Assessing "Wicked Sustainability Problem"-Literacy in Engineering Education

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Abstract

Environmental and sustainability problems are not purely technical problems. Many of the most pressing issues, such as climate change, resource scarcity, and pollution, require holistic approaches that go beyond technical systems analysis and optimization. Such problems have been called wicked sustainability problems (WSPs) because they are highly complex, contested, and lack definite solutions[1,2].

Engineering education has the potential to play an important role in preparing students to contribute to deal with problems such as WSPs[3,4]. To be able to contribute in this way, students need to develop an *ability to holistically and integratively understand and address WSPs while considering the normative context of sustainable development* (here called *WSP literacy*). However, common practice in engineering education more commonly prepares students to address well-structured and tame rather than wicked problems[5,6]. One reason may be that working together to develop complex competencies such as WSP literacy is challenging for students as well as educators. Wiek, Withycombe, and Redman suggest that formulating and operationalizing intended learning outcomes (ILOs) for complex competencies can facilitate this difficult process and thus improve engineering education practice[4].

In this paper, we provide a preliminary matrix of 22 concrete ILOs for WSP literacy, as well as two different approaches to assessing (some of) them in engineering education. We expect that engineering educators will find these ILOs and assessment strategies valuable for adopting a constructive alignment approach for WSP literacy in their teaching.

Introduction

Environmental and sustainability problems are not purely technical problems. Many of the most pressing issues, such as climate change, resource scarcity, and pollution, require holistic approaches that go beyond technical systems analysis and optimization. Such problems have been called wicked sustainability problems (WSPs) because they are highly complex, contested, and lack definite solutions[1,2,6]. Engineering education has the potential to play an important role in preparing students to contribute to deal with problems such as WSPs[3,4]. In fact, problem solving activities already play an important role in engineering education[5], and engineering students have been found to be highly motivated to contribute to address social and environmental problems[7]. To be able to contribute in this way, students need to develop *WSP literacy*, which we define as the *ability to holistically and integratively understand and address WSPs while considering the normative context of sustainable development*.

Unfortunately, engineering education practice more regularly prepares students to address well-structured and tame rather than wicked problems[5,6]. Jonassen, Strobel, and Beng Lee identify "story problems" as the most commonly used problem type in engineering education[5]. In story problems, technical problems are embedded in a short, written story. To solve such problems, "[l]earners are required to identify key words in the story, select the appropriate algorithm and sequence for solving the problem, and apply the algorithm"[8]. In other words, story problems are well-structured and learners are trained to develop skills in logical, linear, deductive and inductive thinking. Addressing ill-structured problems, such as WSPs, requires a different set of skills compared to solving well-structured problems. Jonassen, Strobel, and Beng Lee suggest that dealing with ill-structured problems requires, for example, an ability to reconcile conflicting goals, multiple forms of problem representation, and multiple solution methods[5]. Thus, exclusively teaching engineering students to solve well-structured problems does not adequately prepare them to contribute to address the complex, challenging, and urgent problems that society faces today. In other words, much of engineering education today is characterized by a mismatch between what students need to learn to contribute to sustainable development and the actual educational practice.

A widely used approach to ensure that educational practice matches educational goals is constructive alignment[9,10]. Constructive alignment is an outcomes-based approach to teaching in which pre-formulated intended learning outcomes (ILOs) play a central role. Through the process of constructive alignment, educational activities, methods for assessing student learning, and ILOs are aligned to ensure that students have the opportunity to learn what teachers (and policy makers) want them to learn.

Outcomes-based approaches have been criticized for being overly deterministic and favoring a reductionist approach to teaching, which in turn may lead to an undue focus on easily measurable, lower level competencies[11,12]. However, we contend with Biggs[10] that constructive alignment can be used to design teaching activities for lower level and complex competencies alike; what is needed is a greater focus on formulating and operationalizing ILOs for complex competencies. This may be especially important in education for sustainable development (ESD) where key competencies are highly complex and dependent on each other, at the same time as they are not yet well understood. To improve ESD practice, Wiek, Withycombe, and Redman suggest that it is necessary to "[list] specific learning outcomes and [develop] evaluative schemes" for these competencies[4].

