ANALYZING THE MEANING OF INTERDISCIPLINARY IN THE CDIO CONTEXT

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ABSTRACT

Companies search for potential recruits with interdisciplinary skills. Consequently, to meet this requirement, universities and teaching institutions develop and offer interdisciplinary courses and programs. However, the meaning of interdisciplinarity varies between different actors. In order to be able to compare, monitor and evaluate concepts, it is important to ensure that the concept have the same meaning and content for all actors. Hence, the purpose of this paper is to describe the term interdisciplinarity and its application in higher education with specific focus on CDIO related literature. Moreover, dimensions of interdisciplinarity will be illustrated in an ongoing master program.

This paper consists of two parts. The first part is a theoretical study conducted in order to describe the concept and illustrate the width of applications of interdisciplinarity in the CDIO context. For this purpose, the content of the CDIO knowledge library was surveyed using the following key words: inter*, cross*, trans*, interdisciplinary*, crossdisciplinary*, and transdisciplinary*. The second part is empirical in nature and describes an on-going interdisciplinary master program named “Innovation through Business, Engineering and Design” offered at the Linnaeus University, Sweden, as well as its dimensions of interdisciplinary.

The CDIO approach advocates integrated learning experiences and the use of disciplinary competencies for solving interdisciplinary problems. This is reflected in the body of knowledge represented by the CDIO library: most of the articles reviewed in this study are describing interdisciplinary or transdisciplinary activities. The interaction could be between subjects, skills and courses within the discipline, i.e. in a cross-disciplinary or multidisciplinary mode, or between students representing different disciplines in multidisciplinary, interdisciplinary or transdisciplinary mode. Faculty staff acts as designers and enablers of these activities, both in terms of curriculum development on strategic level and activity creation and activity execution on the operational level. The practical example given in the paper illustrates the importance of an effective administration for succeeding with interdisciplinary activities.

KEYWORDS

Interdisciplinarity, Literature survey, Master program in innovation, Standards: 3, 5, 7, 8

INTRODUCTION

Interdisciplinary studies will prepare the students to meet the complex behavior they will face in their future working life (Newell, 2012). Most modern companies are looking to hire graduates with interdisciplinary skills, so it is important for universities and teaching institutions to encourage interdisciplinary programs (Vanstone et al., 2013). Consequently several universities and teaching institutions have developed interdisciplinary courses to meet the need from future employers, see for instance Augsburg (2003) and Duffield et al. (2012). Interdisciplinarity has multiple faces and the contents vary among involved actors, Nikitina (2006). Supplementary, it is difficult to identify indicators of interdisciplinarity (Porter & Chubin, 1985). Davies and Devlin (2007) define interdiscplinarity as the integration of two or more disciplines in the education. A more elaborated definition is found in Pharo et al. (2012, p. 498): "…the integration of disciplinary perspectives to produce insights that are more than the summing of disciplinary knowledge".

Meeth (1978) describe levels of interdisciplinarity: intradisciplinar, cross-disciplinar, multidisciplinar, interdisciplinar and transdisciplinar. Intradisciplinar studies are studies within one discipline. In cross-disciplinar studies one discipline is viewed from the perspective of another discipline. Multidisciplinarity occurs when multiple, discrete disciplines are applied for solving a common problem. Each discipline suggest solutions to the problem, no knowledge transfer exists though. Interdisciplinary studies also apply different disciplines, but in a more active way for solving the problem. The problem itself thus requires multiple disciplines for being solved. Transdisciplinary goes beyond the disciplines. While interdisciplinary studies start with the discipline, transdisciplinary studies starts with the issue or problem to solve. Davies and Devlin (2010) claim that there are a number of variants of interdisciplinarity and propose three new terms: relational, exchange and modification interdisciplinarity. Relational interdisciplinarity is when a common subject is discussed using related disciplines. These related disciplines are used rather as perspectives on the common subject, and the aim is not integration of disciplines. Relational interdisciplinarity thus resembles the term multidisciplinarity. Exchange interdisciplinarity maintains the disciplinary integrity, but uses other disciplines for a critical exchange of perspectives.

The need for students with interdisciplinary knowledge cannot be mistaken, however interdisciplinary knowledge and skills have many faces and expressions and hence the question arises; How can the concept of interdisciplinary be applied in higher education? Hence the purpose of this paper is to define interdisciplinary and its application in higher education with a specific focus on CDIO related literature and illustrate dimensions of interdisciplinarity in an ongoing master program.

