual peer-reviewed publications. Since publications in peer-reviewed journals can be considered as an established form of communicating scientific results, we propose that students should engage in the whole process including the final publication. However, this demands a long time frame that might often exceed the length of standard study programs.

Sustainability science and its demands on systematic literature reviews. We identify three outputs that sustainability science demand from systematic literature reviews: firstly, the hypothesis driven review approach needs to be replaced by an iterative procedure (e.g. Brandt et al., 2013). More specifically, reviews in sustainability science analyze research that may be originated from a wide array of disciplines with heterogeneous research styles and structures (Abson et al., 2014; Brandt et al., 2013; Luederitz et al., 2015). Part of the challenge of such reviews is the necessity to find common understanding across disciplines and approaches that address the same problem topic using different terminologies and cultures of science. To facilitate this knowledge synthesis, iterative review procedures and rigorous cross-checking between reviewers

are required for ensuring that the literature is being reviewed in a consistent, coherent and reproducible manner (Brandt et al., 2013).

Secondly, systematic literature reviews provide an effective way to evaluate a given research field regarding the methods, tools, and concepts that are practically applied (see Brandt et al., 2013). We acknowledge that literature reviews of conceptual papers are important for synthesizing the state of the art of a research field. However, given the solution-orientated focus of sustainability science (Miller et al., 2014), systematic reviews of case studies – where conceptual approaches are applied to real-world situations – are of particular importance. Such analyses provide insights into the relations between theory and practice and to the extent to which conceptual frameworks are operationalized. To this end, literature reviews that are empirically motivated can examine the extent to which the solution-oriented agenda of sustainability science is pursued in practically applied research (Wiek et al., 2014b).

Finally, interdisciplinary teams are required for integrating diverse perspectives on sustainability science and insights from different research fields into the review process (Lee et al., 2014; Reid et al., 2010). Collaboration among researchers from different disciplinary backgrounds is crucial for examining and integrating diverse approaches, methods and technique as well as appraising the transferability of these approaches across disciplines (Ascher, 2007; Shrum et al., 2007; Spangenberg, 2011). Reviews in sustainability science should be orientated towards synthesis across research fields counteracting justification of particular, disciplinary embedded, methods tools and approaches (Miller et al., 2014).

4. Conclusion

Sustainability science has emerged as vibrant branch of science with a rising number of publications in recent years, generating a potential rich data source for topics that can be explored by following the systematic literature review framework presented here. We argue that student-driven literature reviews represent an effective way to merge research and teaching. Such projects are complementary to other problem-based learning approaches that focus on real-world settings and provide promising environments for developing key competencies in sustainability. While systematic reviews do not engage students in solving real-world problems, they provide efficient and effective means for building science literacy guiding students in becoming sustainability scientists. Based on our experience in international, student-driven research we developed a detailed six-step procedure for organizing such projects: (A), the project initiation (B), the systematic review of data (C) analysis (D) results framing and presentation (E) and the article finalization (F; Fig. 1). Thus, this article offers an iterative review protocol for guiding systematic literature reviews. In addition, it provides comprehensive guidance to the community for actively engage students and junior researchers in such endeavors. Conducting student-driven literature reviews in international settings can contribute to sustainability science on at least four levels:

1) Involving student researchers into the process of publications supports learning-by-doing and enables them to contribute early in their academic careers to sustainability science. Students can thus add to emerging topics, build their reputation and gain an in depth understanding of a specific research field.
2) Conducting research within a group of scholars with regular exchange and discussions on the research topic enables critical reflection on sustainability science. This strengthens reflexivity among researchers regarding the normative and transformational aspects of sustainability science.
3) Pursuing systematic literature reviews with scholars that have different educational backgrounds supports understanding of and building linkages between research fields in sustainability science. While students may contribute through diverse disciplinary backgrounds, the literature review would ideally generate a perspective that is interdisciplinary and based on shared understanding.
4) Opening the restrictive doors of academia. Although systematic literature reviews do not require international research collaborations, the structure outlined in this paper offers a unique possibility for integrating students from different disciplines, universities, and programs (i.e. Master, PhD, Postdoc). This not only invites young scholars into academia but enable them to build networks and gain international learning experience at an early stage of their scientific development.

Student-driven literature reviews are an effective tool for linking research with teaching and learning. Student-driven reviews create inspiring working environments for students in sustainability science, and simultaneously help to advance the field by generating reproducible knowledge based on available data.