King and Kitchener describe some general requirements for assessing students' ability to address ill-structured problems[13]. Applied to WSPs, their recommendations include the following four points: Firstly, assessment of students' ability to address WSPs requires actually using WSPs in the assessment, because addressing ill-structured problems requires different skills than solving well-structured problems[8,14,15]. Secondly, multiple-choice tests and other approaches that require students to provide definite answers are inappropriate since such approaches would be in conflict with the nature of WSPs. In fact, providing such assessment would require students to treat WSPs like well-structured problems – which counteracts the purpose of supporting students to develop their ability to address WSP in a holistic and integrative manner. King and Kitchener suggest the use of interview or essay examinations. Thirdly, it is important to assess the process of how students arrived at suggesting a certain course of action for addressing a WSP. Rather than merely asking students to describe how they would address the problem, the educator should also include questions about how the students arrived at their conclusions. Finally, assessment needs to be tailored to the specific group of students that the educator is working with. For example, engineering students may need more scaffolding for developing WSP literacy than students who are more familiar with complex and ill-structured problems. These guidelines by King and Kitchener can inform the design of assessment approaches for WSP literacy, but they are still rather unspecific and they do not provide specific learning outcomes and evaluative schemes as requested by Wiek, Withycombe, and Redman[4].

In this paper, we attempt to address this gap for WSP literacy. We present preliminary results from an ongoing collaborative action research project that aims to develop a tool for assessing engineering students' development of WSP literacy. Specifically, we provide a matrix of 22 concrete ILOs for WSP literacy, as well as two different approaches to assessing (some of) them in engineering education. We expect that engineering educators will find these ILOs and assessment strategies valuable for adopting a constructive alignment approach for WSP literacy in their teaching.

Study overview

The study reported on in this paper is a collaborative action research project in which the researchers have worked together with different groups of interested engineering educators to make sense of previous empirical research about engineering students' approaches to WSPs[2]. So far, the study has proceeded in four stages:

- Stage 1. Empirical research about engineering students' approaches to WSPs
- Stage 2. Conversations with engineering educators about possible implications of the empirical research for engineering education practice
- Stage 3. Workshop with engineering educators to formulate ILOs
- Stage 4. Workshop with engineering educators to design assessment methods for ILOs

The stages build on each other: the results from one stage provide input for the next stage. Therefore, we describe the design and outcomes from each stage together rather than providing separate descriptions of research methodology and research results for the entire project.

Stage 1: Empirical research about engineering students' approaches to WSPs

The current study builds on previous empirical research about engineering students' approaches to a specific WSP: water shortage in Jordan. In a phenomenographic study, we previously identified four distinct approaches towards the problem[1,2]. In an order of increasing complexity, these approaches are called (A.) simplify and avoid, (B.) divide and control, (C.) isolate and succumb, and (D.) integrate and balance. Approach A is characterized by a general lack of sincere engagement with the problem. Approach B represents an instrumental approach to dealing with the problem. The problem is assumed to be divisible into independent parts that can be solved in isolation from each other. Approach C differs from approach B in the understanding of the problem as a complex and integrated whole. Nevertheless, the problem is still approached by attempting to divide it into unconnected parts. When students use this approach, they realize that such a solution approach is not applicable to the problem, and they conclude that the problem is not solvable at all, that nothing can be done to improve the situation. It seems that students in this approach do not have access to appropriate tools for addressing the problem. In fact, they seem to assume that there are no such tools. In approach D, the problem understanding is similar to that in approach C, but the problem is approached in a more integrative and holistic way that takes into account the dynamic nature of the problem and the presence of multiple and conflicting values. An important aspect of approach D is to recognize the importance of taking action – despite a high level of uncertainty and an impossibility to completely control the situation. The detailed results from the phenomenographic study are reported elsewhere[1,2].

