A PRACTICAL APPROACH TO INTEGRATING RESEARCH AND EDUCATION – A COURSE EXPERIMENT FROM KTH, SWEDEN

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Abstract: In this study we evaluate a project-based learning course called Applied Ecology, within the master program Sustainable Technology at the Division of Industrial Ecology, at KTH – Royal Institute of Technology in Stockholm, Sweden. The case study in the course is focused on the effects of a relatively large Bay, "Burgsviken", situated on the island Gotland in the middle of the Baltic Sea, that has changed due to the eutrophication in the area. The eutrophication of the Bay has initiated bottom up processes of discussion and engagement among the stakeholders in the area, for the enhancement of the water quality and biological services of the bay, that would in turn improve fishing, swimming, biological diversity and tourism. There are several stakeholders involved in the project: a local non-profit organisation, farmers, entrepreneurs, authorities, permanent and seasonal inhabitants, researchers and others. The course is evaluated according to the methodology of Brundiers and Wiek (2013). Student evaluations have been conducted and analysed in relation to four phases: (1) Orienting phase, formulation of research question. (2) Framing phase, methodology and study planning. (3) Research phase, field study and other examinations. (4) Implementation phase, communication of the results with different stakeholders. The Applied Ecology course shares many of the positive features of other PPBL courses in the sustainability field – namely that it focuses on a real sustainability problem and that the student-centred learning approach and interactions between students and stakeholders make the student partnership in the project feel real, thus providing a practical insight of complex societal challenges.There are potential ways of improving all four phases of the course that were studied, but especially in the research phase and the implementation phase more efforts are needed. Feedback and reflections in the research phase could be improved by a clearer communication and to some extent changed pedagogical process through the course. All phases will be improved by increased communication before, during and after fieldwork between student, teachers and stakeholders.

1 INTRODUCTION

Engineers are key players in the development of a more sustainable society. In order to be the change agents that are so urgently needed they need to be equipped with a different set of competences than today (Clift 2006, Mulder 2006).They need to be able to envision, develop and implement sustainable solutions that respect the limitations of natural systems and promote human well-being (Svanström & Gröndahl 2012). This means that we also need to rethink how we educate engineers. Although Sustainable Development (SD) have been integrated in engineering education in many technological universities, the general level of knowledge in SD-issues is still very variable and in many programs, relatively poor. The students views of the SD-concept seems also to be biased toward technological and economic perspectives, excluding the social aspect of SD, and are also lagging behind in the understanding of how technical, ecological and economical knowledge may be integrated in order to solve real sustainability problems (Segalas et al. 2010).

One pedagogical approach to narrow the gap between intradisciplinary theory and transdisciplinary understanding of complex sustainability problems is the problem and project based courses (PPBL) (Lehmann, Christensen et al. 2008, Brundiers and Wiek 2011, Brundiers and Wiek 2013). In PPBL-courses within the sustainability field, students are not only passive receivers of knowledge but active participants in projects concerning real SD questions in ongoing societal or research initiatives of sustainability challenges. Students are often active drivers of the research process from the problem description to the implementation of the results. The PPBL-approach aims to develop collaborative and transdisciplinary research skills, as well as to develop a capacity to analyse complex societal sustainability challenges. That said, some key barriers for success in these courses have been reported, such as how to identify and work with a "real sustainability problem" in courses often limited by short time frames and few possibilities to engage with different stakeholders. Other challenges include true transdisciplinary methodology and correct implementation of the results from the student-driven projects (Brundiers and Wiek 2013).

In this study we evaluate a pilot-version of a newly started PPBL-course called "Applied Ecology" in the Master Program Sustainable Technology held at the Division of Industrial Ecology, KTH Royale Institute of Technology in Stockholm, Sweden. The case study of the course is the sustainability problems attributed to the eutrophication of a Bay (Burgsviken) on Gotland, an island situated in the middle of the Baltic Sea. The problem includes different ecological, social, economic and cultural aspects.

