Interdisciplinarity and the fostering of sustainable competences - implications and limitations.

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ABSTRACT*: This article presents findings from case study research of an interdisciplinary approach to Education for Sustainable Development (ESD) at Higher Education (HE) bachelor level. The interdisciplinary approach was applied in the 'Sustainable Competences in Higher Education' (Sustain-Comp) project, funded by Erasmus Plus (2022-2024). The research question was: To what extent did the interdisciplinary approach to teaching ESD foster sustainable competences – and what were the implications and limitations? Participants in the project were lecturers and researchers from University of Agder in Norway, Masaryk University in the Czech Republic, University of Ljubljana in Slovenia, UCL University College in Denmark. The Community of Prac-tice (COP) developed an interdisciplinary 10 ECTS curriculum that was tested during fall semes-ter 2023 in a full-scale pilot for 25 students. It was integrated in an English as a Second Lan-guage course (ESL) in the Teacher Education department, at UCL University College. The findings suggest that the interdisciplinary, ESD 1,2, and 3 approaches to some extent fostered sus-tainable competences among students regarding cognition (new knowledge), socio-emotions (engaging in problems), behavior (act for solutions).*

KEYWORDS: *ESD1, ESD2 and ESD3; Interdisciplinarity; Socio-Scientific Issues; applied research; Community of Practice*

This case study examines and reflects on interdisciplinarity applied by the SustainComp Community of Practice (COP) (Wenger et al., 2023; McDonald & Cater-Steel, 2023) during development, pilot and implementation of the SustainComp Curriculum in fall 2023 at UCL Teacher Education Department, Odense, Denmark. The case study research method (Yin, 2009) is applied with the aim of contributing to the field of ESD by combining theory and practice to obtain practical wisdom on how to act on social problems in a particular context (Flyvbjerg et al., 2012).

Introduction, methods and conceptual framework

The process of the project

The participants in the COP were lecturers and researchers from the four partner institutions. SustainComp is an abbreviation for Sustainable Competences in Higher Education, which was a 'Partnership for Cooperation Project' co-founded by the Erasmus Plus Program from 2022-2024 1. The SustainComp curriculum bears 10 ECTS and consists of four modules that can be taught separately (each for 2,5 ECTS) or as a whole: a coherent educational resource for teaching throughout an academic semester. The general aim is to develop sustainable competences of students at higher education institutions at bachelor level (HEI) via interdisciplinary educational resources (see more about SustainComp project in Chapter 2).

In 2022 a SustainComp State-of-The-Art report was published, based on a survey among lecturers at the four partner HEIs (Ruge et al., 2022). The findings indicated a need among lecturers for student oriented, innovative and interdisciplinary educational resources. Based on these findings, the first developmental stage with two pre-pilots were conducted in spring 2023 to test central didactical methods: Collaborative Online International Learning (COIL) and problem- and project-oriented approaches (Janík, 2024; Ruge et al., 2024). Via a design-based research approach the educational resources were adjusted and then tested in fall 2023 by a full-scale study of all four modules over a three-month period. Each module was conducted over two weeks by the respective development teams in collaboration with lecturers from UCL. The interdisciplinary SustainComp curriculum was integrated into an ESL course for first year teacher students. The course was open for Bachelor of Education students at UCL, as well as for exchange students to the Teacher Education Department. Students had regular ESL classes from the beginning of the semester, from August till October and then - for the remainder of the semester - the SustainComp project-oriented and more experimental teaching was initiated. At the end of the semester a final dissemination event was held on the 6th of December, where student groups presented their work in the form of poster sessions and workshops for internal and external guests.

In this article, we ask the following research question from a participatory action research (Baum, 2006) position: To what extent did the interdisciplinary approach foster sustainable competences – and what are the implications and limitations?

Conceptual framework

Already in the last century, Wolfgang Klafki informed education and research with the 'Core Problems of the Modern World and the Tasks for Education' (Klafki, 1996). Klafki formulated a vision for international education that would focus on epochal key problems of the modern world – including environmental problems - by means of problem studies conducted in an interdisciplinary way: "depending on the theme, such problem studies combine facets of several traditional subjects, but also have to include subject-specific course components from the subjects at hand" (Klafki, 1996, ibid., p. 16). Klafki suggested that teachers would collaborate

[1] https://www.ucl.dk/international/sustaincomp

in teams to design and develop interdisciplinary, integrative lessons in a project-oriented way based on principles of Exemplary teaching and Learning, Method-oriented Learning, and Action-oriented Learning (Klafki,1996, p.17). Klafki's visions and suggestions significantly inspired the COP in the early stages of SustainComp curriculum development in 2022, particularly the principle for action-oriented learning has been a core topic for reflection and discussion among COP participants.

In the 20th century, the notion of 'sustainable development' emerged because of a long trajectory and became well known following the release of the Brundtland Report in 1987 (Brundtland, 1987). In the 21st century, the early definitions of sustainable development have served as a cornerstone of the United Nations' endeavors toward sustainability, transitioning from a focus on mere sustainability to the broader framework of sustainable development" (Garsdal, 2024). In the SustainComp project, this broader framework especially included the notion of 'Education for Sustainable Development' (ESD) and the inclusion of the UNSDGs. Vare and Scott (2007) introduced the notion of two complementary forms of ESD: ESD1 (learning for sustainability) and ESD2 (learning as sustainability). Acknowledging the Great Acceleration (Steffen et al, 2015; Steffen et al., 2018) and the associated inequality as stated by Richardson (2023) it seems futile to apply ESD1 as an adequate teaching method and does not include capacity building via critical thinking.

However, some natural science lecturers claim that ESD1 is the only way to teach the topic of sustainability in schools and at HEIs. This claim is opposed to the 'normativity' that is inherent in the critical ESD2 principles and perceived as a distraction regarding the learning objectives in Natural Science. In ESD2 there is an inherent understanding that we need to apply critical thinking in teaching, learning and capacity building for sustainable development to achieve a change of direction. Other scholars suggest that Bildung, open-ness and critical thinking in general has a role to play regarding the relation between societal problems and didactics and curriculum (Krogh et al., 2022). Further, Garsdal (2024) with reference to the framework of Vare and Scott (2007) recently suggested a holistic ESD3 approach to incorporate broader 'existential depth and cultural critique. A framework that could be better suited for the current challenges as it "offers an approach to education that is attuned to the complex interplay between human societies and the natural world" (Garsdal, 2024, p.33). How this 'complex interplay' between human societies and the natural world turns out for the coming years is apparent, as the threat of global warming probably will unfold if adequate actions are not put in place (Steffen et al., 2018). Therefore, it is highly relevant to discuss the tasks of education and what actions HEI lecturers can recommend their students to do, given that what used to be environmental problems in the 19th century have turned into a planetary crisis with devastating tipping points with the potential to transform Planet Earth into an un-inhabitable place for humans, animals and plants in the near future (Steffen et al., 2018). Also, the 2024 state of the climate report predicts perilous times on planet Earth (Ripple et al., 2024) and the scientists ask researchers, policy makers and the public to take action.