Stage 2: Conversations with engineering educators about possible implications of the empirical research for engineering education practice

In the spring of 2014, we conducted interviews with four engineering educators about their understandings of the results from the phenomenographic study. The purpose of those interviews was to get an idea about how we could further elaborate on the theoretical results to render them more useful for educational practice. Four engineering educators from a large technical university in the US were selected for the interviews. All four were engaged in ESD at the university and had a great interest in educational questions.

Two rounds of interviews were conducted. In the first round, the first author had informal conversations with each of the four educators about their ESD experiences, their familiarity with research in engineering education, and their approaches to teaching and learning. After those initial conversations, the educators each received a four-page synopsis about the results from the above-mentioned phenomenographic study (stage 1). The educators read the synopsis on their own as a preparation for a second interview.

In the second round of interviews, the educators were asked to recount their understanding of the research that was described in the synopsis. They were also asked to relate those results to their own teaching, for example by formulating appropriate learning outcomes for their current ESD courses. Finally, the educators were asked how they think the results should be further developed to make them more directly applicable to their teaching practice.

In the second round of interviews, the educators provided both general and specific suggestions. General remarks concerned the relationship between engineering education research and practice. The educators suggested that engineering education research needs to relate to realistic contexts and conditions, rather than idealized situations that are not replicable in everyday educational practice. They recounted experiences of frustration when reading engineering education research articles that neglected the constraints of everyday practice, such as a constant lack of resources, large student groups, and a lack of formal incentives for improving ones teaching. The educators further suggested that engineering education research needs to address the concrete challenges of everyday educational practice. Assessment of ESD competencies was mentioned as one important challenge for which the educators would appreciate concrete, research-based guidance.

On the basis of these conversations with ESD educators, we decided to work with assessment related to students' approaches to WSPs. As a first step, we needed to elaborate the description of the learning that should be assessed. Drawing on the results from the phenomenographic study as well as literature from the fields of human problem solving, engineering education, and ESD, we defined WSP literacy as the *ability to holistically and integratively understand and address WSPs while considering the normative context of sustainable development*. In this definition, the "normative context of sustainable development" refers to the presence of conflicting norms, values, and interests among diverse societal actors, which in turn leads to multiple conflicting interpretations of what sustainable development is and how it should be achieved.

We further identified three components of developing WSP literacy:

1. Learning to use a fully integrative approach when addressing WSPs, i.e. approach D as described above;
2. Learning to distinguish WSPs from tame and well-structured problems; and
3. Learning to understand and consider the normative context of sustainable development when addressing WSPs.[2]

We have used these components of WSP literacy as theoretical input for two workshops with engineering educators. The workshops aimed to develop a set of ILOs (workshop 1), and concrete assessment approaches for these ILOs (workshop 2). Both workshops were audio-recorded after informed consent was obtained from all participants.

Stage 3: Formulating ILOs in workshop 1

The first workshop was held in November 2014 during a seminar at the Center for Environment and Sustainability in Gothenburg, Sweden. The seminar was organized in collaboration between Chalmers University of Technology and Gothenburg University as part of a seminar series with recurring, biannual seminars on ESD. Most of the 27 participants had extensive experience in working with ESD in their own teaching practice, either in engineering education or in higher education in general. The seminar lasted for three hours, of which about 90 minutes were used for the workshop. Other activities during the seminar included information about ongoing projects for implementing ESD in higher education in Sweden, and a newly started ESD teacher education program at Gothenburg University.