Our objectives in this study are to,

- Evaluate the course from a student perspective, especially regarding their view of the course as research in a "real sustainability problem".

- Analysing the student opinions in relation to the four different phases of the course (orienting phase, framing phase, research phase and implementation phase), and suggest improvements of the course in these phases.

1.1 The Burgsviken case study and the course Applied Ecology

The participants in Applied Ecology course includes both Swedish and International students in their first or second year of the master program. The students have various educational backgrounds from different engineer programs (energy and environmental, mechanical, industrial management, biotechnology, chemical engineer). The overall aim of the course is to increase the students' knowledge about ecology, ecological methods and how ecological knowledge could be applied in a broader context in relation to real sustainability challenges in our society.

The thematic sustainability issue in the course, concerns the real problems of eutrophication in the Baltic Sea. Which have severe implications for the population around the sea both on a regional and local scale. The study area is located on the southern part of Gotland that is the largest of the islands in the Baltic Sea. The case study is focused on the effects of a relatively large shallow Bay "Burgsviken" that has shifted from an oligotrophic to a eutrophic ecological state since the 1970s. This change has resulted in a loss of ecosystem services from the Bay and as a result, the Bay no longer provides good fishing, swimming or yachting. In the Bay large stand of reed (*Phragmites australis*) cover the inner parts, and in the mouth and centre of the bay the sandy beaches are covered with organic matter from floating opportunistic filamentous red algae. In 2012 local stakeholders around Burgsviken decided to create the "project Burgsviken", a local initiative to save the Bay and restore the ecosystem service of Burgsviken. More than 50 local groups including the municipality, local companies and landowners are involved. Industrial Ecology, KTH are involved as an academic partner and in 2013 and 2014 we have used the Applied Ecology course and our students to help the project in Burgsviken to solve the sustainability problems of the Bay in close cooperation with the local initiative.

The pedagogic tools used in the course include literature seminars, lectures and excursions, but most central is the group work where groups of 3-5 students develop and conduct a study (student projects) of an ecological research question within the larger frame of the eutrophication problem of the Burgsviken Bay. The students form, plan, conduct and report the results from the study. The studies include the use of classical ecological field methods, but also some social, cultural or economical perspectives in relation to their question through the contact with stakeholders, interviews and literature studies.

The student's projects have mainly focused on the problems of reed, red algae and effects of eutrophication on the bottom fauna of the bay. The overall research question regards whether the extensive biomass of reed and algae in the bay caused by eutrophication may be harvested or collected and used for feed or bioenergy (biogas). Thus the problem may be turned into an opportunity and may help the bay to recover while creating new socio-economical values around the bay.

2 METHODS

For the evaluation of the course we used two anonymous online student evaluations. The first evaluation (Evaluation 1) was a general basic evaluation including questions about general impression of the course, the contents and teaching, but also included some more specific questions such as the importance of the field work for the learning outcomes of the course, and how the course could be improved. This gave us a general picture of whether or not the course approach was well founded in order to present and work with "a true sustainability problem" (objective 1 above). The second evaluation (Evaluation 2) was structured according to an evaluation approach suggested by Brundiers and Wiek (2013) based on ideas in an earlier study (Talwar et al. 2011). The method uses an evaluative framework where the PPBL-courses are analysed in relation to four phases: orienting phase, framing phase, research phase and implementation phase. We use the core structure of this framework and formulate eight statements about the course - two statements for each phase - for the student to consider in Evaluation 2. Student opinions were collected in an online anonymous evaluation using a five graduated scale from 1-5, where 1 was described as "No I don't agree at all" and 5 was described as "Yes I agree completely". Values 2-4 were not described in words but were presented as intermediate choices in relation to their distance from 1 and 5. The students could also comment on the questions (Evaluation 1) or statement (Evaluation 2) and develop their answers in a text box after each question/statement. Some of these comments are used in the discussion as singular observations in relation to the quantitative evaluations. Here follows a short description of the four phases, as interpreted by the authors of this paper in relation to the course approach, and the statements formulated to represent each phase in the evaluation.