In 2022 the SustainComp COP agreed to adopt both ESD1, ESD2 and an ESD3 holistic and interdisciplinary educational approach, because it was necessary to work with the complexity related to climate and environmental problems (Figure 1). This contrasted with the subject-specific, classroom based, teaching methods that were more common at the participating institutions prior to the project, as the State-of-the-Art case study found out (Ruge et al, 2022). To this aim, the UNESCO guidelines for ESD constituted an important source of information and inspiration for the SustainComp COP development. Especially, the specifications of the

cognitive, socio-emotional and behavioral domains for ESD (Rieckmann, 2017). The well-structured 'Education for Sustainable Development Goals: learning objectives' (UNESCO Rieckmann, 2017) and the follow up publications constituted a shared, interdisciplinary language or lingo for the participants across countries, HEIs and cultures. The participatory action research, conducted via case study research methods (Yin, 2009), during the development of the SustainComp Curriculum (2022-2024) took the point of departure in the urgent need for an educational approach that aimed to counter unsustainable systems and conditions. This was a normative approach, supported by UNESCO (2020), EU and Erasmus policies that encouraged HEIs to take part in the development of a 'future-oriented' interdisciplinary curriculum (Erasmus Call, 2021) that would enhance students' competences regarding actions to promote sustainable development including an ESD 3 educational perspective. It was obvious that the suggestions for action would not always be aligned with the general expectations of teacher education programs at European HEIs. An example of this is evident from the UNESCO road map about how 'Transformative Learning Environments' should encourage learners to become 'change agents' who can take transformative action for sustainable development (UNESCO, 2020). It is worth investigating to which extent HEIs would be able to encompass these transformative actions conducted by agents of change for sustainable development.

Fostering interdisciplinarity via the SustainComp model

This section provides an overview of the sources that informed and inspired the interdisciplinary approach applied by the SustainComp COP during the design-based research development process. Here, we focus on the final stages of the process, where the modules were developed and tested in the interdisciplinary full-scale pilot (in the period of August-December 2023). Based on the shared conceptual framework, the development process took the point of departure in the participants' shared understanding of the need to combine and integrate different scientific disciplines in an innovative way to reach the aim and objectives for the SustainComp curriculum. The 'swirl' model in Figure 1 is the result of the development process in the COP and reflects the dynamic concept of constructive and interactive relations between the scientific disciplines. The disciplines were represented by the lecturers and their associated subject-specific expertise as lecturers within natural science, social science, health science and human sciences, including pedagogy and didactics and intercultural education. The aim was to bridge the gap between former educational, sector-divided curricula with a versatile, integrated and transformative Higher Education curriculum.

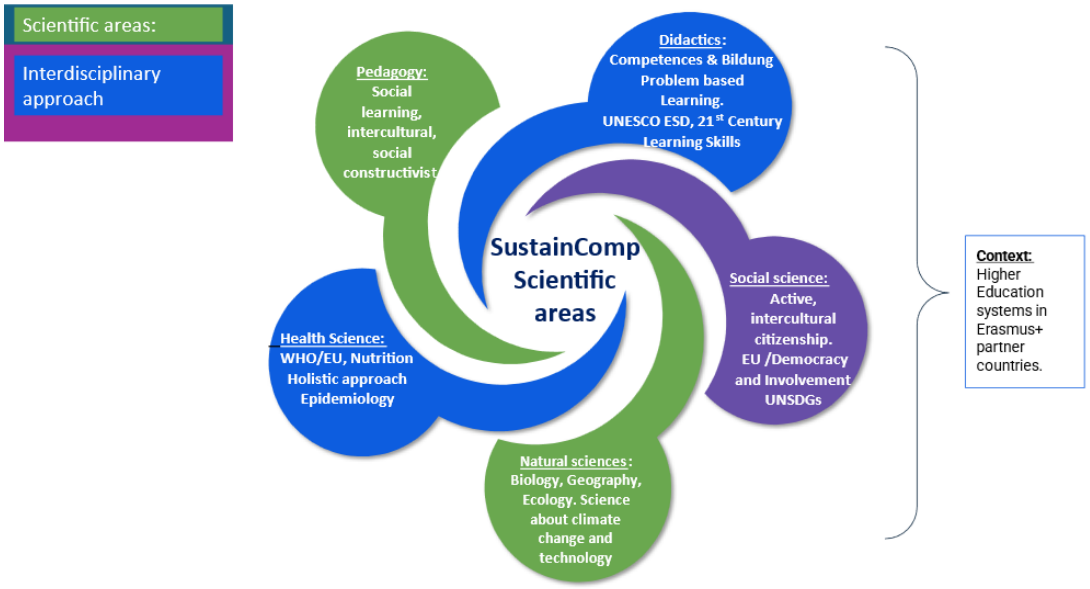


Figure 1. The SustainComp model for interdisciplinary approach to ESD (Ruge et.al., 2022)

Given the complexity of the problems related to un-sustainability, all participants in the COP knew that it was important and necessary to try to apply an interdisciplinary approach. It took courage, because all participants felt most comfortable and confident within their 'own' subject-specific topics and within the paradigm of their 'own' disciplines. The concrete output of the joint efforts of the COP were the four modules:

- Sustainable Diets (2,5 ECTS)
- Resources, Inequality and Sustainability (2,5 ECTS)
- Sustainable Consumer Behavior (2,5 ECTS)
- Health and Sustainability (2,5 ECTS)

The four modules were based on the different subject-specific, scientific fields that provided the framing of the themes and topics in the full curriculum[2]. The impact of the interdisciplinary approach was intended within the cognitive, socio-emotional and behavioral domain in the form of the following student learning outcomes:

1. New ideas for teaching sustainability in school
2. New knowledge about UN Goals for Sustainable Development
3. New knowledge about UNESCO and teaching sustainability
4. Intercultural knowledge
5. Inspiration for action - action competence

[2] In chapters 4, 5,6, and 7 it is explained how the interdisciplinary approach encompassed various forms of content and didactics in the SustainComp curriculum.

6. English language competences
7. Knowledge and experience with problem-based learning
8. Knowledge and experience with Socio-scientific issues

Typology for interdisciplinarity at HEI

According to Frodeman (2013) interdisciplinarity refers to the integration of knowledge across disciplines (ibid. p.3). This contrasts with a discipline-oriented approach, which is regarded as the general perspective in HE. Letouzey-Pasquier et al., (2023) state that ESD differs from school disciplines by the absence of an academic referent and therefore of a clearly established curriculum and this poses specific challenges for teachers in compulsory schools (p.1157): it requires teachers to plan teaching sequences in an interdisciplinary way.

This research applied a typology framework that was suggested by Yazdani & Hajiahmadi (2021) as a framework for understanding interdisciplinarity for Higher Education. Yazdani & Hajiahmadi suggested that "For real-world problems, a comprehensive development of the nationwide universities requires identification and intervention and effective strategies for interdisciplinary development" (Yazdani & Hajiahmadi 2021, p.10). The framework is based on a 'multilayered model' that takes the symbolic boundaries between scientific disciplines into consideration to establish an understanding of interdisciplinarity that recognizes for instance: Philosophical backgrounds, culture, language, focus and interest, aim, fund of knowledge. Table 1 (from Yazdani & Hajiahmadi 2021, p.6) illustrated interdisciplinarity regarding 'focus and interest of the scientific discipline' (ibid).

Table 4: The strategies and implications of interdisciplinarity development operationalization elicited from the "focus and interest of the scientific discipline" layer

The main layer	The subsidiary layer	Integration layers			
		Cross-disciplinary	Multidisciplinary	Interdisciplinary	Trans disciplinary
The focus and interest of the scientific discipline	The discourse domain	Cross-disciplinary discourse awareness	Pluralistic discourse/ multistakeholder discourse	Problem-focused open discourse	Transdisciplinary discourse
	The problematics	Cross-disciplinary problematic enrichment	Pragmatic shared problematic	Interdisciplinary problematics	Unified problematic
	The priorities	Exchanging priorities	Participatory priority setting	Shared priority setting	Shared goals for priority setting

Table 1. Typology of Interdisciplinarity in higher education. According to this typology the work of the SustainComp COP can be characterized as cross-disciplinary or interdisciplinary (Yazdani & Hajiahmadi, 2021)