The first author initiated the workshop with a short introduction on the nature of WSPs, the results from the above-mentioned empirical research about engineering students' approaches to WSPs, and a description of WSP literacy as a general learning outcome in ESD. Assessment in higher education and ESD was also discussed in brief. In particularly, the theory of constructive alignment[9,10] was shortly introduced (constructive alignment is widely used as a curriculum planning approach at both Chalmers and Gothenburg University). After the theoretical introduction, participants engaged in group work to identify specific ILOs for WSP literacy. Seven groups (with approximately four participants in each group) were formed for this purpose. At the end of the workshop, each group summarized their discussions and presented their suggested ILOs to the other groups. Discussions during the workshop were animated and participant feedback after the workshop was positive. The first author concluded the workshop with an invitation for further collaboration for developing and testing an assessment approaches for WSP literacy.

After the workshop, the suggestions from all groups were consolidated. In this process, the ILOs were categorized as pertaining to an understanding of (a.) the concept of sustainable development, (b.) the problem situation in WSPs, and (c.) possible courses of action for addressing WSPs. ILOs were further categorized according to what kinds of learning outcomes they represent. For this purpose, a category system for different types of ILOs was developed, which builds on existing descriptions by the Swedish National Agency for Higher Education (this description is commonly used in Swedish course and program descriptions in higher education)[16,17], the UNESCO (with a specific focus on types of outcomes that are relevant in ESD)[18], and Bloom's taxonomy (which is widely known and used by educators in both Sweden and the United States)[19,20]. The category system for types of learning outcomes that was developed includes five items: (1.) knowledge and comprehension, (2.) skills (application of knowledge), (3.) advanced thinking processes (analysis, synthesis, evaluation), (4.) attitudes and values (approaches, valuation), and (5.) action competence. Finally, the ILOs were formulated using active verbs that describe observable student actions. This is a common practice in constructive alignment, because it is assumed that

> "knowledge is constructed through the activities of the learner. The key to good teaching then is to get the learner to engage in those activities that are most appropriate to the ILO in question."[10]

The process of structuring and clarifying ILOs resulted in a set of 22 concrete ILOs, which are presented in table 1. The table was sent to workshop participants who had expressed an interest in further information about the progress of the project.

We suggest that the ILOs that are presented in table 1 provide a basis for a constructive alignment approach for WSP literacy. Depending on the subject matter of a specific course, educators can choose one or several of these ILOs to guide the design of assessment methods and educational activities. An example of how an ILO from table 1 can be used to design assessment of student learning is given in the next section.

Table 1. Intended learning outcomes for wicked sustainability problem (WSP) literacy (preliminary)

Type of intended learning outcome	**(a.) Sustainable Development (SD)**	**(b.) WSPs – Problem situations**	**(c.) WSPs – Courses of action**
(1.) Knowledge and comprehension	*Describe* different perspectives on what could be seen as SD and what a sustainable society could be. *Describe* how different societal actors may use the SD concept in various contexts. *Describe* what it means that SD is a political concept.	*Describe* the general characteristics of WSPs, particularly in contrast with tame problems.	*Explain* why it is not possible to find "absolutely correct" solutions to WSPs.