The orienting phase describes the formation and early presentation of the course and research project. The background to the project is presented and the learning objectives of the course. Statements 1 and 2 represent the orientating phase:

1. The Burgsviken project (central in the course) was presented as a sustainability challenge in the course. (S1 = *Sustainability challenge*)
2. One of the goals of this course was to contribute to the solution of the problem of eutrophication in Burgsviken. (S2 = *Course contribution*)

The framing phase is about delimiting different project tasks/research questions for each project group in the course. What should be each group's contribution, aspects and goals within the larger overarching sustainability issue? And what kind of methodology should be used for answering the question?

3. The methods used in your study were appropriate for the aim of the project to contribute to the information needed to solve the problem of eutrophication in the bay. (S3 = *Appropriate methods*)
4. The project task was interesting and most relevant for the Burgsviken project (given the limited time and resources of the field visit). (S4 = *Project task*)

The research phase in this course concerns especially the activities during the field visit at Burgsviken, where the actual work in the project is taking place e.g. meeting and working with stakeholders, conducting ecological inventories, estimations and interviews.

5. You got enough feedback on the methodological approach to solve your project task during the preparation of the study and during the field visit. (S5 = *Methodological feedback*)
6. During the course, did you have the possibility to reflect over the quality of processes and products of your project work? (S6 = *learning reflections*)

The implementation phase includes the presentation of each project task and the relation to the main sustainability question in the project (How can the negative eutrophication effects of Burgsviken be decreased?). How will the contributions of the students work be used in the Burgsviken area in practise or in further research, societal development or educational programmes?

7. The outcomes from your study will be reported/used/or saved and may be used for future research or societal needs in some way. (S7 = *Study usefulness*)
8. You took part in a societal/research project at the same time as you were participating in a university course for your own learning. (S8 = *Societal project participation)*

3 RESULTS

Evaluation 1 – General opinions and sustainability view

The general picture from the first evaluation was that the students had a positive view of the course for the three questions about: general content in the course (Fig.1a), importance of the field visit for the learning outcomes (Fig1b) and whether the course managed to increase the students' understanding of the integration of ecological theory, ecosystem management in practise and sustainability issues in society (Fig.1c).

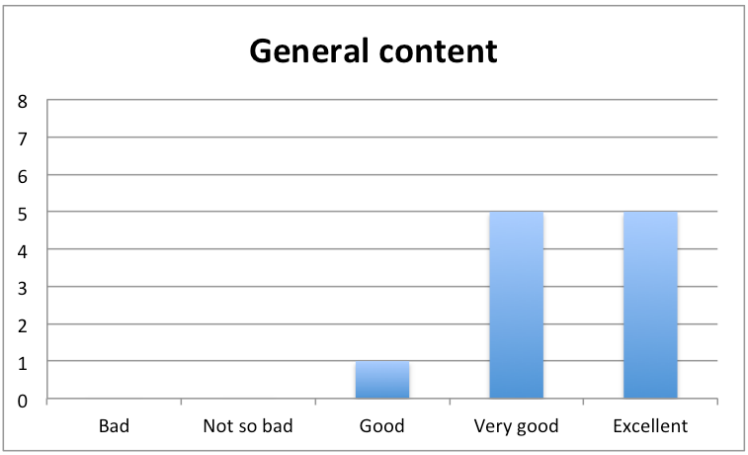

Figure 1a: Looking at the course as a whole, are you pleased with the content of the course?

