Integration of Chemistry and Professional Studies in Environmental Engineering

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ABSTRACT

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In this study the first year experience on course integration according to new curricula of the Degree Programme of Environmental Engineering is presented. The connected courses were Basic Chemistry (basic course), Soil Science and Engineering (professional course) and Writing Scientific Reports in English (language course). The outcome of the first years' experience was analyzed based on teachers' experiences and students' feedbacks. The problems were identified and some suggestions for further improvement of integration of chemistry are presented.

Integration of the courses was definitely a positive experience for the students and for the teachers as well. It promoted the most essential skills students should possess: complexity thinking, self-directed learning, self-reflection and collaborative skills. Overall integration enhanced learning of Basic Chemistry as well. Because of the need of careful planning and close collaboration between teachers, integration might be time consuming in the beginning, but later will probably ease the teachers' work. Additionally, it provides the teacher with a more holistic view of the teaching program.

Improvement is still needed in teacher collaboration and timing to avoid student confusion. Other disciplines should in some form be connected to the courses mentioned in this work. With respect to the connection of Chemistry and professional disciplines, small problem-based tasks that require environmental considerations, support the chemistry theory and are meaningful tasks in the professional course would engage students even more in the process of constructing their own knowledge.

Key words: interdisciplinary, integration, chemistry, professional studies

CONTENTS

1 INTRODUCTION

Integration is a teaching strategy that means a deliberate design of crossing the boundaries between disciplines with the scope of making lasting and meaningful interconnections (Brears & O'Sullivan 2011). The models and types of integrated and interdisciplinary curriculum integration are described in detail in literature, where it is emphasized that the curriculum should be standard-based, meaningful and relevant and should engage students to solve real world problems (Loepp 1999).

Esprivalo Harrell (2010) collected several theoretical descriptions of integration. Firstly, a curriculum can be integrated by fusion, incorporation, correlation and harmonization. Fusion means joining together two similar disciplines, like e.g physics and chemistry; incorporation is adding an applied discipline to a basic one; correlation is timing the teaching of a subject to overlap within more disciplines; harmonization it means teaching skill across the curriculum. Another approach to describe integration defines the following forms of it: integration of content, integration of skills and processes, integration of school and self and holistic integration meaning all school-based influences on learning. From teacher's point of view integrated curriculum was defined as a process in which teachers assimilate concepts from more than one disciplines. (Esprivalo Harrell 2010)

Loepp (1999) describes three models of curriculum integration: the **interdisciplinary model,** the problem-based model and the theme-based model. In the interdisciplinary model traditional subjects are thought in blocks of time to a given number of students thought by a small group of teachers. This practice is applied mostly in the middle school level and has the advantage of allowing teachers to work with each other and with a limited number of students having flexibility in timing. The **problem-based model** puts a technology question ("problem") in the center and the different disciplines serve as a base of solving the problem. The main advantages of this approach are the relevant problems that are highly motivating for the students. This model is widely applied in medical education (Lim 2012), but it is an efficient teaching strategy in science and technology higher education as well (Brears et al. 2011). In the **theme-based integration model** the disciplines are integrated in a theme-based curriculum in which teachers of different disciplines form a team within a theme. Students learn in learning cycles by applying the concepts and skills in problem solving, utilize authentic assessments, perform group works, use standards etc. (Loepp 1999)

Previous studies suggest that students should be engaged in activities in which doing and thinking are interrelated enhancing in this way their skills to solve complex problems that the 21'st century working life requires. The most efficient activities are reported to be those that are experience based and require reflective thinking (Loepp 1999; Zheleva & Zhelev 2010; Brears et al. 2011). Further, according to Viskari and Bacon (2001) integration of language course with a professional study course enhanced the learning of both subjects. The essential skills students should have to meet the needs of working life were listed by Brears et al. (2011) to be: complexity thinking (thinking at the "whole"), metacognition (thinking about thinking), self-motivation, self-directed learning, self reflexion and collaborative skills.

Though considered an efficient teaching strategy that promotes the development of the above mentioned skills of the students, there are also challenges related to successful implementation of an integrated curriculum. One of them is teachers' generally low understanding of the component parts of the curriculum (Esprivalo Harrell 2010; Brears & O'Sullivan 2011). Another challenge is to find ways to benefit most of the latest technological developments, such us online teaching or wireless technology, within an integrated curriculum (Zheleva & Zhelev 2010; Rogan et al. 2012). Additionally, the very latest publications reveal that embedding sustainability and green chemistry in a university curriculum is a difficult task mainly because of the fact that the lectures do not see green chemistry relevant to their own discipline (Schultz 2013).

The Degree Programme of Environmental Engineering belongs to Technology, Communication and Transport unit of TAMK having a new curricula since study year 2013/2014. The program has an international orientation aiming to provide students with competence to work in international environment. The students acquire knowledge in monitoring and managing the environment as well as knowledge of technologies and principles that contribute to sustainability. The program offers students with possibilities to get complementary skills as well, in energy technology, quality management, entrepreneurship and logistics. Since the environmental engineering is a multidisciplinary field that needs to give solutions to huge real world problems, course connections and active engagement of the students to solve real problems during their studies must have central role in teaching of this field.