By applying this typology to the development stages of SustainComp curriculum and the outputs, we suggest that the activities can be categorized as 'cross-disciplinary' or 'inter-disciplinary' based on the integration layers. Among the SustainComp COP participants there has been an on-going cross-disciplinary discourse and a problem-focused, open discourse awareness. This can be exemplified by the discussions and reflections of the participants concerning the 'Resources, Inequality and Sustainability' submodule. The focus of this module was directed to the impact on nature, environment and people affected by sand extraction because of multinational companies´ sandmining in vulnerable areas in Asia, Africa or Greenland. The COP participants acknowledged that they were missing factual knowledge about the subject

matter, and this demanded an openness from all participants towards subject disciplines, within the natural sciences. Further, understanding the impact of the unsustainable sand extraction as a 'Socio Scientific Issue' (Amos & Levinson, 2023) required an interdisciplinary professional attitude that encompassed both social science, health science and intercultural domains of learning. The need for interdisciplinarity was also strongly associated with the modules 'Sustainable Diets', 'Sustainable Consumer Behavior' and 'Sustainability and Health'. This case study research cannot claim that a transdisciplinary approach was applied, because there was a division of work between participants in the COP, working respectively from Norway, the Czech Republic, Slovenia and Denmark. Initially, a cross-country groupwork that might have had a larger transdisciplinary potential and stronger inclusion of ESD 3 approaches was considered among the COP. However, due to restraints in the form of differences in cultural and educational contexts, HEI schedules, transport and other coordination issues (which arose after the project application process) the participants agreed to do the developmental work on modules in country specific groups. Further, to have an ongoing bilateral or multilateral, critical reflection in the international and cross-country teams.

The impact of an interdisciplinary approach on students' sustainable competences.

A mixed methods approach was applied for data collection and analysis (Creswell, 2017) in the case study (Yin, 2009). Semi-quantitative surveys were used to collect data about student learning outcomes. The sources for data were:

Survey data from questionnaires
Answers in the open fields of survey
Students' welcome speeches
Student products in the form of assignment posters and presentations.

The thematic analysis was conducted by the SustainComp COP based on Braun and Clarke's theoretical framework (Braun & Clarke, 2019). The themes and the codes were constituted by eight indicators of impact from the interdisciplinary approach. The question was, to what extent did the interdisciplinary approach foster sustainable competences in the form of these learning outcomes:

1. New ideas for teaching sustainability in school
2. New knowledge about UN Goals for Sustainable Development
3. New knowledge about UNESCO and teaching sustainability
4. Intercultural knowledge
5. Inspiration for action - action competence
6. English language competences
7. Knowledge and experience with problem-based learning
8. Knowledge and experience with Socio-scientific issues

Data collection and findings

To investigate students learning outcomes a survey was sent to students to self-assess and report on their newly acquired competences following each module in the pilot. The questions regarded students' participation and their self-reported learning outcomes. The small numbers of students did not allow the use of statistical inferential analysis, so only descriptive statistics are applied in this case study.

The data gathered in the four questionnaires were cross tabulated and integrated into a total analysis of students learning outcomes (N=107) from 4 surveys with respectively 25/37/25/20/ respondents (students)[i]. These answers provided a databased ground for understanding students' outcomes and enabled comparison across the modules (mean value). For the SustainComp COP these learning outcomes were regarded as indicators of the sustainable competences students acquired as a result of their participation in the course.

Interdisciplinary approach: survey findings across the modules

The students' answers from the four surveys were cross tabulated for the purpose of descriptive analysis. The question asked was structured as follows 'Did you have an outcome from participation with regard to....'' '(N=107). Students were asked to mark their answer based on the scale categorized as 'Low degree', 'some degree', high degree'. The collected data for Question 1-8 is presented in Figures 1-8, mean values are emphasized:

Question 1. New ideas for teaching sustainability in schools?

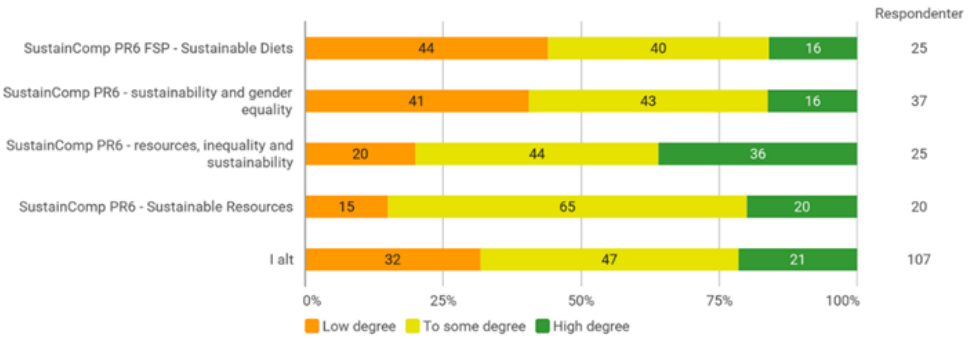


Figure 1. Forty seven percent of respondents (mean value) stated that they 'had an outcome regarding new ideas for teaching sustainability in schools to 'some degree', 21% indicated they developed the competences to a high degree, while 32% to a low degree.

Question 2. New knowledge about UN Goals for Sustainable Development?

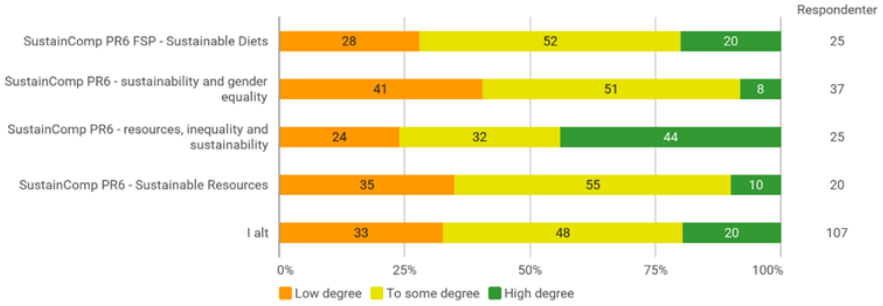


Figure 2 Forty eight percent of respondents (mean value) self-reported that they developed 'new knowledge about UNSDGs to some degree, 20%to 'high degree', and 33% to 'low degree'.

Question 3. New knowledge about UNESCO and teaching sustainability?

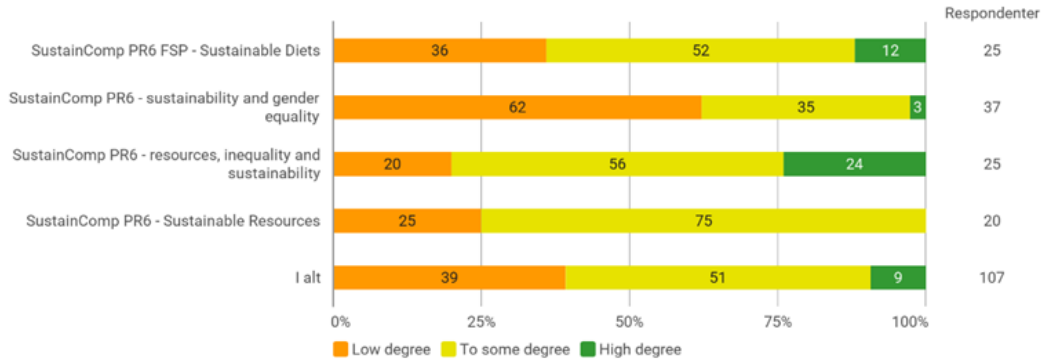


Fig. 3 With regards to new knowledge about UNESCO and teaching sustainability, 51% of respondents (mean value) indicated development to some degree, 9% to high degree', and 39% to low degree.

Question 4. Intercultural knowledge?