APPLICATION OF INTERDISCIPLINARITY IN THE CDIO CONTEXT

Study description

Our research is based on a literature review focusing on interdisciplinary articles and the meaning of interdisciplinarity. The literature review has been based on articles presented and published in former CDIO conferences and its accompanying papers. The content of the CDIO knowledge library was surveyed using following key words: inter*, cross*, trans*, interdisciplinary*, crossdisciplinary*and transdisciplinary*. The survey resulted in 47 hits representing 43 unique articles. Of these 8 were not within the topic, 6 tangent the topic but were outside the actual investigation area and 29 were relevant, see table 1. The activities described in the CDIO literature were categorized and analyzed with respect to two aspects: type of activity and type of interaction. The summarized results of the study are found in appendix 1. In the following, the main findings are presented.

Interdisciplinary defined in the CDIO context

Few publications include a definition of interdisciplinarity. Nordal and Busk Kofoed (2012) use the definition by Meeth (1978) that describes levels of interdisciplinarity. They also discuss the T-shaped student, i.e. a student with both disciplinary and interdisciplinary skills. The theory of T-shaped people is also used as a theoretical foundation in Elmquist and Johansson (2011). Kans et al. (2014) discuss variations of cooperation, including interdisciplinary cooperation, and use definitions by Davies and Devlin (2007) and Pharo et al. (2012) that address the characteristics as well as variations of interdisciplinarity, and Waterman et al. (2011) that discusses interdisciplinary cooperation. Spooner (2011) argues for the transdisciplinary approach to product and process design. They declare that transdisciplinarity puts focus not only on the problem solution but also on the problem choice. Moreover, they propose the cooperation between faculty staff: “to achieve a virtually seamless product experience, design staff must constantly cross disciplinary boundaries.” Jørgensen et al. (2011) propose an own multidisciplinary approach for design engineering consisting of "creative, synthesis oriented competences", "innovative, socio-technical competences" and "reflective technological engineering competences".

Table 1. Results by key word

Key word	Hits	Relevant*	Related	Not relevant
Cross	8	6	0	2
Inter	3	3	0	0
Trans	0	0	0	0
Crossdisciplinary	6	4	3	0
Interdisciplinary	27	17	3	6
Transdisciplinary	3	3	0	0
Total	**47**	**33**	**6**	**8**

* The number of unique articles was 29

The most commonly used term for describing the interdisciplinary activity is “interdisciplinary”. 13 out of 29 articles use this term. The terms “multidisciplinary” and “cross-disciplinary” is used in 6 articles each. ”Transdisciplinary” is used in 3 articles while 2 articles did not use any explicit term for describing the activity. Interdisciplinary activities are found in all kinds of subject areas and the articles represent all types of engineering education. The level of education is both undergraduate, mainly Bachelor of Engineering, and graduate, i.e. masters level. Main part of the articles describes activities on undergraduate level, with one interesting exception: For articles using the term “multidisciplinary” the activities are evenly distributed between levels. Some articles described activities on both undergraduate and graduate level.

Interdisciplinary activities in the CDIO context

The type of activities spanned from modules in a course, such as an examination form, an exercise or a workshop, to full programs. The activity could thus be a module, a project, a course, several courses or a full program. In addition, one article describes an interdisciplinary mechatronics platform used for several types of interdisciplinary activities (Habash et al., 2010). The most common types of activities are projects and courses. Examples of interdisciplinary courses are found in seven of the articles. Some courses are given within one program, thus mainly promoting the students to use different disciplines to solve a task or study a concept, such as the obligatory introductory engineering project courses described in Wetterö et al. (2006) and Ingeman-Nielsen and Christensen (2011). The latter course trains teamwork and project management skills, communication and writing skills as well as critical thinking, while applying disciplinary knowledge. The Materials Project Laboratory course at MIT integrates material science, business economics and communication in a project-based setup (Tarkanian and Caulfield, 2013). Courses and projects that in an interdisciplinary mode collaborates with other courses given during the semester are found in several programs at DTU, see for instance Jørgensen et al. (2011), Clement et al. (2011) and Birk et al. (2014). This is the result of a university wide adaptation of CDIO in 2008.

Most of the interdisciplinary activities are obligatory for students enrolled in certain programs, but other initiatives are voluntary, such as those described in Al-Atabi (2013) and Törnqvist (2015).Some courses are cross-disciplinary and engage students from two or more programs and/or disciplines, such as the course taken by Architectural Engineering and Civil Engineering students (Karlshøj and Dederichs, 2011). The multidisciplinary capstone course described in Seidel et al. (2011) is run in collaboration with several faculties (Engineering, Business, Creative arts). Spooner et al. (2011) reports on transdisciplinary product design projects engaging engineering, industrial design and business students. In Kans et al. (2014) four project-based courses which mix students from different programs and/or universities are described. An approach to restructure two master's programs for allowing more cross-disciplinary collaboration is found in Elmquist and Johansson (2011). A new introductory course, a joint second semester course and more collaboration in the final degree project were suggested.