The new curriculum follows the theme-based integration model containing study-modules (themes) of 10-15 credits, each module being formed of 5-6 courses (see Appendix 1) . The aim is to find common "interfaces" in between the courses of the same or different modules and to connect these courses through the common interfaces found in order to facilitate the understanding and learning of the students. In fall 2013 we started to teach the first year students according to new curriculum. We found common interfaces among three courses: Basic Chemistry (basic course), Soil Science and Engineering (professional course) and Writing Scientific Reports in English (language course). A fourth course Computer and Software Tools was also connected to Writing Scientific Reports in English.

The main aim of this study was to improve the integration of the curriculum in Environmental Engineeging degree programme by finding the efficient ways to connect the different disciplines mentioned. The outcome of the first years' experience was discussed based on teachers' experiences and students' feedbacks. The problems were identified and suggestions for further improvements of the integration were done.

2 INTEGRATION OF THE COURSES IN THE DEGREE PROGRAMME OF ENVIRONMENTAL ENGINEERING

Connection of the courses was realized among the first year students of Environmental Engineering from Tampere University of Applied Sciences in study year 2013-2014. Writing Scientific Reports in English and Computer and Software Tools belong to module named “Engineering tools 1” aiming to provide students with language and software skills necessary to work with experimental data and report properly the experimental results. Basic Chemistry and Soil Science and Technology are part of the module “Structure and Function of Natural and Industrial Environments 1” having the aim of providing student background knowledge necessary to understand the functioning of natural and industrial systems. Table 1 contains a more detailed description of the mentioned courses.

Table 1. Description of integrated courses

Course	cu	Objective	Content
Computer and Software Tools	3	To know to write, present and manage numerical and written data with the aid of computers and software. To be able to use appropriate TAMK computer services and network.	Basic use of Microsoft Windows Word, Excel and Power Point software. TAMK computer services for students.
Writing Scientific Reports in English	3	To achieve the following skills: realistic evaluation of one’s own language (English) learning skills. Accessing information from a wide range of sources. Critical evaluation of information. Competence in scientific reporting	Practicing producing reports which are logically structured, cover sufficient and relevant content, include appropriately labelled graphics, follow the norms for referencing and lay-out, and are written in clear and accurate English. Developing skills in summarizing, paraphrasing and synthesize source materials.
Basic Chemistry	5	To understand the fundamental laws of chemistry. To write the formulas of compounds, balance chemical equations and to use the equations for calculations. To learn to work in the laboratory in a safe manner.	Measurements, atoms and elements, molecules and compounds, chemical quantities, chemical reactions, laboratory safety issues, laboratory exercises.

Soil Science and Technology	4	To know soil properties, soil formation processes, structure, function and biology of soils and their significance as a raw material reserve. To be able to take and manage soil samples for further analysis. To know the basic pre-treatment and physico-chemical analysis methods of soils and can use them in practice. To know the phenomenon of water flow in soils, groundwater formation and the practical applications related. To know the basics of geotechnology, soil management and soil pollution	Basic geology and soil science, biological and physical processes in soils, environmental impacts of soil utilization, hydrology, movement of water, air and gases in soils, soils as construction material, basics of geoengineering

During a discussion session and previous considerations the teachers found several connection interfaces between the courses. Basic Chemistry is related to Soil Science and Technology by the chemical compositions and structures, properties of different soils and by laboratory measurements. Therefore we connected the two courses by laboratory measurements. During Soil Science and Technology course students had site visits and soil sapling session followed by simple basic laboratory measurements of physical properties of different soils. They preserved their soil samples for chemical analysis that was performed several weeks later. By that time the theoretical background for measurement of chemical properties of soil samples was discussed, also the laboratory safety issues were discussed. The analysis of the previously preserved soil samples was one (out of three) laboratory exercise of Basic Chemistry course.

The Writing Scientific Reports in English course was connected to the previous ones by the one common report wrote by the students for the three courses. The students submitted their final report on soil properties that included the physical, chemical analyses and results to each three courses, using the software skills acquired at Computer and Software Skills course that in this way was connected as well. Each of the teachers assessed separately the reports.

3 METHODS USED

3.1 Research methods used

The method used in this study on course integration was formative evaluation, which is generally used when developing or improving an educational program (Postlethwaite 2005). It means collection of information on the process –in our case course integration- during its ongoing phase in order to identify the strengths and weaknesses. Since the curriculum is in its starting phase of integration, it can be considered that we are at the beginning of the formative evaluation process. The tools used were group discussions of the participating teachers and an inquiry with open questions addressed to students. The data collected by discussions and inquiry was subjected to an inductive content analysis. This form of data analysis is used generally when there is not enough former knowledge acquired (Elo and Kyngas 2008), being our case on the integration of the three courses described. The observations and answers were grouped in categories and subcategories based on their content, these are basically the main outcomes of this study.