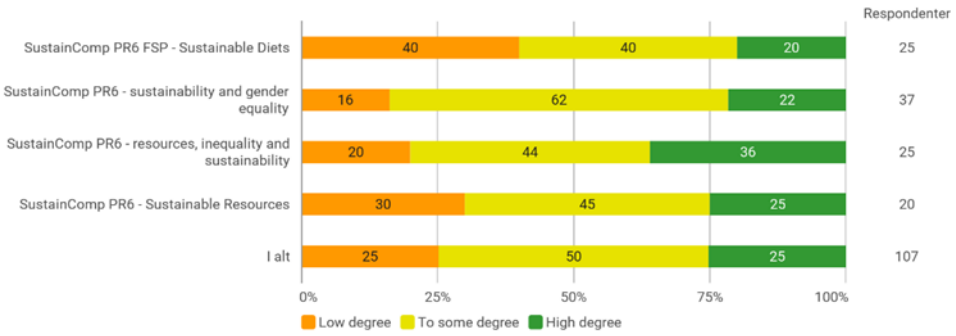


Figure 4. Fifty percent of respondents (mean value) self-reported to have developed intercultural knowledge 'to some degree', 25% to 'high degree', and 25% to 'low degree'.

Question 5. Inspiration for action - action competence?

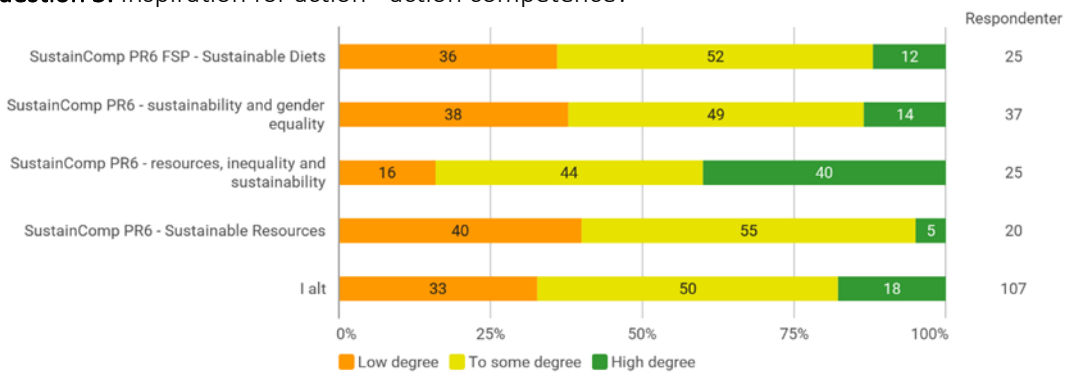


Figure 5. Fifty percent of respondents (mean value) were inspired for action 'to some degree', 18% to 'high degree', and 33% to 'low degree'.

Question 6. English language competences?

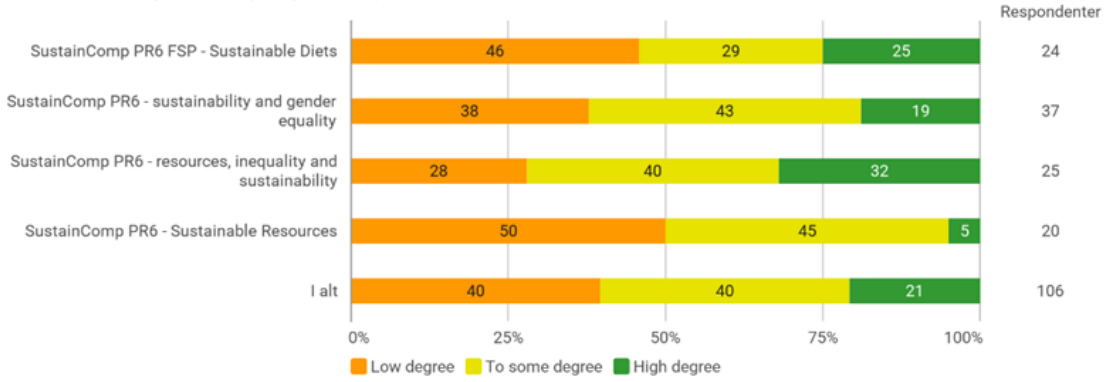


Figure 6. Forty percent of respondents (mean value) indicated they developed English language competence 'to some degree', 21 % in 'high degree', and 40% in 'low degree'.

Question 7. Knowledge about and experience with problem-based learning?

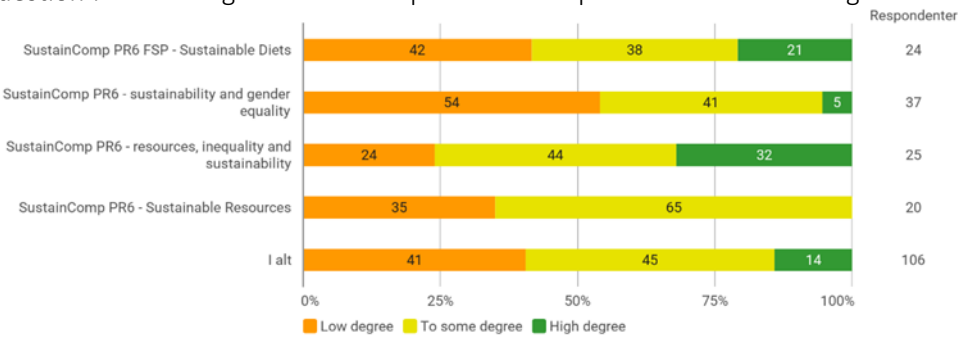


Figure 7. Forty-five percent of respondents (mean value) marked that they extended their knowledge about problem-based learning, 14% high degree, and 41% low degree'.

Interdisciplinary approach: answers in the open survey field.

The following answers to the question" Did you have an outcome from participation regarding…" come from the open field for 'Other outcomes' in the survey. Original student formulations and spelling are preserved to maintain the authentic 'voice of students':

- I learned about a new global issue that I never would have guessed was this big of an issue.
- To better create a lesson plan for the students.

- I've learned what is important for kids to possibly learn and what would be interesting and what would not.
- I have learned a lot of new things that I will take with me when it is my time to teach. Example making posters about different kinds of sustainability.
- To be open about how this world is currently doing, no hiding facts or not asking.
- I've learned about the 21st century skills and intercultural competences.
- I learned a lot about sand and the fact we are running out, I also got an idea of why sand is such a meaningful resource and how there's not a lot of things that can be used instead.
- Focus points for the sand crisis that are relevant for various age groups.
- nothing, in the sense that I can't really explain it. It's a little "unstable" what we learn, so it's kind of difficult to describe.
- We made a lesson plan, and I really think it was relevant.
- I love the 21st century skills the most, which I did not notice there are such skills. before. And I feel that it is very important not only for teaching the students in the future but also to value ourselves as a better teacher.
- I've learned way more about the different issues we have in our world. For example, the sand shortage.
- There is a sand crisis, sand is round or angular, which is important for construction. Using teaching aids is helpful, knowing the vocabulary of your own subject is critical, from fellow students that various forms of activities are essential.
- I sadly haven't been here much, but I did learn how sand is the second most used natural resource.
- We practiced using some different models.
- It is knowledge that I will bring with me into my classroom in the future.
- I gained a lot of new knowledge when it comes to the sociocultural issue of the sand crisis.
- I learned how to be able to teach at different levels because first up we have been taught ourselves and afterwards made a lesson plan for a class of our choice, which we then presented to other groups and gained insight in different levels of learning.
- I have learnt about sand in Greenland, sand-crisis and how it affects people in the world.
- I wouldn't say I learned a lot new about the subject itself. I did get to work with how I can implement it in teaching classes.
- I have learned more about sustainability than I already knew, but I have trouble understanding why this is relatable to our education.
- I did not learn much, because I think that this generation (my generation) already knows this stuff.
- How you can wear old clothes to make new things and use them in class.
- I have learned a lot about sustainability, but I have had trouble understanding why this is related to our education.
- I think most of the info that was taught I already knew, however using recycled materials in your teaching is a great idea.
- I've become aware of the fact that it is our responsibility as future teachers to try and pass on important knowledge on some of these subjects, although it would have been nice to have a foundation for how to use it.
- To be fair and honest, I didn't learn anything new.