Type of intended learning outcome	(a.) Sustainable Development (SD)	(b.) WSPs – Problem situations	(c.) WSPs – Courses of action
(2.) Skills (application of knowledge)	*Utilize* the SD concept in discussions about a WSP in accordance with how it is commonly used in the political and scientific context of SD (as opposed to how it is used in e.g. marketing).	Independently *identify* a WSP in the context of one's future profession and *describe* why it is a WSP. *Identify* relevant aspects of a WSP and *describe* how they are interrelated.	With reference to the general characteristics of WSPs, *describe* how different societal actors attempt to deal with a current WSP.
(3.) Advanced thinking processes (analysis, synthesis, evaluation)	Critically *examine* and *assess* alternative descriptions of what could be seen as SD and what a sustainable society could be.	Critically *examine* and *assess* alternative descriptions of a WSP. Independently *identify* relevant knowledge that would contribute to a holistic understanding of a WSP, especially when one does not have substantial prior knowledge about the situation.	*Use* duly substantiated social, ecological, economical, cultural, political and technical perspectives to *suggest*, *discuss*, and *assess* alternative courses of action for a WSP.
(4.) Attitudes and values (approaches, valuation)	*Explain* how different sets of values among societal actors contribute to the diversity of descriptions of what could be seen as SD and what a sustainable society could be. *Identify* relevant personal values and describe their influence on ones own understanding of what could be seen as SD and what a sustainable society could be. Deliberately and transparently *apply* different sets of values to *develop* different descriptions of what could be seen as SD and what a sustainable society could be.	*Explain* how different sets of values among societal actors contribute to the diversity of descriptions of, and preference for certain courses of action for, a WSP. *Identify* relevant personal values and describe their influence on ones own understanding of, and preferences for certain courses of action for, a WSP. Deliberately and transparently *apply* different sets of values to *develop* different descriptions of, and assess possible courses of action for, a WSP. *Demonstrate* an open attitude towards, and *elicit support* from, different knowledge domains that may be relevant for describing and addressing a WSP in a holistic manner.	
(5.) Action competence	*Demonstrate* initiative, perseverance, and a sense of responsibility for SD.	*Demonstrate* initiative, perseverance, and a sense of responsibility for addressing a WSP, despite high levels of uncertainty, lack of information and knowledge about the situation, the ambiguous and contested nature of the SD concept, and the need to work across e.g. disciplinary and national borders.	

Stage 4: Designing assessment methods in workshop 2

The second workshop was held in January 2015 during the annual pedagogical conference for teaching and learning at Chalmers University of Technology. The workshop was scheduled as one of the last sessions of the conference and many conference participants had already left. Thus, only five participants were present apart from the two authors of this paper. One out of those five participants had also attended the first workshop (stage 3).

This second workshop lasted for approximately 60 minutes. The first author started by briefly introducing the concepts of WSPs and WSP literacy. She also provided information about the previous workshop and handed out table 1 to the participants. The participants first read and shortly discussed the list of ILOs. They were then divided into two groups (group I with two participants, and group II with three participants) and asked to design an assessment activity for one or several of the listed ILOs that they could use in their own ESD practice. At the end of the workshop, each group briefly reported their ideas to the other group and the two researchers. The two groups approached the given task very differently. Group I chose one specific ILO to work with. Group II argued instead that all of the listed ILOs could and should be addressed in one examination task.

Peer assessment of video-recorded argumentation. Group I focused on the ILO "*Independently identify a WSP in the context of one's future profession and describe why it is a WSP*" (ILO category 2b in table 1). They suggested that each student in the class should choose a WSP from the context of their future profession. They should then write a short note to the teacher in which they report which problem they have chosen, including one argument for why they think it is a WSP. The teacher either approves the students' choices, or provides feedback for why the chosen problem may not be seen as a WSP. Once students have received approval from the teacher, they work in pairs. Each pair records a short video in which each student describes his/her chosen problem to the other student, and provides arguments for why the problems should be seen as a WSP. After submitting their video to the teacher, each pair is also required to provide written feedback to presentations from four of their peers (i.e. two other videos). Thus, each student is exposed to, and required to critically assess, six different problem descriptions. Assessment criteria for this review process should be provided before students record their videos.

The teacher has access to all videos and written feedback statements to be able to quickly assess whether the students have performed the required tasks in an acceptable way. Group I initially suggested that this assessment should be done on a pass/non pass level, but they added that graded examination could be possible by asking students to vote for a favorite among the five presentations that they have reviewed. We suggest that it could be even more valuable to ask students to grade those five presentations based on the assessment criteria that they received before recording their own videos. This grading exercise could be included in the peer feedback exercise.