Acknowledgments

This paper is the result of six educational research projects between Leuphana University of Lüneburg (Germany) and multiple collaborating universities. We are grateful to the highly motivated students that participated in our projects and the joint learning experience. Many thanks also to the faculty that supported the establishing of inter-university collaboration. We thank three reviewers for their comments on an earlier version of this paper.

References

Abson, D.J., von Wehrden, H., Baumgärtner, S., Fischer, J., Hanspach, J., Härdtle, W., Heinrichs, H., Klein, A.M., Lang, D.J., Martens, P., Walmsley, D., 2014. Ecosystem services as a boundary object for sustainability. Ecol. Econ. 103, 29–37. http://dx.doi.org/10.1016/j.ecolecon.2014.04.012.

Ascher, W., 2007. Policy sciences contributions to analysis to promote sustainability. Sustain. Sci. 2, 141–149. http://dx.doi.org/10.1007/s11625-007-0031-z.

Barth, M., Michelsen, G., 2012. Learning for change: an educational contribution to sustainability science. Sustain. Sci. 8, 103–119. http://dx.doi.org/10.1007/s11625-012-0181-5.

Beckmann, M., von Wehrden, H., 2012. Where you search is what you get: literature mining – Google Scholar versus Web of Science using a data set from a literature search in vegetation science. J. Veg. Sci. 23, 1197–1199. http://dx.doi.org/10.1111/j.1654-1103.2012.01454.x.

Bettencourt, L.M.A., Kaur, J., 2011. Evolution and structure of sustainability science. Proc. Natl. Acad. Sci. U. S. A. 108, 19540–19545. http://dx.doi.org/10.1073/pnas.1102712108.

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D.J., Newig, J., Reinert, F., Abson, D.J., von Wehrden, H., 2013. A review of transdisciplinary research in sustainability science. Ecol. Econ. 92, 1–15. http://dx.doi.org/10.1016/j.ecolecon.2013.04.008.

Brink, E., Aalders, T., Ádám, D., Feller, R., Henselek, Y., Hoffmann, A., Ibe, K., Matthey-Doret, A., Meyer, M., Negrut, N.L., Rau, A.-L., Riewerts, B., von Schuckmann, L., Törnros, S., von Wehrden, H., Abson, D.J., Wamsler, C., 2016. Cascades of green: a review of ecosystem-based adaptation in urban areas. Glob. Environ. Chang. 36, 111–123. http://dx.doi.org/10.1016/j.gloenvcha.2015.11.003.

Brundiers, K., Wiek, A., 2011. Educating students in real-world sustainability research: vision and implementation. Innov. High. Educ. 36, 107–124. http://dx.doi.org/10.1007/s10755-010-9161-9.

Brundiers, K., Wiek, A., 2013. Do we teach what we preach? An international comparison of problem- and project-based learning courses in sustainability. Sustainability 5, 1725–1746. http://dx.doi.org/10.3390/su5041725.

Buter, R.K., Raan, A.F.J., 2012. Identification and analysis of the highly cited knowledge base of sustainability science. Sustain. Sci. 8, 253–267. http://dx.doi.org/10.1007/s11625-012-0185-1.

Cooper, H.M., 1982. Scientific guidelines for conducting integrative research reviews. Rev. Educ. Res. 52, 291–302. http://dx.doi.org/10.3102/00346543052002291.

Correia, P.R.M., Xavier do Valle, B., Dazzani, M., Infante-Malachias, M.E., 2010. The importance of scientific literacy in fostering education for sustainability:

theoretical considerations and preliminary findings from a Brazilian experience. J. Clean. Prod. 18, 678–685. http://dx.doi.org/10.1016/j.jclepro.2009.09.011.
Elkana, Y., Laubichler, M.D., Wilkins, A.S., 2010. Call to reshape university curricula. Nature 467, 788. http://dx.doi.org/10.1038/467788c.
Garrard, J., 2013. Health Sciences Literature Review Made Easy. Jones & Bartlett Learning, Burlington.
Gwet, K., 2014. Handbook of Inter-rater Reliability: the Definitive Guide to Measuring the Extent of Agreement Among Raters, third ed. Advanced Analytics, LLC., Gaithersburg.
Hmelo-Silver, C.E., 2004. Problem-based learning: what and how do students learn? Educ. Psychol. Rev. 16, 235–267.
Kajikawa, Y., Ohno, J., Takeda, Y., Matsushima, K., Komiyama, H., 2007. Creating an academic landscape of sustainability science: an analysis of the citation network. Sustain. Sci. 2, 221–231. http://dx.doi.org/10.1007/s11625-007-0027-8.
Khan, K., Kunz, R., Kleijnen, J., Antes, G., 2011. Systematic Reviews to Support Evidence-based Medicine: How to Review and Apply Findings of Healthcare Research. Hodder Arnold, London. http://dx.doi.org/10.1016/S1036-7314(00)70624-2.
Knutson, K., Smith, J., Nichols, P., Wallert, M.A., Provost, J.J., 2010. Bringing the excitement and motivation of research to students; using inquiry and research-based learning in a year-long biochemistry laboratory: part II-research-based laboratory-a semester-long research approach using malate dehydrogenase as a research. Biochem. Mol. Biol. Educ. 38, 324–329. http://dx.doi.org/10.1002/bmb.20401 a Bimon. Publ. Int. Union Biochem. Mol. Biol.
König, A., 2015. Changing requisites to universities in the 21st century: organizing for transformative sustainability science for systemic change. Curr. Opin. Environ. Sustain. http://dx.doi.org/10.1016/j.cosust.2015.08.011.
Krasny, M.E., Delia, J., 2015. Natural area stewardship as part of campus sustainability. J. Clean. Prod. 106, 87–96. http://dx.doi.org/10.1016/j.jclepro.2014.04.019.
Lee, Y.-N., Walsh, J.P., Wang, J., 2014. Creativity in scientific teams: unpacking novelty and impact. Res. Policy. http://dx.doi.org/10.1016/j.respol.2014.10.007.
Lozano, R., Lukman, R., Lozano, F.J., Huisingh, D., Lambrechts, W., 2013. Declarations for sustainability in higher education: becoming better leaders, through addressing the university system. J. Clean. Prod. 48, 10–19. http://dx.doi.org/10.1016/j.jclepro.2011.10.006.
Lozano, R., Ceulemans, K., Alonso-Almeida, M., Huisingh, D., Lozano, F.J., Waas, T., Lambrechts, W., Lukman, R., Hugé, J., 2015. A review of commitment and implementation of sustainable development in higher education: results from a worldwide survey. J. Clean. Prod. 108, 1–18. http://dx.doi.org/10.1016/j.jclepro.2014.09.048.
Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., Panzer, L., Partelow, S., Rau, A., Sasaki, R., Abson, D.J., Lang, D.J., Wamsler, C., Von Wehrden, H., 2015. A review of urban ecosystem services: six key challenges for future research. Ecosyst. Serv. 14, 98–112.
Martens, P., Roorda, N., Cörvers, R., 2010. The need for new paradigms. Sustain. J. Rec. 3, 294–303. http://dx.doi.org/10.1089/SUS.2010.9744.
Mayring, P., 2000. Qualitative content analysis. Forum Qual. Soc. Res. 1.
McMahon, M., Bhamra, T., 2012. "Design beyond borders": international collaborative projects as a mechanism to integrate social sustainability into student design practice. J. Clean. Prod. 23, 86–95. http://dx.doi.org/10.1016/j.jclepro.2011.10.022.
Miller, T.R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., Loorbach, D., 2014. The future of sustainability science: a solutions-oriented research agenda. Sustain. Sci. 9, 239–246. http://dx.doi.org/10.1007/s11625-013-0224-6.
Mochizuki, Y., Yarime, M., 2016. Education for sustainable development and sustainability science. Re-purposing higher education and research. In: Barth, M., Michelsen, G., Thomas, I., Rieckmann, M. (Eds.), Routledge Handbook of Higher Education for Sustainable Development, pp. 11–24. London.
Newig, J., Fritsch, O., 2009. The case survey method and applications in political science. Polit. Sci. Assoc. 49, 3–6.