3.2 Implementation of the study

Teachers shared their own experiences by short conversation meetings after the course. Each teacher told about positive and negative experiences related to integration and the outcomes of the fall courses, these were the two “main” categories identified. The observations within each category were than grouped based on their meaning, these are the “subcategories” that were listed under the main categories. The main issues related to experiences were grouped in a table as positives and challenges.

From each course there was written student feedback collected separately after the courses ended, at the end of the fall period. These were the usual feedbacks collected after any course by the teachers involved, with open questions for the Soil Science and Engineering and Writing Scientific Reports in English courses. The Basic Chemistry feedback was collected through TAMK intranet having both open-ended and closed-ended questions, the formers referring to the grading of teacher, student and learning performances. The closed-ended question answers were not included in the data analysis of this work since the content of the Basic Chemistry course has changed in fall 2013 and there was no basis for comparison with the previous year course performances.

In spring a second feedback was collected with the scope of getting their opinion on the integration of the courses (see Appendix 2). The questions were again open-ended reflexion questions. The students were asked about their perception on their own learning, their opinion about what was successfully and less successfully implemented on courses and their connections, what they learned best and what they did not like in connecting the courses. Each feedback was used also to collect students' suggestions for improvement.

The outcomes of the students' feedbacks were grouped in three main categories: positives, challenges and improvement suggestions. In each category two subcategories were identified. In "Positives" there could be a clear distinction in between the positives referring to learning performances ("Learning") and those referring to organizational and other issues ("Others"). In "challenges" category the two subcategories were "Teachers to blame" and "Others" referring mainly to organization of the integration and administrative aspects. The "Improvement suggestion" category was divided into "more integration" and "others". Within each subcategory the comments having the same meaning were grouped in subcategories that were listed in the main categories. When analyzing data all of the course feedbacks were taken into account as a whole. The identified subcategories are practically the outcomes of this study.

For Writing Scientific Reports in English 19 students gave written feedback in paper form. For Soil Science and Engineering 26 student feedbacks were registered in Tabula. For the Basic Chemistry course 23 students gave feedback through intranet feedback system. In spring period 24 students gave again written feedback on the integration. Based on the previous experiences on the willingness of the students to give feedbacks, we believe that numbers over twenty from a group of 35 students can be considered as significant.

4 EXPERIENCES

4.1 Teachers' experiences

The main outcomes of teachers' conversations are collected in Table 2.

Table 2. Summary of the teachers' experiences on connection of the courses

Positives	**Challenges**
-Reporting of real experimental sample analysis" makes sense" for the students, it is a meaningful thing to report. It "simulates" the real life work situation, where different specialties are not separated but interconnected -The students' interest was at its height in the laboratory and toward the laboratory work related to the real life soil analysis. They took care of the samples of their own group, so took complete responsibility on that -Group work and collaboration was efficient -Overall the written laboratory reports structure and the content were proper, theoretical backgrounds were reported and only few mistakes in calculations were observed -The acid-base theory we discussed in detail later was easier embraced by the students, since they measured and reported pH values before under real-life experiment conditions -Teachers learned a lot about each other's material	-Administratively course connection and overall integration might cause problem, for example if a student does not complete the reporting at one course that causes missing credits at several other courses -Other problem that appeared was incomplete report because of missing information (data or result) from other course and/or other group mate, that caused difficulties in assessment of the reports -Course planning is more time consuming than in traditional teaching and compromises and adjustments need to be done. E.g measuring pH in the laboratory was done before taking the theory, so it was needed to have a brief and rather superficial discussion about the background theory (Basic Chemistry course)

The teachers overall experienced an apparent increase in the students motivation. The "meaningful" task made them to collaborate in groups, to take responsibility in sample handling and to be more active in the laboratory. The reports submitted by students were of good quality with respect to the structure and content.

The challenges identified by teachers were related to administrative aspects. The most significant challenge is that integration increases the risk of falling behind of the students. This happens automatically in the case the student cannot complete the report for some reason (e.g. missing the laboratory exercise), that means that will miss the credits of three courses. In order to avoid this situation extra planning is needed to insure that the student can eventually recover the key missing parts (like field sampling, laboratory exercise sessions etc.). This needs extra planning and adjustments from all participating teachers. A less significant challenging aspect is the fact that some group(s) did not submit the common analysis result in time and that caused delay in report submission of the other groups. Therefore, the reports could not be evaluated as planned by the teachers leading again to extra planning and time adjustment. The third challenge identified is the least significant one, it is the fact that some measurements are done before the background theoretical aspects were discussed in depth. The experience has shown however that students could manage the practical tasks with the very brief introduction done in the fall period and later in spring, when the detailed theory was discussed, they felt they learned it easier.

4.2 Students' experiences based on feedback

All of the students felt that the shared laboratory works and reports improved their learning. The main outcomes of the student feedbacks are collected in Table 3.