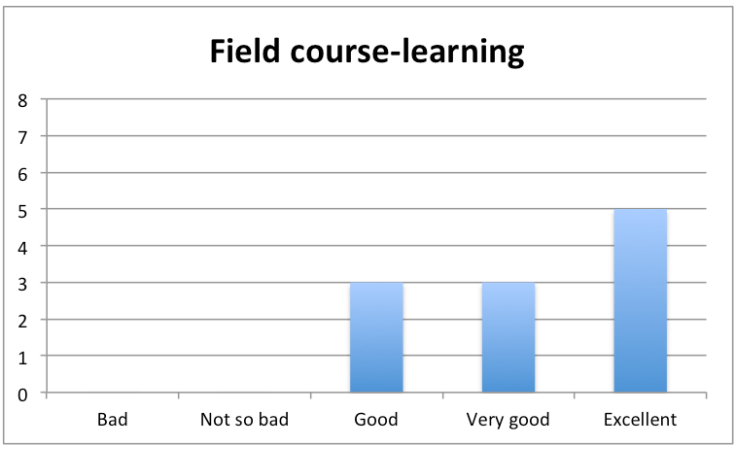

Figure 1b: What is your opinion about the importance of the field course for the learning outcomes of the course?

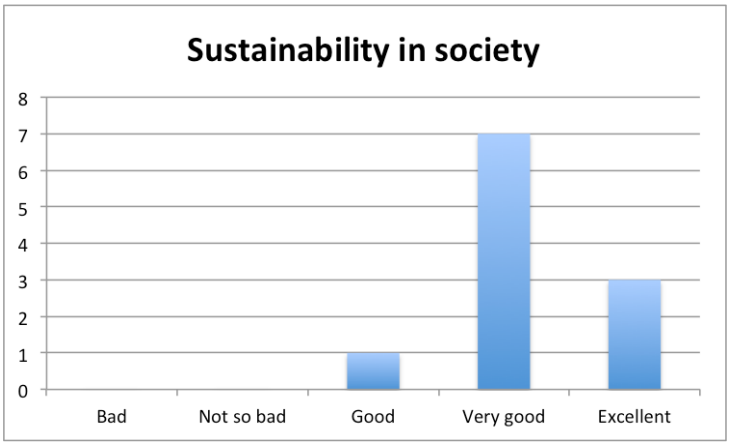

Figure 1c: How has this course managed to: increase your understanding of the integration of ecological theory, ecosystem management in practise and sustainability issues in society?

Fig. 1 a-c show the results from the student evaluation 1 in the course Applied Ecology 2014. The Y-axis shows the number of student answers graduated as: bad, not so bad, good, very good and excellent in response to the question.

Evaluation 2 – Evaluation of the four phases in the course

Evaluation 2 had a response rate of 42% (8 of 19 students). Figure 2 shows the results for the statements 1-8 (see methods) related to the four phases in the course described in a polar coordination diagram based on the mean value for each question (based on the 1-5 evaluations). Again the overall picture is positive for all phases with a mean value over 4.0 for all statements except for No 7 (“The outcomes from your study will be reported/used/or saved to be used for future research or societal needs in some way”) that had a mean value of 3.6. The mean value of the first two phases (four questions) was generally very high with mean values over 4.2. The research phase had somewhat lower scores compared to the other phases (about 4.0).