- I think it's a great topic to teach about but it's been hard to get work done because of the zoom meetings. I get that we had to speak English which extends our vocabulary, but it just didn't work. On the other hand, I did learn about new topics regarding to environmental world problems and about different cultures (Czech) and their gender problems.
- I learnt how to think more about the clothing I buy and how to be more resourceful with clothing.
- Got some inspiration of how it could be taught to students. That's about it.
- I learned to think more about the clothes I buy, and how to be more sustainable. I also got some ideas for teaching sustainability in a classroom.
- I feel like most of the assignments were like the ones I had in high school which is not what I expected. I think we didn't get enough didactic use out of the lessons.
- The importance of circular economy. When the cost of different resources is decreasing, people would rather pay for a new one, but not reuse resources. It is very important to teach at school to emphasis the action of reusing resources.
- I have learnt new creative ways to introduce sustainability to younger learners.
- I learned different methods to teach students with. A lot of what the subject was about I'd already learned about in my previous bachelor.
- To use Physical examples, work greatly with younger and preteens.

Interdisciplinary approach: student products

Students' welcome speeches on final event

Students' welcome speeches at the final seminar on December 6th were video recorded[3] and transcribed. The speeches were included in full length as data in this section, because they provided valuable information about how students with an interest for 'leading the change' experienced participation in the SustainComp project.

Welcome speech 1. Student A (she)

Welcome! We have been through the 17 Sustainable Development Goals and these problems are relevant all over the world and it is highly important that we educate the next generation on these matters. These problems affect the entire planet, even though they don't happen in our backyard. You need to stay actively critical of global news and get introduced to people from different parts of the world and expand our cultural knowledge, and that's something that we got to do very well in this module. How can we as future teachers have an impact on the environmental change that needs to happen in the future years? As we have learned through the module, information, other cultural opinions and overall awareness – are a crucial part in taking the big steps towards a better future. To be able to teach about the environmental impacts and crises overall, we first need to be informed. I hope that what I've said today has brought to you some level of understanding as to why it's important to include all

[3] LINK video recording from Multiplier Event 6th of December 2023

voices and people around the world when we're trying to find solutions so that we can collectively save our planet. I really hope that you have enjoyed what we have prepared for you today.

Welcome speech 2. Students M (he) and S (she):

Hello, my name is M. I'm 21 years old and I'm studying here at UCL teacher education, and I have been participating in this program with my study group. Hello, I'm S. I'm 21 years old and I'm also studying to become a teacher at UCL. Both of us are on our first semester and I have also been a part of the SustainComp program. It's been interesting to participate in SustainComp and we can be the first to try it out and test it and we have finished the product. We have had some exchange students who participated in the study groups that we work with, and this has been exciting also to know we are able to improve the course going forward and make it better for the future. We have learned a lot about different sustainability topics and the relevance it has for us as future teachers. We have also been working with different teaching aspects and the benefits of intercultural competencies and with different teaching aspects and the benefits in cultural competencies as well as working with interdisciplinary teaching. This is something we can take with us in the future, when we will be able to teach these subjects to our own students. We had four main subjects that we worked on. We had sustainable diets, where we got to learn about the environmental footprint of food and other problems, and here we got some deeper knowledge about eating habits and life tools for teaching in the future that we can use in classes. We also got to work with sustainable gender equality. Here we learned about stereotypes, the positive and negative response, and we learned how to manage differences in classes that we will be teaching in the future and how to neutralize negative stereotypes. And in sustainable resource inequality, we learned about sand shortage and what effect it has on a local and global stage. We were also allowed to work with lesson plans, and that can be used at our internships in the teacher education. And then we had sustainable consumption materials and sources where we learned how to reuse and upcycle the old products into didactic tools that could be used in classes. And in my study group, we chose to make a didactic 'communication ball' which is going to have the purpose of learning students how to communicate well. And for example, I like that every single student likes to get the chance to speak. And then I will finish off by saying that I'm happy for you guys to be listening. And we were so glad to have the opportunity to participate in the SustainComp and we prefer to try it out and help improve it for later usage.

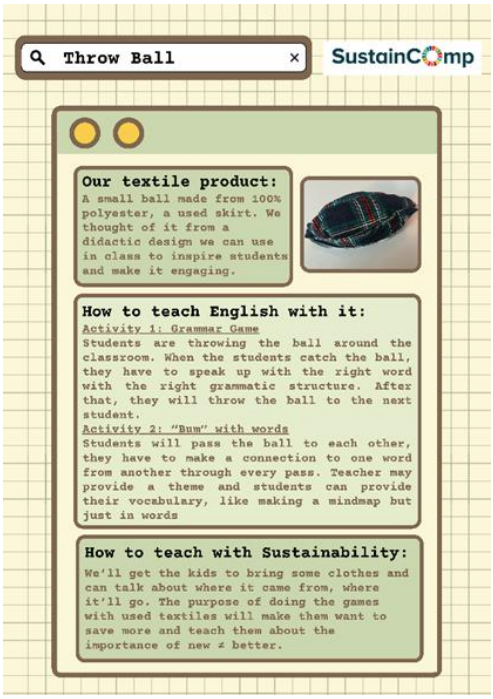
Posters as student products.

All groups produced a poster for/per each of the four modules. The posters served as components in the assignment for the SustainComp full-scale pilot during the semester course in English as a Second Language (10 ECTS). The criteria for the posters were that study groups had to formulate a research question that they would like to investigate and illustrate by making posters in a clear and creative way. The answer to the questions was formulated in a word document that included a lesson plan for schools as part of the assignment. The posters had to be presented during the final dissemination event in December 2023. Many posters are available via this link[4].

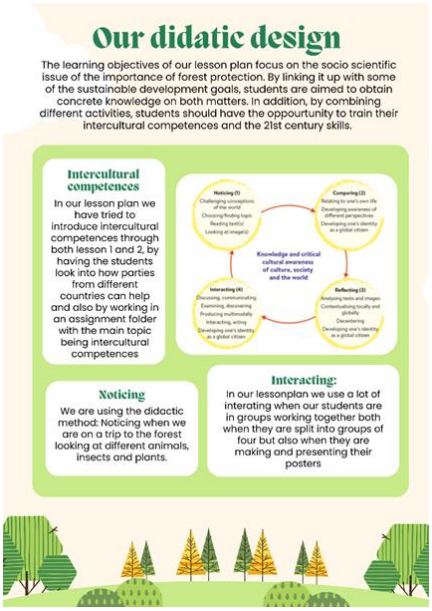
[4] https://sustaincomp.splet.arnes.si/student-products/

In chapters 3,4,5,6 there are analysis of posters in relation to each module. In this chapter, two posters are selected as an illustration of how interdisciplinary approach was conducted (see Image 1,2).

Poster Image 1. Poster from 'Sustainable Consumption of energy and textiles' (Student Group A).



Poster Image 2. Poster from 'Resources, Inequality and Sustainability' – Theme:Forest protection (Student Group B).



Interdisciplinary approach: analysis of data

Analysis - students' welcome speeches.

As the final teaching activity in the semester, students attended an international SustainComp event in a large assembly hall at UCL, Denmark. The aim was to disseminate preliminary results of the SustainComp interdisciplinary methods and student products, which were produced throughout the full-scale SustainComp pilot in front of a larger professional audience that included students and lecturers at UCL campuses as well as guests from the SustainComp partners' and other HEIs. Lecturers from SustainComp partner HEIs conducted workshops about their respective modules in collaboration with groups of students. The partners' objective was to structure the event for students so that they had the opportunity to present the outcomes of collaboration in the form of poster sessions delivered at an international, scientific conference on education for sustainable development.