"Learning" subchapter had the most of the positives showing that the students felt that their learning improved because of the course connection. The most highlighted positives emerging from the students' feedbacks were the following two issues: 1. the similarity of the common tasks with the ones in working life and 2. they felt they learned better by tightening together the different subjects. Time saving was a very important positive experience for them as well.

Challenges were equally distributed between "Teachers to blame" and "others". Teachers were mostly criticized for confusing sometimes the students by the different instructions and deadlines different teachers were giving. The challenging administrative issues identified by the teachers were noticed by the students as well and were grouped in the "Others" subchapter.

Table 3. Summary of student feedbacks

Positives	**Challenges**	**Suggestions for improvement**
Learning -Learning tasks that are done in working life later -Subjects tied together to form an entire that helped understanding (see things from broader point of view) -Understanding of the soil properties was improved -Laboratory exercises were interesting and basics of working in the laboratory learned -English grammar and vocabulary learned well -Learned how to write a good report and how to manage the time when writing it (Importance of Discussion chapter learned) **Others** -One single report was assessed for more courses (time saving) -Forced to do a lot of self-study -Become motivated to write the report well, since grades of three courses depend on it -Feedback from several teachers is enlightening	**Teachers to "blame"** -Teachers were not shore about each other's instructions and that confused sometimes the students (Confusion with the deadlines) -Information not always available at right time -Clear instructions needed **Others** -Too long report and is student´s responsibility to stay on track -Students had done previously some parts of the courses might have problems when courses are connected -Gathering the information from other groups was time consuming	**More integration** -More connection between different courses, more laboratory works that are connected, one single laboratory and one single reporting instruction **Others** -First it should be feedback from English, than submit the report for others -More contact teaching -More outside lectures -Same deadline for the courses

With respect to the suggestion for improvements students thought that more integration would definitely improve their learning. They would like to have integration of mathematics and physics with professional courses and they would like to have the other laboratory exercises connected to professional subjects. The suggestion for more contact teaching is probably because they feel they can understand better/faster when it is explained to them directly and they do not have to spend time with searching for information. The other suggestions are the remedies for the previously discussed challenges. Asking for having first the English report checked and after that to submit the report for professional and chemistry course it seems a justified suggestion, since the general structure of a scientific report is explained in during the language course.

5 DISCUSSION

Connection of the courses was definitely a positive experience for the students and for the teachers as well. According to previous studies, for deep learning students should be engaged in practical experiences combined with activities that require reflective thinking (Loepp 1999; Zheleva & Zhelev 2010; Brears et al. 2011). The common interfaces of the courses served exactly these purposes: practical real world experiences of sampling and analysis of the samples and reporting that promoted reflective thinking based on the analysis outcomes and theory. Brears et al. (2011) emphasized on several essential skills students should possess: complexity thinking, self-directed learning, self-reflection and collaborative skills. The positives given in the student feedbacks reflect exactly these essential issues: “see things from a broader perspective”, “forced to do a lot of self-study”, “importance of discussion chapter”, “time saving”, therefore from the learning point of view connection of the courses was a success.

Previously it was found that integration of language course with a professional study course enhanced the learning of both subjects (Viskari & Bacon 2001). The connection of Basic Chemistry course in the fall period showed that chemistry is treated with a more friendly attitude than before. The motivation and self-initiative in the laboratory was at maximum when analyzing the “real world” soil samples and the written laboratory reports structure and the content were proper, theoretical backgrounds were reported and only few mistakes in calculations were observed, suggesting that course connection enhances learning of Chemistry as well.

Regarding the challenging side of the integration, there is still room for improvement for a better organization and collaboration between the teachers to eliminate the confusions about deadlines and instructions. Our first year experiences showed us that in integrated teaching there must be a closer collaboration among the teachers and a very careful planning. In most of the cases it is necessary to rethink the course planning and to adjust the different theory chapters according to the other course need. The possible timing of the laboratories might sometimes be difficult because of the space and time constraints. Common meetings and discussions need to be done and the participating teachers have to learn a lot about each other’s materials. This might be time consuming in the beginning, but later will probably ease the teachers’ work. Other benefit of teacher collaboration is the more holistic view of the teaching program they gain through course connections, having the effortless possibility to teach their own material through more “natural” and meaningful topics that align within the program.

6 IMPROVEMENTS FOR FUTURE

Course integration or interdisciplinarity it is taken in application already in the Degree Programme of Environmental Engineering since 2013 fall. Based on the results of this work we can conclude that learning outcomes are good. Improvement is still needed however in teacher collaboration and timing to avoid student confusion. Other disciplines, such as mathematics and physics should in some form be connected to the courses mentioned in this work.

With respect to Chemistry and professional disciplines, there are endless common interfaces in between. Among the many possibilities the aspects should be emphasized in future are the environment and green chemistry. Small problem-based tasks that require environmental considerations, support the chemistry theory and are meaningful tasks in the professional course as well would engage students even more in the process of constructing their own knowledge. These could include laboratory works and/or recent technologies, reporting and language course or could be in form of project studies.