Take-home essay exam with open-ended question(s). Group II argued that it is not necessary to assess student learning of individual ILOs since the ILOs are inseparable from each other – if a student achieves one of them, he/she will achieve others as well. One of the group members suggested that the teacher should "simply ask students to address such a big, complex problem". The group suggested that examination could be done in the format of a take home exam. The following question was mentioned as an example for a suitable exam question: "What solution do you recommend for solving the climate problem?" Group II expected that students fulfill all ILOs by answering such a question (and possibly a few subquestions). The group suggested that the take home exams should be handed in to the teacher who assigns grades by assessing the quality of the texts, for example by judging the quality and precision of the language used, the number of perspectives used on the problem, and the number of arguments provided for the points of view that students express in their texts.

Discussion

The ILOs in table 1 are a result of consolidating the suggestions from the seven groups that were formed during the first workshop (stage 3). The groups used different approaches to identifying and formulating ILOs. One group specifically grouped ILOs according to the types of ILOs suggested by the UNESCO[18]. Other groups used types of ILOs implicitly, or focused more on only some types of ILOs. The diversity of the approaches used in the groups contributed to the fact that many different aspects of WSP literacy were considered.

The ILOs have been developed on the basis of a one and a half-hour workshop; they have not yet been used in practice. It is likely that they will need to be further developed and refined once they are used to inform the development of concrete educational activities, and they should therefore be seen as preliminary. We further expect that the ILOs need to be adapted to every concrete educational situation in which they are used. The ILOs in table 1 have been developed by an interdisciplinary group of educators who teach a diverse set of courses. They share a general interest in ESD rather than a subject domain. This may be the reason why the ILOs are formulated in general terms rather than relating to specific degree programs or courses. The ILOs could be adapted to fit specific courses by, for example, specifying in which profession students should be able to identify WSPs (ILOs 2b), or by formulating a certain description of sustainable development and certain knowledge domains that are seen as particularly important for the profession or field of study (ILOs 1a & 2a). However, such formulations are still rather general. We suggest that a more thorough integration of the ILOs with specific engineering subject domains could facilitate the use of the ILOs in concrete educational practice. This could for example be done in workshop settings with discipline-specific groups of engineering educators.

In fact, active engagement with adapting and reformulating ILOs for a specific educational context may be an important step in an educator's own learning process. This can be illustrated by one of the ILOs suggested by a group in the first workshop: "The students shall be able to apply ~~the right~~ appropriate tools for the specific situation". Note how the group first seemed to assume that there is a "right" way of addressing a WSP – which would be in conflict with an understanding of WSPs as a kind of problems that *lacks* "right" solutions. It seems that, as the group continued working with the task of formulating their ILOs, they became aware of this mismatch between WSP theory and their suggested ILO. Before presenting their suggestions to the other groups, they exchanged "the right tools" for "appropriate tools" in their description. In the second workshop, we also noticed that prior engagement with actually formulating ILOs seemed to be beneficial for constructively working with assessment approaches for the ILOs. One of the participants in workshop 2 had also been present during workshop 1. She was able to more quickly and constructively engage with the ILOs in table 1, which also affected the group work during workshop 2 (stage 4).

The researchers' impression during the second workshop, and while listening to the audio recordings from the workshop, is that group I (which included the participant who had also taken part in workshop 1) was working much closer to the provided list of ILOs than group II. It seemed that group II was discussing assessment in ESD on a general level, based on personal experiences from working with ESD rather than the provided ILOs for WSP literacy. Therefore, we suggest that the ILOs in table 1 should be used as a starting point for developing context-specific ILOs as suggested above.