Reid, W.V., Chen, D., Goldfarb, L., Hackmann, H., Lee, Y.T., Mokhele, K., Ostrom, E., Raivio, K., Rockström, J., Schellnhuber, H.J., Whyte, A., 2010. Earth system science for global sustainability: grand challenges. Science 330, 916–917. http://dx.doi.org/10.1126/science.1196263.
Rosenberg Daneri, D., Trencher, G., Petersen, J., 2015. Students as change agents in a town-wide sustainability transformation: the Oberlin Project at Oberlin College. Curr. Opin. Environ. Sustain. 16, 14–21. http://dx.doi.org/10.1016/j.cosust.2015.07.005.
Rowe, D., 2007. Education for a sustainable future. Science 317 (5836), 323–324. http://dx.doi.org/10.1126/science.1143552.
Shrum, W., Genuth, J., Chompalov, I., 2007. Structures of Scientific Collaboration. MIT Press, Cambridge.
Smith, P., Rust, C., 2011. The potential of research-based learning for the creation of truly inclusive academic communities of practice. Innov. Educ. Teach. Int. 48, 115–125. http://dx.doi.org/10.1080/14703297.2011.564005.
Spangenberg, J.H., 2011. Sustainability science: a review, an analysis and some empirical lessons. Environ. Conserv. 38, 275–287. http://dx.doi.org/10.1017/S0376892911000270.
Srnka, K.J., Koeszegi, S., 2007. From words to numbers: how to transform qualitative data into meaningful quantitative results. Schmalenbach Bus. Rev. 59, 29–57.
Stauffacher, M., Walter, A., Lang, D.J., Wiek, A., Scholz, R.W., 2006. Learning to research environmental problems from a functional socio-cultural constructivism perspective: the transdisciplinary case study approach. Int. J. Sustain. High. Educ. 7, 252–275. http://dx.doi.org/10.1108/14676370610677838.
Stewart, G.L., 2006. A meta-analytic review of relationships between team design features and team performance. J. Manag. 32, 29–55. http://dx.doi.org/10.1177/0149206305277792.
Trencher, G., Terada, T., Yarime, M., 2015. Student participation in the co-creation of knowledge and social experiments for advancing sustainability: experiences from the University of Tokyo. Curr. Opin. Environ. Sustain. 16, 56–63. http://dx.doi.org/10.1016/j.cosust.2015.08.001.
Van De Keere, L., 2012. Database of Graduate Programs in Sustainability. College of Sustainability, Dalhousie University, Halifax, Nova Scotia.
Vilsmaier, U., Lang, D.J., 2015. Making a difference by marking the difference: constituting in-between spaces for sustainability learning. Curr. Opin. Environ. Sustain. 16, 51–55. http://dx.doi.org/10.1016/j.cosust.2015.07.019.
Vincent, S., Bunn, S., Stevens, S., 2012. Results from the 2012 Census of U.S. Four Year Colleges and Universities. National Council for Science and Education, Washington.
Wiek, A., Kay, B., 2015. Learning while transforming: solution-oriented learning for urban sustainability in Phoenix, Arizona. Curr. Opin. Environ. Sustain. 16, 29–36. http://dx.doi.org/10.1016/j.cosust.2015.07.001.
Wiek, A., Harlow, J., Melnick, R., van der Leeuw, S., Fukushi, K., Takeuchi, K., Farioli, F., Yamba, F., Blake, A., Geiger, C., Kutter, R., 2014b. Sustainability science in action: a review of the state of the field through case studies on disaster recovery, bioenergy, and precautionary purchasing. Sustain. Sci. 10, 17–31. http://dx.doi.org/10.1007/s11625-014-0261-9.
Wiek, A., Xiong, A., Brundiers, K., van der Leeuw, S., 2014a. Integrating problem- and project-based learning into sustainability programs. Int. J. Sustain. High. Educ. 15, 431–449. http://dx.doi.org/10.1108/IJSHE-02-2013-0013.
Wiek, A., Withycombe, L., Redman, C.L., 2011. Key competencies in sustainability: a reference framework for academic program development. Sustain. Sci. 6, 203–218. http://dx.doi.org/10.1007/s11625-011-0132-6.
Yarime, M., Takeda, Y., Kajikawa, Y., 2009. Towards institutional analysis of sustainability science: a quantitative examination of the patterns of research collaboration. Sustain. Sci. 5, 115–125. http://dx.doi.org/10.1007/s11625-009-0090-4.
Yarime, M., Trencher, G., Mino, T., Scholz, R.W., Olsson, L., Ness, B., Frantzeskaki, N., Rotmans, J., 2012. Establishing sustainability science in higher education institutions: towards an integration of academic development, institutionalization, and stakeholder collaborations. Sustain. Sci. 7, 101–113. http://dx.doi.org/10.1007/s11625-012-0157-5.