7 LITERATURE

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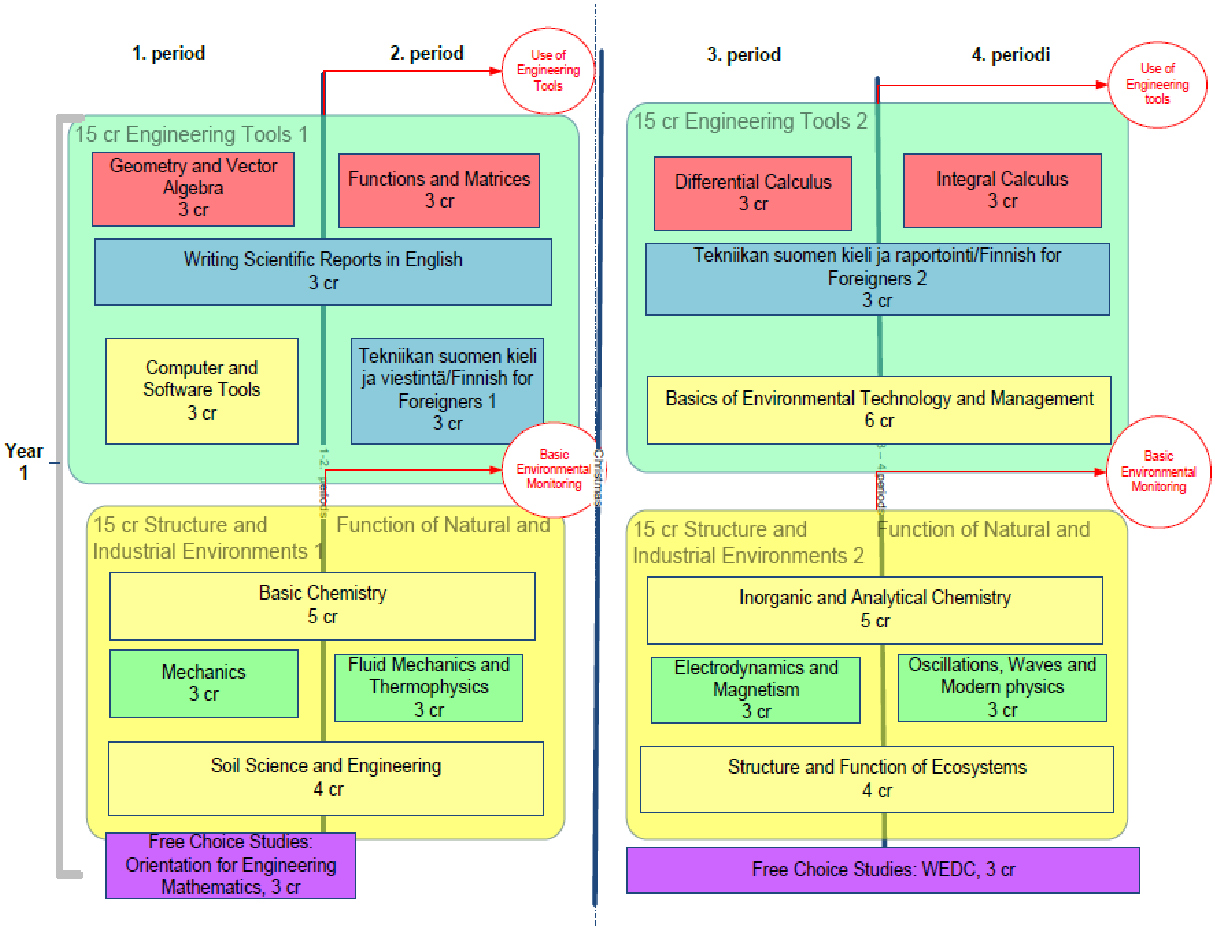