Students were asked by teachers to deliver a welcome speech in English and to include a student perspective on ESD. Three students volunteered for this task, and they prepared two speeches that were held in front of the audience (See full text in 2.2.4). The student speeches included cognitive aspects related to the theme: 'New ideas for teaching sustainability in school':

> We have learned a lot about different sustainability topics and the relevance it has for us as future teachers. We have also been working with different teaching aspects and the benefits of intercultural competencies and with different teaching aspects and the benefits in cultural competencies as well as working with interdisciplinary teaching" (M &S Speech)

In addition, speeches included the theme 'New knowledge about UN Goals for Sustainable Development': "We have been through the 17 Sustainable Development Goals and these problems are relevant all over the world "(A's Speech).

Regarding the socio-emotional, and behavioral aspects of ESD the speeches emphasized the need for actions to promote sustainable development as well as students' responsibility as future teachers:

> You need to stay actively critical of global news and be introduced to people from different parts of the world and expand our cultural knowledge, and that's something that we got to do very well in this module (A's speech)
>
> /…/ we had sustainable consumption materials and sources where we learned how to reuse and upcycle the old products into didactic tools that could be used in classes (M&S's speech)

The speeches that were authored by the students themselves were to a high degree positive, compared to the expressions of reservation and frustration from some of the anonymous comments in the open fields of the questionnaire (See 2.1.3). There were indications that these students had acquired awareness of the need to incorporate both cognitive, socio-emotional and behavioral aspects into teaching sustainability by working problem-based and interdisciplinary. Students' welcome speeches aimed to motivate the audience to engage in the SustainComp curriculum by taking some of the responsibility on their shoulders.
An example of this is A's 's final remark: "I really hope that you have enjoyed what we have prepared for you today" (Student Speech A).

We cannot generalize about these three students to all the students who participated, but we can assume that they represent more students than themselves and this supports the internal validity of the findings. In summary, the speeches indicate that several of the eight intended learning outcomes in the full-scale-pilot were met regarding the aim of student participation in the full-scale-project (see more in 3.0).

Analysis - posters at the multiplier event

As part of the multiplier event at UCL University College in December 2023, students presented posters documenting the outcomes of their group work in each of the four full-scale pilot modules (See Poster Image 2.2.4).

Analysis - poster Image 1.

The text in the poster 'Throw Ball' is divided into three sections: 1) Our textile product; 2) How to teach English with it; 3) How to teach with Sustainability. Already from this first impression, it is evident that the poster integrates several disciplines: 1) Arts & Crafts 2) English as second language and 3) ESD. This group of students developed a Throw Ball as a didactical and functional resource: it was developed for teaching as a tool - or vehicle - for pupils learning. The text constitutes a guideline that can scaffold other teachers' use in practice. It is rather explicit

about the didactical and pedagogical intentions for this educational resource and the interdisciplinary intentions. The visual appearance supports the impression of an educational resource that is 'ready to use' by the chosen 'school typo' and squared background.
The intended learning outcomes regarding up- and recycling of textiles is integrated with learning outcomes for English Grammar. According to students' action-oriented perspective: "the purpose of doing the games with used textiles will make them want to save more and teach them about the importance of new versus better" (last line in text). Regarding indicators of students interdisciplinary learning outcomes, the poster includes both the cognitive (knowledge), socio-emotional and behavioral domains and apply several of the eight themes for interdisciplinarity, especially 1. New ideas for teaching sustainability in school; Inspiration for action - action competence; English language competences; Knowledge and experience with Socio-scientific issues.

Analysis - poster Image 2.

The text in the poster 'Our didactic design' indicates that this group has chosen to focus their poster on the didactical intentions underlying their lesson plan about how to 'Protect the forest'. In the upper section of the poster the introduction states what the interdisciplinary intentions were by choosing a socio-scientific issue, linked with some of the UNSDGs and combined with educational activities. This group included an illustration of the didactical model that they applied: the four-stage model of intercultural learning (Svarstad & Risager, 2024). Also, another text box emphasizes that 'noticing' is included as an important method for supporting teacher awareness of students learning outcomes. Intercultural collaboration is suggested as an action-oriented method for protecting the forest and thus, students argue that their main topic is intercultural competences.
The graphic illustration supports the impression of an educational resource that is concerned about the forests, both from cognitive, socio-emotional and behavioral perspectives. Regarding the more specific indicators of interdisciplinary learning outcomes this poster applies to several of the eight themes, especially 1. New ideas for teaching sustainability in school; 2. New knowledge about UN Goals for Sustainable Development; 4. Intercultural knowledge; 5. Inspiration for action - action competence; 6. English language competences; 8. Knowledge and experience with Socio-scientific issues.

Interdisciplinary approach: analysis of cross-tabulated results and answers in open fields.

Overall, the cross tabulated results in Figure 1-8 indicate that the interdisciplinary approach in the SustainComp curriculum fostered students' sustainable competences 'to some degree'.

The survey data, including respondents' entries in the open sections of the questionnaire, were subjected to critical reflection by the participants in the SustainComp COP. It is relevant to mention the varying degree of participants' English language competences, both among teachers and students. In some situations, and communication contexts involving students and teachers from different cultural and linguistic backgrounds, students found it challenging to understand one another - and the lecturers as well. Therefore, communication was impeded not only due to language accents, but also because of the lack of intercultural competences, such as the ability of mindful listening to non-native speakers and giving them more time to express themselves (Lee et al. 2012).

The development of English language competence along with intercultural competence, or intercultural communicative competence (Fantini, 2021) is essential for interdisciplinary and international education at HEIs and as such should be included in sustainable competences. Based on this reasoning the intention was to integrate ESD with the subject of English language teaching as part of the interdisciplinary topics and themes in the full-scale pilot. However, there were indications that the ambitions and ideas sometimes exceeded the abilities of the students during the three-month full-scale pilot.

Students seemed to gain a well-balanced interdisciplinary knowledge and developed their competences evenly. For example, while they expected to learn more in the subject of English, they expanded their knowledge in spheres and topics that were new to them:

> I get that we had to speak English which extends our vocabulary, but it just didn't work. On the other hand, I did learn about new topics regarding to environmental world problems and about different cultures (Answers in open fields)

Some students seemed to be unprepared for obtaining knowledge from various disciplines and rather than building their English language competence through examining and critically thinking about interdisciplinary topics, they insisted on a single discipline-based approach:

> Make sure that the students know why they have this topic, I had no idea. It doesn't make sense for the most part. We chose English as our first /teaching / subject, not Natural science (Answers in open fields)

This statement indicated that the introduction from UCL lecturers may not have been adequate for all students. Even if aims and objectives were presented - including the 'pilot' - before the course was initiated, some students found that the activities were too advanced or difficult to decode. The quote also represents the student who seemed to be sceptic towards interdisciplinary teaching methods, which is a fair argument as the Bachelor of Education degree in Denmark (2023 reform) supports the subject-specific teaching methods to a high degree – and the interdisciplinary teaching methods to a low degree. Other student voices were more positive regarding interdisciplinary learning outcomes:

> I have learned a lot of new things that I will take with me when it is my time to teach. Example making posters about different kinds of sustainability.
> I've learned about the 21st century skills and intercultural competences.
> I learned to think more about the clothes I buy, and how to be more sustainable. I also got some ideas for teaching sustainability in a classroom.
> (Answers in Open fields)

Students seem to have had a positive outcome in the cognitive domain, but some students commented that the level was too low, because they already knew a lot about sustainability – and did not understand the relationship between this topic and teacher education:

> I have learned more about sustainability than I already knew, but I have trouble understanding why this is relatable to our education.
> I did not learn much, because I think that this generation (my generation) already know this stuff.