Another difference between the groups was the degree of specific guidance that they wanted to provide for the students. While group I suggested a very concrete, well-defined, and delimited task, group II suggested a much more open-ended task. Both approaches have advantages and disadvantages. A high level of guidance, if used in a formative manner, can provide a means for the teacher to carefully and gradually scaffold students' progression towards developing WSP literacy. This approach may be useful for students who are not familiar with working with sustainable development and/or complex problems. Many engineering students are likely to benefit from such an approach since complex problems are seldom used in engineering education[5]. On the other hand, a more open approach allows students to be more creative and innovative. Group II suggested that an open approach may be appropriate for advanced students who study in fields such as industrial ecology and who are already used to thinking about complex sustainability issues. This suggestion is in line with King and Kitchener's recommendation that assessment should be carefully tailored to the group of students one is working with[13]. Since our tool is mainly intended for educators who do not have extensive experience of, and do not feel comfortable with assessing student learning in ESD, we will continue working with predominantly concrete and delimited assessment approaches. We believe that such approaches are more accessible to educators who feel insecure about how to assess WSP literacy.

Finally, the groups differed in their approaches to allocating the responsibility for assessment of student learning. Group I suggested peer assessment with only sporadic and superficial control from the teacher. Such an approach may be particularly useful for large groups and/or when teaching resources are limited. Peer assessment may also provide a means for students to share experiences and personal viewpoints. As one of the members of group I pointed out, students enter courses with diverse perspectives and previous experiences that the teacher might not be able to offer him/herself. Group II used a different approach. They suggested that the teacher alone is responsible for assessing student learning. In combination with the chosen examination format (individual, written take home exam), such an approach requires extensive resources and is therefore feasible only in smaller, well-staffed courses. On the other hand, the approach also provides an opportunity for extensive and high quality feedback and deep learning for the students, which may be more limited in the approach suggested by group I, in which the teacher's main responsibility is to ensure that each student has performed the required tasks.

Group I suggested using video presentations, and group II favored an essay approach. Both of these approaches are in line with King and Kitchener's suggestion that interview and essay approaches to assessment (rather than multiple choice tests and questions with definite answers) are preferable[13]. Neither group has explicitly suggested an approach that would allow the educator to assess how students arrive at their conclusions. While the approach suggested by group I requires students to provide arguments for why they think a certain problem is a WSP, it does not require students to reflect on the process of identifying the problem and arguments for it's description as a WSP. We suggest that this aspect could be added by asking students to also explain to each other how they have identified the WSP that they are presenting. Students could also be asked to share possible struggles that they have encountered as they prepared their argumentation. For group II's approach, a sub-question could be added in which students are asked to describe how the have worked with the problem, and how they have arrived at their conclusions about what course of action they would recommend.

Unfortunately, only five participants took part in the second workshop (stage 4). It is likely that additional aspects that are relevant to consider in assessment of WSP literacy would have been exposed with higher attendance. Higher attendance could also have resulted in ideas for assessing more ILOs for WSP literacy and/or a greater variety of approaches to assessing specific ILOs. Finally, higher attendance would have made it possible to divide participants into discipline-specific groups, which might have provided insight into how the ILOs can be adapted to specific engineering programs and courses.

Conclusions and further work

In this paper, we have reported preliminary results from an ongoing collaborative action research study that aims to formulate and operationalize ILOs for WSP literacy. We have provided a matrix of 22 concrete ILOs for WSP literacy, as well as two different approaches to assessing (some of) them in engineering education. We suggest that the ILO-matrix presented in table 1 is a significant first step that, in itself, provides a valuable resource for engineering educators who want to adopt a constructive alignment approach for WSP literacy in their teaching. The two (very different) examples of approaches to assessment of WSP literacy suggested by participants in the second workshop provide inspiration for designing assessment for the ILOs. In our further work with the project, we aim to further refine the list of ILOs, and develop a library of ideas for assessing each of the suggested ILOs. We also hope to provide concrete examples of how the ILOs could be adapted to a specific engineering program and/or course. For these purposes, we hope to conduct additional workshops with engineering educators. We also plan to empirically evaluate some of the ILOs and assessment approaches in concrete educational settings. We welcome all forms of comments, ideas, or practical collaboration to further develop the ILOs and assessment strategies.

Acknowledgment

We thank the three anonymous reviewers for insightful suggestions to improve the readability of this paper.

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