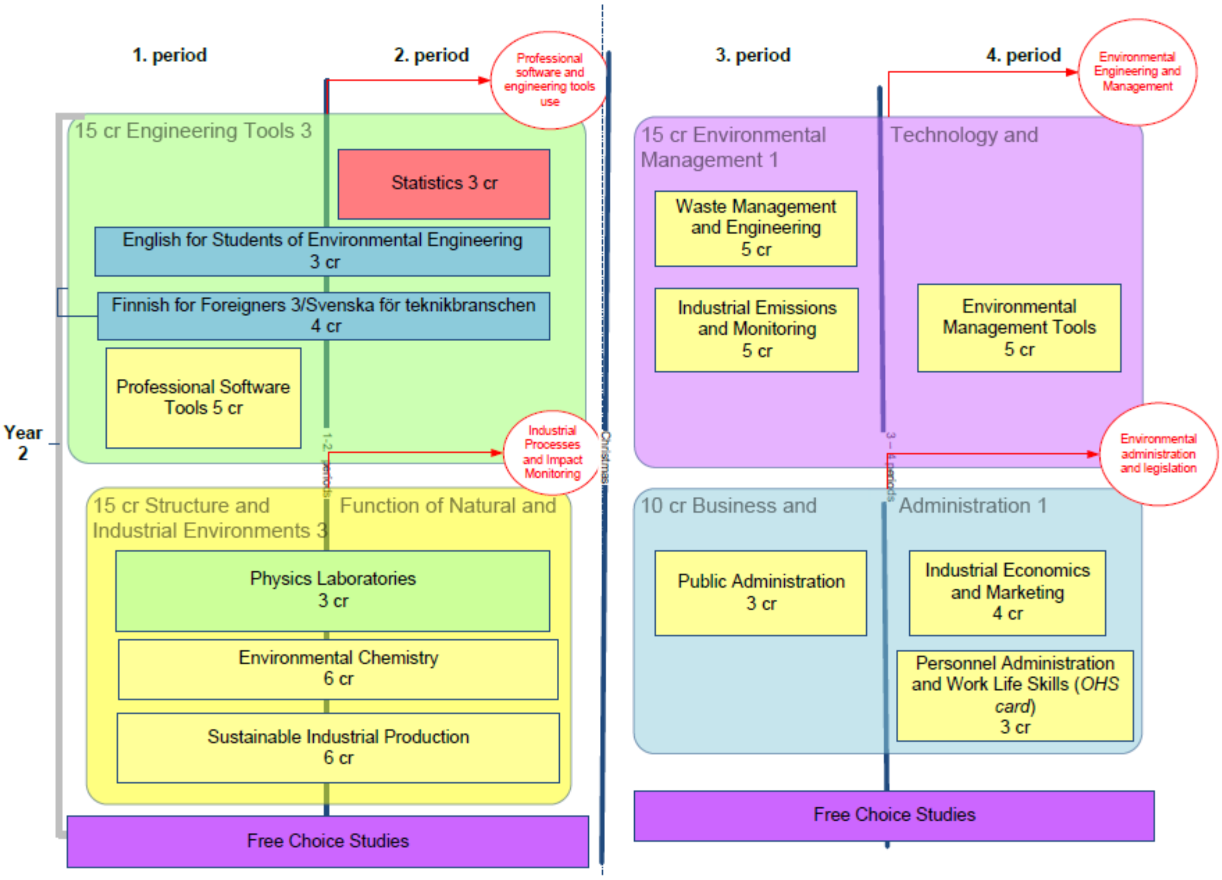
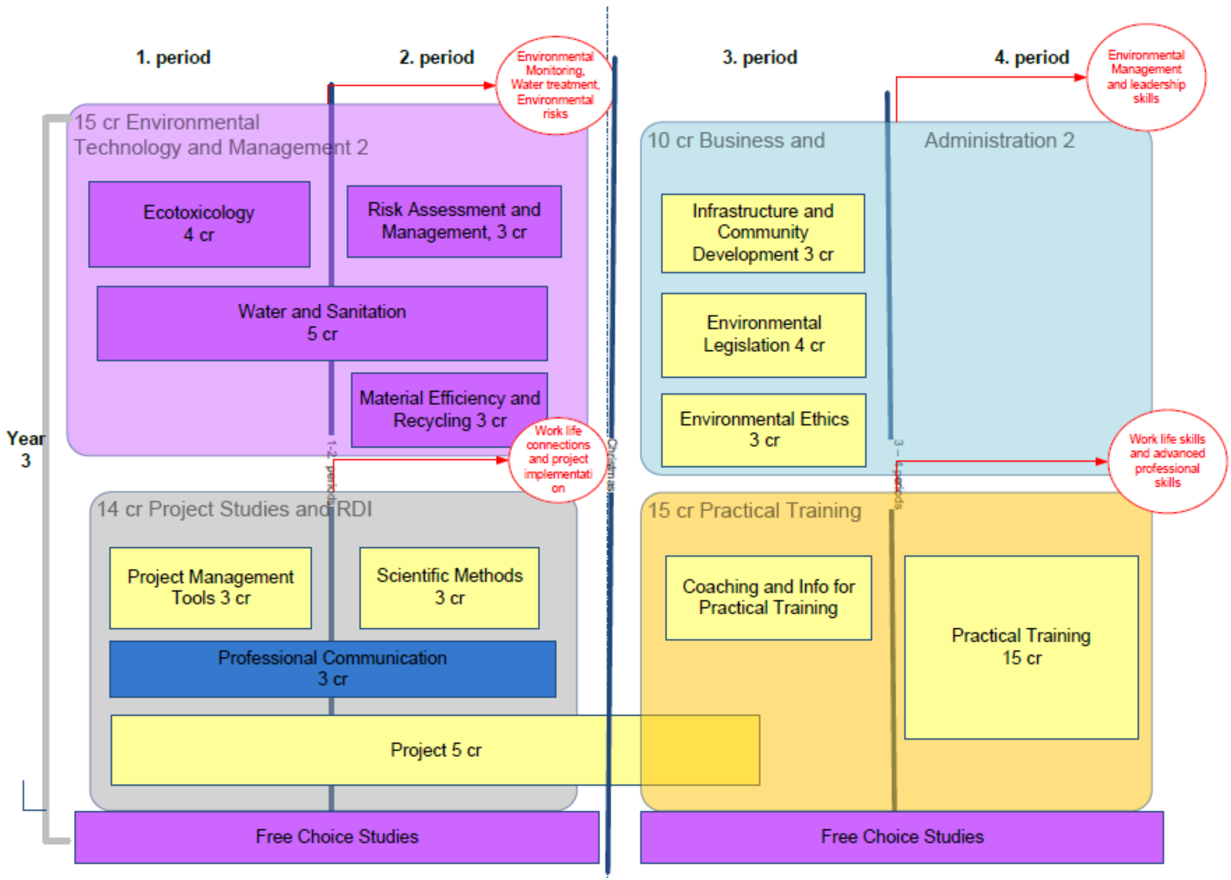
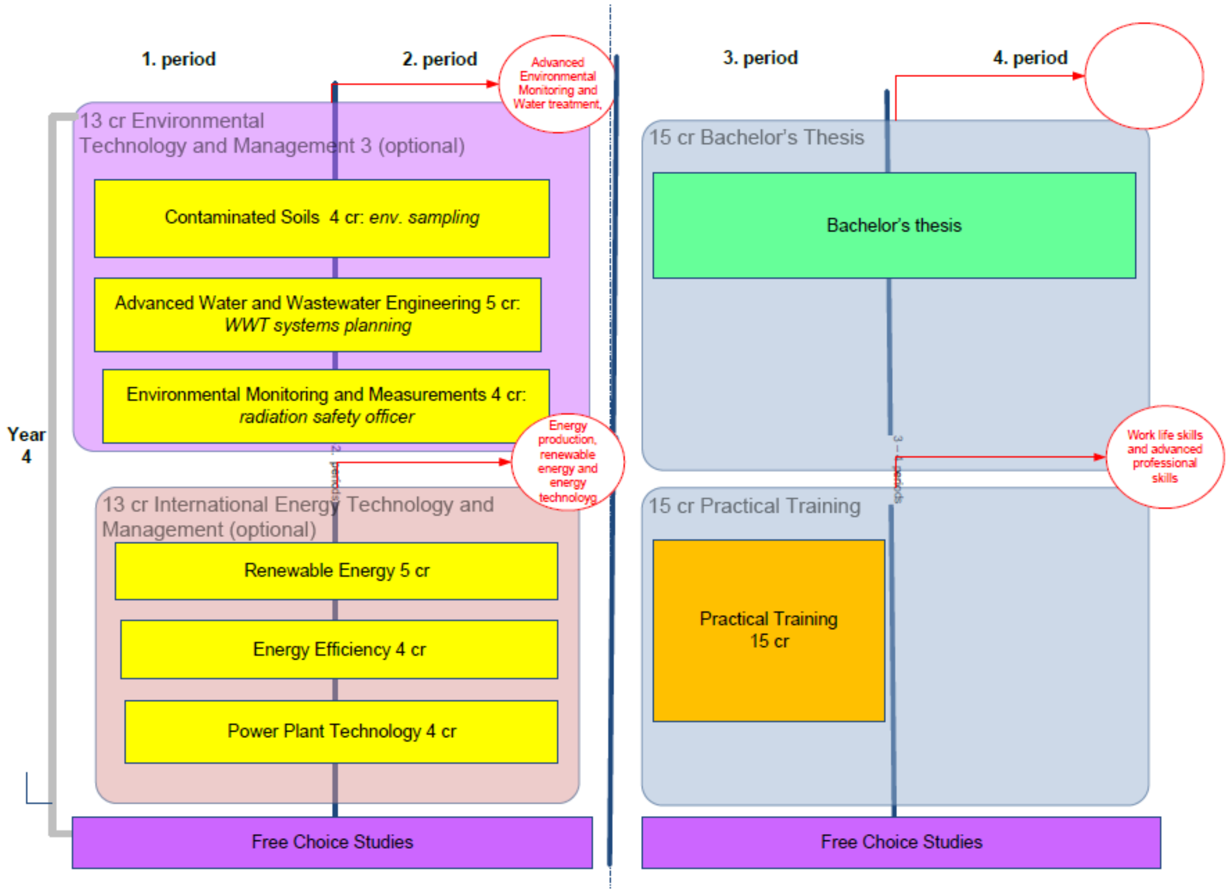
8 APPENDICES