These comments point to the need for differentiation that apparently was not met sufficiently during the semester. It should be acknowledged that the full-scale pilot's activities were highly experimental for both lecturers and students. The efforts to support and facilitate online, cross-institutional teaching sometimes tended to reduce the awareness of the topic-specific content and at least to support students with special challenges e.g. regarding understanding and speaking English language. Regarding the 'meaningfulness' it is relevant to mention, that the new executive order for Bachelor of Education degree (Ministry of Education, 2023) in Denmark explicitly states that the teacher education must prepare the students to work actively, independently and responsibly in the development of the municipal primary and lower secondary school in accordance with the purpose of the school and in a democratic and sustainable perspective (Ministry of Education Denmark, 2023).

The democratic and sustainable perspective is an innovation in the executive order and the formulation is open to interpretation. From the point of view of the full-scale pilot the new executive order (Ministry of Education Denmark, 2023) was only known by the lecturers and the implications for ESD were not implemented yet in the general teaching activities in the bachelor program or explained to the students.

The module 'Resources, Inequality and Sustainability' was the only one that was conducted, where both lecturers were present at UCL Campus. Looking at the results for this module, there were indications that the physical presence of the two teachers, who represented the subjects of respectively English and Natural Science, to a high degree promoted student outcome of the interdisciplinary teaching activities (Gericke et al., 2024). Likewise, the digitally conducted lectures had to pass through the 'zoom' educational channel, before reaching the students and to some students this was an unpleasant experience, maybe because of memories from previous online lectures during the COVID-19 epidemic. Also, varying levels of audio and visual technical delivery at times may have been a distraction from the overall learning experience.

Summary and discussion of findings

Table 2. 'Overview of results' accessible in attachments[5] offers an overview of all sources of data and results of analysis from this case study of full-scale pilot activities. In Table 2, results of data analysis are structured according to the eight indicators of students' interdisciplinary learning outcomes, which are also regarded as sustainable competences. Results from analysis of all data: survey data, answers in open fields, student speeches and student products, indicate that students to some degree obtained outcomes in the form of interdisciplinary sustainable competences. In a research perspective, we regard this as an acceptable and important result for an experimental, interdisciplinary 'full-scale-pilot' that was integrated in a regular English subject (ESL) at a teacher education program. It would have been a better result if more answers were 'positive outcome to a high degree' and less answers were in 'positive outcome to a low degree'. However, in this context-sensitive, action research-based case study it is relevant to reflect upon various reasons for this average result. First, the experimental nature of the full-scale pilot is a factor that represents some risk for an average result. Second, taking the settings, the staffing, the design-based research approach and the 1st year students into consideration, the total result is good – and regarding students' acquisition of 'Intercultural competencies': very good.

In summary, the case study documents that there is a direct relationship between curriculum and students' learning outcomes. Therefore, lecturers will need access to network based information about how to teach ESD1, ESD2 and ESD3 via interdisciplinary didactics and the SustainComp curriculum, to get inspiration and learn from each other.

During the design-based research stages in the SustainComp project the organic figure - Figure 1. for the interdisciplinary approach - served as a guideline and dynamic working model for the SustainComp COP. Finally, in the implication stages we have added features to the figure to update and clarify how the four modules comply with the interdisciplinary methods that have been applied. This is illustrated in Figure 8, where we have conceptualized the SustainComp model for interdisciplinary approaches in curriculum, according to the most prominent scientific domains for the four modules.

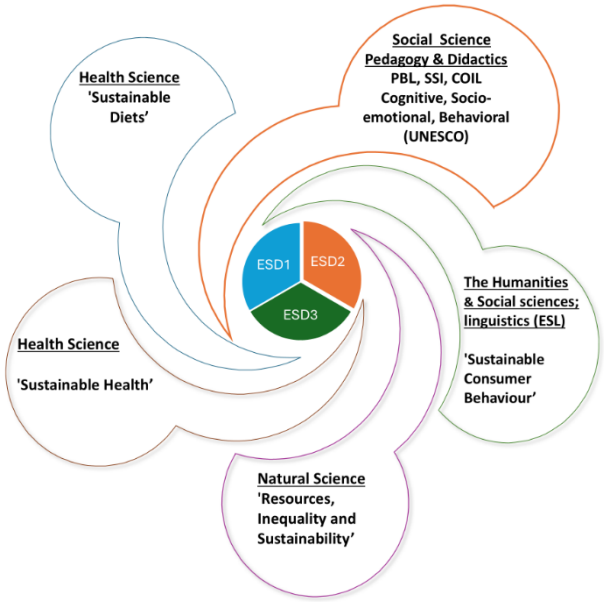
The SustainComp model in Figure 8 illustrates how each developed module relates to a prominent scientific domain and how the module is simultaneously interdisciplinary and integrated with the other scientific domains in the full 10 ECTS curriculum. During the development stages it has become clear that the Humanities and the Social Sciences, including linguistics and 'English as second language' (ESL) is a major prerequisite for teaching and learning from the SustainComp Curriculum. Especially the importance of students' acquisition of intercultural competences cannot be overstated as a prerequisite for students' understanding of the complexity that characterizes Education for Sustainable Development in a European and global context. We regard the SDGs and the UNESCO guidelines (Rieckmann, 2019) as a semantic educational resource, that has turned out to be a useful tool for students' acquisition of both cognitive, socio-emotional and behavioral learning outcomes. Regarding 'Pedagogy

[5] Internal link to attachment Table 2. Overview of results

and Didactics' in the initial Figure 1, we have adjusted Figure 8 to include 'Social Science Pedagogy', which implies a need for a holistic and 'critical thinking' approach, that supports the notion of ESD2: 'Teaching as sustainability' (Vare and Scott, 2007). Also, the notions of Problem Based (PBL), Socio-Scientific Issues (SSI) and Collaborative Online International Learning (COIL) have been added to emphasize the didactical methods that have proved to be applicable and useful in ESD according to the SustainComp Curriculum. As a new component in Figure 8 the complementary ESD1, ESD2, ESD3 approaches have been placed in the center to illustrate the importance of integrating all three dimensions in the interdisciplinary approach.

By using the conceptual model in Figure 8 as an adjusted working model, we hope that readers and users will be able to apply the SustainComp Curriculum in ways that are also adjusted to the local educational context. We assume that lecturers and students in the future will add more sub-themes within each module that comply with the interdisciplinary approach - and that students will obtain sustainable competences, similar to what is documented in this paper.

Figure 8. Conceptualized SustainComp model for interdisciplinarity in the SustainComp curriculum, taking the complementary EDS1, ESD2, ESD3 dimensions in consideration (Ruge et al., 2024).



Implications for practice

Cognitive perspectives

The implication for practice of the analysis for future SustainComp activities, is to give priority to introductions and to include students pre-understanding to engage and involve students in interdisciplinary activities. This research suggests that co-teaching (Friend et al., 2007) is an important didactical approach for scaffolding interdisciplinarity at HEIs. Co-teaching provides cross-disciplinarity even if the institutional schedule does not allow a fully project-oriented approach, lasting 1-2 weeks. Regarding students' participation, it is important to give time for problem formulation to support engagement and involvement. Rather, we would recommend - as far as possible - adopting project-oriented approaches where the stages in the inquiry are clearly defined. Another result from this research regards the uncomfortable emotions that students sometimes associate with the topics or 'problems' associated with ESD in the lectures. The intention from the SustainComp COP was that facts and figures could easily be transformed into constructive ideas for teaching and for actions such as making lesson plans for school children. However, these transformative actions were not that obvious for all students. The complexity in this topic can be illustrated by data from discussions in class, where some students stated that they would prefer not to tell their future pupils about the problems related to obtaining the SDGs because they did not want to cause environmental- or climate anxiety among pupils.