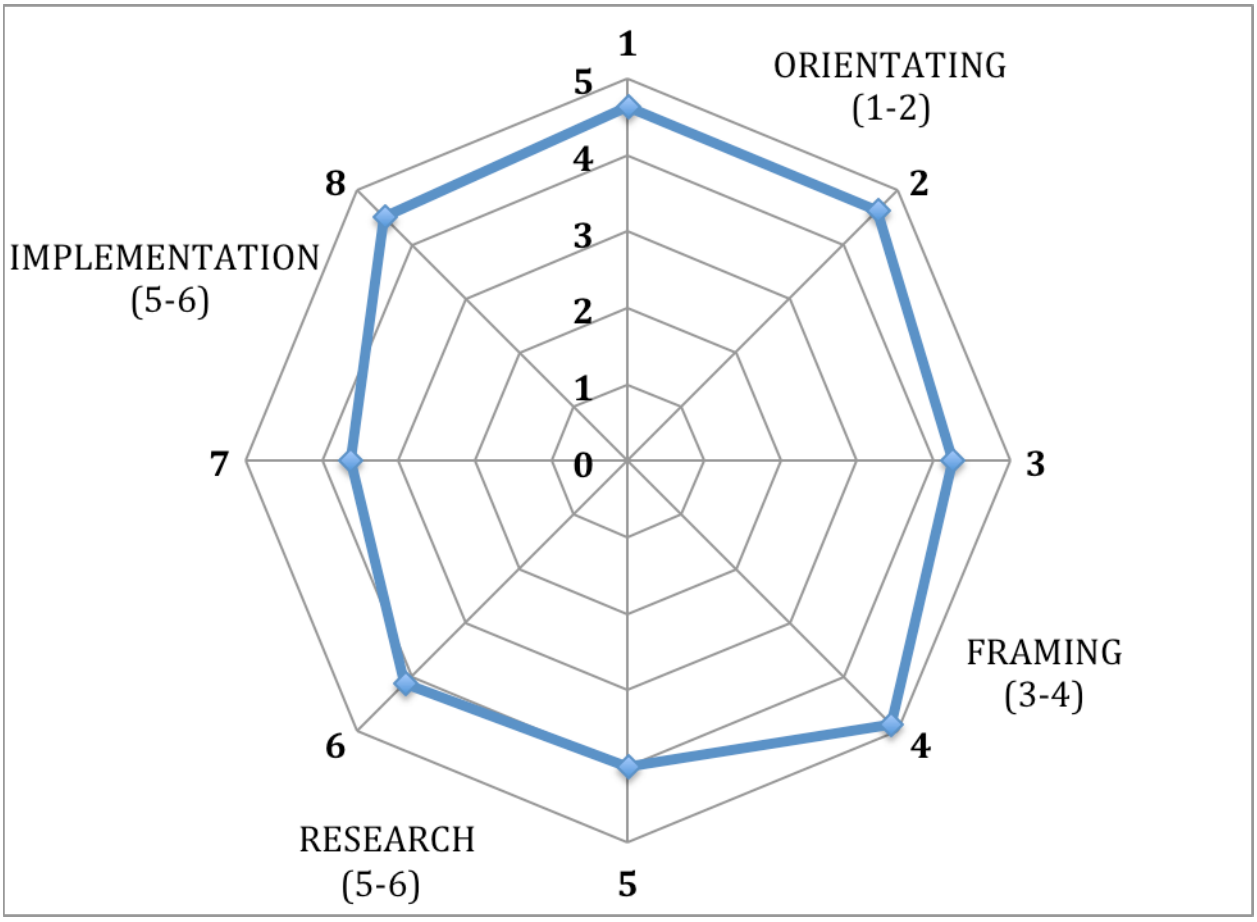

Figure 2: shows the results from the evaluation in a polar coordination diagram. The mean value for each statement is marked in the diagram. S1 = *Sustainability challenge* S2 = *Course contribution* S3 = *Appropriate methods* S4 = *Project task* S5 = *Methodological feedback* S6 = *learning reflections* S7 = *Study usefulness*, S8 = *Societal project participation.* Values in the Orienting phase (S1 = 4,6 S2 = 4,6), Framing phase (S3 = 4,25 S4 = 4,9), Research phase (S5 = 4,0 S6 = 4,1), Implementation phase (S7 = 3,6 S8 = 4,5).

4 DISCUSSION

Is the case of Burgsviken an appropriate example of a "real sustainability problem" that could be used in sustainability teaching?

The main idea behind the course "Applied Ecology" was to increase the student's knowledge both in ecological theory and methodology but also to evaluate the finding from their project task within the wider context of the sustainability issue of understanding and improving the situation of the eutrophicated Bay of Burgsviken. The course evaluation shows that the students appreciate the general features and contents of the course and seem to experience the course as dealing with a "real" sustainability issue (see fig 1c and fig 2). One obvious strength in the course is that it at least partly takes place "outside the classroom" (Brundiers and Wiek 2011), where the core of the identified sustainability problem is located geographically. Students have close contact with different stakeholders and examine at least some minor part of the problems in situ. The Burgsviken case could also be described as a "wicked problem" (Brundiers and Wiek 2011), which means that the problems are highly complex including many ecological, socio-economic and cultural aspects, and could not be solved by a single technical or economic quick-fix. Looking at the response to a question about the positive aspects of the course

several students underline the increased understanding of the sustainability problem due to the connection between theory and practice.