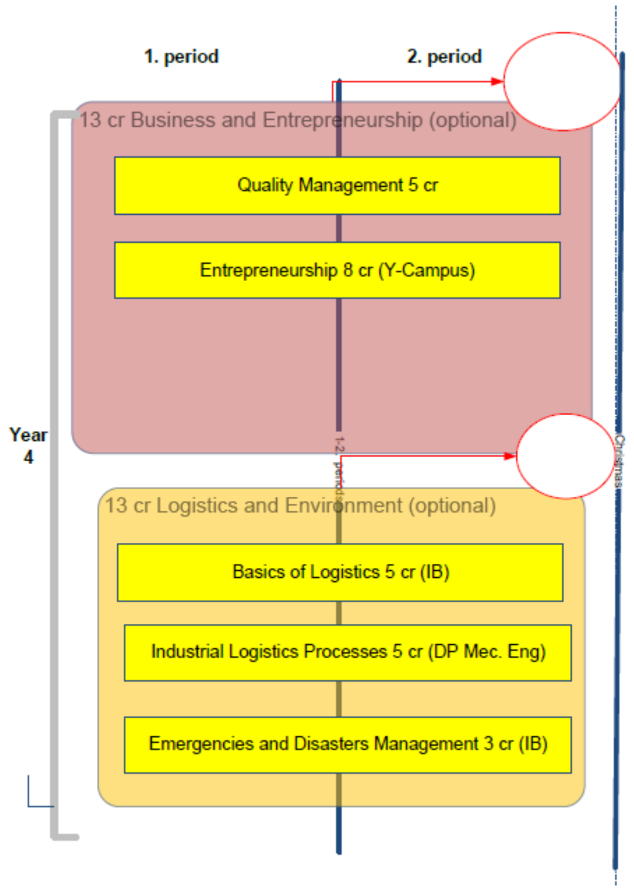
Appendix 1.