Socio-emotional and behavioral perspectives

The submodule 'Sustainable Diets' and 'Sustainable Consumption' suggest to a high degree changes of behavior at the individual level, which also turned out to be a provocation to some of the students. An example could be a suggestion for reducing intake of red meat, or an encouragement for higher awareness of gender minorities and domestic violence towards women, or a suggestion not to buy new clothes – rather than to upcycle and recycle used clothes. These actions would take place outside the HEIs and the SustainComp COP had an

internal critical reflection on whether lecturers were having the legitimacy to formulate instructions for students to become 'agents of change' as required by UNESCO and other actors. Teacher students were aware that lecturers sometimes encouraged sustainability, without acting sustainable themselves. The call for more justice and intergenerational solidarity ought to be included in the future ESD 3 efforts for a more holistic approach (Garsdal, 2024) to expand the teaching for sustainable development. The SustainComp full-scale pilot will never be repeated the same way again, because the SustainComp Curriculum from now on will be available online from an Open Access e-learning platform, where teachers can select and download the educational resources in the SustainComp Curriculum and adjust to their own teaching practices. To scaffold teachers' use of the e-learning platform, course materials have been developed for teachers self-paced courses or for local level workshops with colleagues6.
The insights from this research will be incorporated into the guidelines for teachers so they can make their own interdisciplinary lessons with inspiration from the SustainComp curriculum. The results from research in the SustainComp curriculum pilot have the potential to contribute to practice and to the new pool of knowledge that must support integration of ESD in the teacher program at UCL and other University Colleges in Denmark, in accordance with the new executive order from 2023 (Ministry of Education in Denmark, 2023).

After the pilot of the SustainComp curriculum, colleagues from other subject-specific fields in the UCL Teacher Education Department showed interest in the methods and educational resources in the SustainComp project. The Math teachers' team at UCL conducted a course on sustainability & sand extraction from a problem-based approach, inspired by the notion of socio-scientific issues (Amos & Levinson, 2023) in relation to sand extraction (see chapter 4). In this case, the interdisciplinarity regarded Math and Natural Science, which is sometimes referred to as STEM (Science, Technology, Engineering and Math). The Math group recognized that it was sometimes difficult to conduct STEM teaching as the interdisciplinarity was not occurring automatically (Toft et al., 2024). However, the socio-scientific and inquiry-based approach, as well as the concrete theme about sustainability and sand extraction, seemed to engage students to a higher degree. This inspired the students to ask more questions, that prescribed interdisciplinary answers, while at the same time trained general math competences (Toft et al., 2024). Similarly, a Visual Arts teacher, Christensen, at UCL in spring semester 2024 used an interdisciplinary approach during a course on the SDGs where students formed 'clay tableaus' in relation to sustainability issues. In autumn 2024 one of the Visual Art groups decided to work with the theme of sand extraction in relation to resources, inequality and sustainability. Their point-of-departure was a case entitled 'Fisherman's Family' made by lecturers in the SustainComp COP. Based on the roles and open-ended stories of the family members in the case description, the group created a tableau that functioned as a visual and socio-emotional illustration and a comment on the
inequality and the un-sustainable impacts of sand extraction in vulnerable native communities [7]. Lecturers and students from the Visual Arts study are collaborating on a shared research

[6] https://sustaincomp.splet.arnes.si/teacher-training-course/
[7] See photos of 'clay tableaus' at the SustainComp homepage: https://sustaincomp.splet.arnes.si/

article about the ideas, outputs and interdisciplinary outcomes that will be available in spring 2025. Implication for practice also includes the COIL method to a high degree: Collaborative Online International Learning. For more information about the COIL method in the SustainComp Curriculum, see a more comprehensive presentation of the theoretical framework and the concrete experiences from the full-scale pilot in Janêk (2024).

Implication for research

The implication for research is that more research is needed regarding interdisciplinary didactics as basic sustainable competences in ESD1, ESD2, ESD3 at HEIs. The complex interplay between nature and culture puts a demand on more research and the UNESCO guidelines and UNSDG framework constitute highly relevant educational resources for this purpose. Also, there is a need to investigate how HEIs can support students in their ambitions of conducting actions and contribute to change. The UNESCO Road map is clear about how 'Transformative Learning Environments' should encourage learners to become 'change agents' who can take transformative action for sustainable development (UNESCO, 2022). To do this, more research is needed to show how HEIs can facilitate lecturers and students' sustainable actions. The teacher training module is an additional component to the SustainComp curriculum, that would need to be followed closely by a participatory action research approach.

Limitations

The limitation of the case study is the small size of the target group in this research and that it is a single-case study. The implication of this is that the internal validity is strong and external validity is weak, because the results only concern this specific course and these students. Cross-disciplinary teaching demands resources in the form of teachers, time and flexible settings. Both regarding the physical setting, staffing of such learning situations, subject-related openness, motivation for working across disciplines.

Further, the survey gathered self-reported data by assessing the students' perceived improvement in sustainable competences. Self-reported quantitative data is inherently subjective and, as such, should be supplemented by more qualitative data in the form of interviews, focus group discussion, and other qualitative methods. In this case, qualitative data was included in the form of student products and survey answers in open survey fields. Additionally, student speeches and posters that constituted their module-assessment provided information about the development in specific sustainable competencies and should be regarded as a coherent 'student voice'.

Conclusions

The research question for this case study was: *To what extent did the interdisciplinary approach to teaching ESD foster sustainable competences – and what were the implications and limitations*? Based on findings from this action research in the SustainComp full-scale pilot there is reason to conclude that the interdisciplinary approach to teaching in SustainComp

curriculum to some extent fostered sustainable competences among teacher students. Results indicated that this regarded both the cognitive, socio-emotional, behavioral domains. The implications of these results are that the interdisciplinary approach to ESD in the SustainComp curriculum is relevant for integration in regular teacher education programs at HE.
Therefore, we would like to suggest that the documented need among lecturers for a more student oriented, innovative and interdisciplinary educational resource in the State-of-The-Art report (Ruge et al., 2022) has been met in the form of the new, interdisciplinary SustainComp curriculum. In a wider perspective, it would also be relevant to implement the SustainComp curriculum in a comparable format, such as a 'summer school' or an independent hybrid Blended International Learning course. In the short term, HEI teachers and students will have a good opportunity to use and implement the SustainComp curriculum from the e-learning, Open Access, platform from November 2024. The limitations regarding this single case study of a certain phenomenon that was conducted in fall 2023.

However, the transparent description of the activities, analysis and overview of results, combined with the Open Access availability of the SustainComp curriculum, will facilitate a contextualized application by lecturers, researchers and students from now on. Also, the conceptualized SustainComp model in Figure 8 will support both the applications, but also a continued co-development by the users of the e-learning platform.

There are indications in this case study that interdisciplinary and inquiry-based didactics have the potential to foster students' motivation for complementary ESD1, ESD2 and ESD3. It will be a moral obligation for HEIs to include and encompass teacher students who are conducting transformative actions as agents of change for sustainable development in a caring way (ESD3). HEIs may need to transform the didactical form and structure of their degree programs in ways that might lead to more transdisciplinary forms of education to provide: a transdisciplinary discourse, a unified problematic and shared goals for priority setting regarding the tasks for international education in relation to ESD, as suggested by Yazdani & Hajiahmadi (2021).

In conclusion, we find that the SustainComp COP case study contributes with applied research in the development of new knowledge about interdisciplinarity in an ESD1, ESD2, ESD3 based degree program at HE. We suggest that this case study as real social science can contribute to the field with applied phronesis in the Aristotelian sense: "Practical wisdom on how to act on social problems in a particular context" (Flyvbjerg et al., 2012). Following this, we hope that other HEIs will be able to obtain similar positive results by using and integrating the conceptualized didactic model and the SustainComp curriculum which is now available from Open Access due to support from Erasmus Plus funding. More options for international collaboration and sharing of case studies based on the e-learning platform will be investigated by the SustainComp COP in the near future.

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