"To practically do something for real. To really see what we were talking about in theory, both about eutrophication, how it is to take samples, how reed may be harvested, and meet local stakeholders and others were very positive"

"It was fun to have a practical course and to see how knowledge in ecology and ecosystem theories can be applied in real life."

We believe that a key mission of this course is to facilitate the students' understanding of their own project tasks in relation to the overarching general sustainability question. We find the challenge to bridge the gap between the student's own research and "the sustainability question in Burgsviken" as one of the most important missions for improving the course.

How could the course be improved in relation to the four phases?

The 2nd evaluation also supported the view of the course as a good case of a real sustainability problem, showing high values (students agree to a large extent with statements) in all four phases. Although, the results give us also some ideas of how the course could be improved in relation to the four phases. The results indicate that the two last phases in the course process: the research and implementation phase could be improved for next year. This is also further indicated by some of the student comments regarding methods and feedback in the statements for the research phase.

"*We didn't get so much feedback during the preparation of the study, but we got some good feedback and hints during the field visit"*

"The feedback was a bit unclear from times to times, but in the end it turned out good anyway".

"Maybe give some more directions about the field work and the report so we could start with it earlier - even though it might have been hard to do, since we didn't have such a good understanding about what was possible to do to begin with."

"To clarify and specify better, from the beginning, what the field visit and the project is about and which are the tools and the equipment available."

One idea of developing the work with methods during the course is to use participatory peer-review evaluation in a cooperation between students, teachers and different stakeholders, as suggested by Brundiers and Wiek (2013). Since there is limited time for the students during the course both for the planning of the fieldwork (6 weeks) and the actual research phase on Gotland (3-4 days). A possible solution would be to form a focus group including different stakeholders, which could be ready to give feedback to the groups already from the start of the course.

The focus group could be used as early as the framing phase, to help the students formulate relevant and valid research questions and to give feedback on proposed methods. The group could continue the feedback during the research phase on Gotland and the implementation phase when students are writing the project reports (peer review) or presenting their results.

In agreement with the review of other sustainability PPBL-courses (Brundiers and Wiek 2013), the implementation phase was identified as the least successful phase in the sustainability course process, by looking at the students' opinions for statement number 7 - "The outcomes from your study will be reported/used/or saved to be used for future research or societal needs in some way" - which showed a relatively low mean value (3.6). This is also to some extent supported by comments from the students: *"The outcomes are too uncertain to use directly and the project too small to give a correct view of the problem, but the result could at least give a hint in the right direction."*

The implementation of the results depends on the quality of the contributions from the students during the course. This is highly dependent on the research question and whether results could be directly applied and may lead to a change in society. Here again the stakeholders and the suggested “focus group” could play a central part in the process of implementation. Actually engaging stakeholders in earlier phases of the course (discussed above) will probably increase the possibilities for implementation of the student’s contributions to the project Burgsviken. This work will be strengthened and deepened if we could formalise our partnership with different stakeholders in the project (see (Brundiers and Wiek 2013).

5 CONCLUSIONS

The Applied Ecology course shares many of the positive features of other PPBL courses in the sustainability field – namely that it focuses on a real sustainability problem and that the student-centred learning approach and interactions between students and stakeholders make the student partnership in the project feel real, thus providing a practical insight of complex societal challenges.

There are potential ways of improving all four phases of the course that were studied, but especially in the research phase and the implementation phase more efforts are needed. Feedback and reflections in the research phase could be improved by a clearer communication and to some extent changed pedagogical process through the course. All phases will be improved by increased communication before, during and after fieldwork between student, teachers and stakeholders.

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