1. period
2. period
3. period
4. period
Professional software and engineering tools use
Environmental Engineering and Management
15 cr Engineering Tools 3
Statistics 3 cr
English for Students of Environmental Engineering 3 cr
Finnish for Foreigners 3/Svenska för teknikbranschen 4 cr
Professional Software Tools 5 cr
Year 2
Industrial Processes and Impact Monitoring
15 cr Structure and Function of Natural and Industrial Environments 3
Physics Laboratories 3 cr
Environmental Chemistry 6 cr
Sustainable Industrial Production 6 cr
Free Choice Studies
Christmas
1-2 periods
15 cr Environmental Technology and Management 1
Waste Management and Engineering 5 cr
Industrial Emissions and Monitoring 5 cr
Environmental Management Tools 5 cr
Environmental administration and legislation
3-4 periods
10 cr Business and Administration 1
Public Administration 3 cr
Industrial Economics and Marketing 4 cr
Personnel Administration and Work Life Skills (OHS card) 3 cr
Free Choice Studies


1. period
2. period
3. period
4. period
Environmental Monitoring, Water treatment, Environmental risks
Environmental Management and leadership skills
15 cr Environmental Technology and Management 2
Ecotoxicology 4 cr
Risk Assessment and Management, 3 cr
Water and Sanitation 5 cr
Material Efficiency and Recycling 3 cr
Work life connections and project implementation
Year 3
14 cr Project Studies and RDI
Project Management Tools 3 cr
Scientific Methods 3 cr
Professional Communication 3 cr
Project 5 cr
Free Choice Studies
Christmas
1-2 periods
10 cr Business and Administration 2
Infrastructure and Community Development 3 cr
Environmental Legislation 4 cr
Environmental Ethics 3 cr
Work life skills and advanced professional skills
3-4 periods
15 cr Practical Training
Coaching and Info for Practical Training
Practical Training 15 cr
Free Choice Studies


1. period
2. period
3. period
4. period
Advanced Environmental Monitoring and Water treatment,
Year 4
13 cr Environmental Technology and Management 3 (optional)
Contaminated Soils 4 cr: *env. sampling*
Advanced Water and Wastewater Engineering 5 cr: *WWT systems planning*
Environmental Monitoring and Measurements 4 cr: *radiation safety officer*
Energy production, renewable energy and energy technoloyg
13 cr International Energy Technology and Management (optional)
Renewable Energy 5 cr
Energy Efficiency 4 cr
Power Plant Technology 4 cr
Free Choice Studies
15 cr Bachelor's Thesis
Bachelor's thesis
Work life skills and advanced professional skills
15 cr Practical Training
Practical Training 15 cr
Free Choice Studies


1. period
2. period
Year 4
13 cr Business and Entrepreneurship (optional)
Quality Management 5 cr
Entrepreneurship 8 cr (Y-Campus)
Christmas
13 cr Logistics and Environment (optional)
Basics of Logistics 5 cr (IB)
Industrial Logistics Processes 5 cr (DP Mec. Eng)
Emergencies and Disasters Management 3 cr (IB)

Appendix 2

Feedback on integration of three courses: *Soil Science and Engineering; Basic Chemistry; Writing Scientific Reports in English*

1. Do the shared laboratory works and reports improve learning ? (Yes/no/I do not know)

2. What was in your opinion successfully implemented in connecting the three courses?

3. What was in your opinion not successfully implemented in connecting the three courses?

4. What you have learned (best) from connecting the courses? (in general and in each discipline separately)

5. What you did not like in connecting the courses? (What was bad, annoying, stressful, what you could have done better….?)

6. What suggestions you have to improve course connection?

7. Any other comments or suggestions to teachers….