Course modules are described in three articles. Sunnerhagen et al. (2006) describe an examination form with an interdisciplinary context, in which chemical biology students presents research plans for medical doctors. Being experts in the discipline but not in research methods the medical doctors ask questions to the students, and the ability to describe, explain and reason around the subject is graded by the teachers. A company based workshop in product design which forms a part of an interdisciplinary course is described in Elmquist et al. (2014). The course is a joint course for students enrolled in three different master programs and the workshop was developed by faculty representing these disciplines. Palm and Törnqvist (2015) describe a course module which includes the subject specific as well as soft sides of technical projects, such as group processes and ethics. The paper addresses the possibilities to integrate ethical aspects in a technical project course by real-life resembling scenario cases.

Two articles address interdisciplinary educational programs. Nordahl and Busk Kofoed (2012) describe interdisciplinary programs in Medialogy, which is defined by the authors as an interdisciplinary science. Helenius (2010) describe a multidisciplinary master program with cross-disciplinar intake of students. The program recruits students from computer science, software engineering, information systems, telecom or digital media. In addition, several cross-program initiatives are described. An institution wide adaptation of more than 30 programs to the CDIO approach assisted by a cross-disciplinary faculty team described in Leong-Wee and Pee (2007) resulted in a revised syllabus, a new engineering introduction course and improvement in the third year project course. Lourenço Jr and Veraldo Jr (2015) also report on a school wide reforming of the syllabus, affecting six engineering programs. The paper describes interdisciplinary projects each semester covering at least two disciplines and covering both soft and hard skills. In the multidisciplinary engineering design course described in Tien and Hajibeigy (2014) two students from each discipline form teams and apply mainly their disciplinary knowledge to create functioning artifacts.

An approach to link academy and industry is described in de Roza (2010). Amongst the various activities and platforms the paper mentions multi-disciplinary industrial projects which involve students and staff from different disciplines. The curriculum is flexible and schedules are designed to enable and support student participation in industrial projects. The opposite problem occurred in Rudd et al. (2011), i.e. obstacles to succeed with interdisciplinary projects due to tight and fixed schedules. Rudd et al. report on four System Engineering projects within the involving sixteen students from four different majors and three departments. The interdisciplinary teams developed functioning prototypes for various needs, and amongst the lessons learned was that teams working in a web-based mode due to conflicting schedules affected the outcome negatively.

Interdisciplinary interactions in the CDIO context

The type of interdisciplinarity was categorized with respect to the entities which interact. Subject interdisciplinarity is when different subjects are combined and/or required for the activity. Student interdisciplinarity requires students from different disciplines to interact. Staff interdisciplinarity describes activities where faculty staff representing different disciplines interacts. In addition, we also noted if the activity address interaction with industry. The majority of the papers describe activities in which different subjects interact, see Appendix 1. Such descriptions can be found in almost half of the papers. The common characteristic of subject interactivity is that it exists within the same study program. The activity, often in project form, requires or uses previous knowledge or skills gained in the course or in previous courses for solving a problem or investigating a phenomenon. Some of the programs are interdisciplinary in their nature and would naturally train students in an interdisciplinary mode, see Nordahl and Busk Kofoed (2012) and Helenius (2010).

The interaction between students from different disciplines and programs is described in twelve of the papers. In most cases the interaction happens between different engineering students while other initiatives are school or university wide, see previous descriptions above. Several of the activities are focusing on solving industry or societal problems. Six papers describe interaction with industry. In addition, interaction between students and professionals is found in Sunnerhagen et al. (2006), see above for a description of the activity. Faculty staff interaction is addressed in eight of the papers. Staff often interacts in teams for developing curricula, courses or modules and for running different activities, but de Roza (2010) also give examples of staff and student interaction in industrial projects. An example of an interdisciplinary program at Linnaeus University is given in the following section.

APPLICATION IN HIGHER EDUCATION EXAMPLE: INNOVATION THROUGH BUSINESS, ENGINEERING AND DESIGN

The master program Innovation through Business, Engineering and Design was developed in line with the Linnaeus University vision (Linnaeus University, 2015):

"a creative and international knowledge environment promoting curiosity, creativity, companionship and utility"

The program is a two-year Master's program that aims to develop the students' ability to work in interdisciplinary groups as well as to deepen their subject knowledge. The program trains students in project and innovation management, process and product development, business and system development, and social entrepreneurship.

This program reveals several dimensions of interdisciplinarity:

- **Student groups**

In order to create interdisciplinary learning for the students enrolled in this program, the students work together in groups with students from other faculties/disciplines (the involved faculties are Business Administration, Engineering and Design). Each group consists of equal number of students from engineering, design, and business administration. The students will work in the assigned interdisciplinary groups throughout the semester. The groups are rearranged, with regard to its members, to the coming semester.

- **Problem/task for the student groups**

Focus in the fall semester is local innovation and innovation in local companies and in the spring semester are multinational companies, non-governmental organizations, and other organizations. In the student's work are of interdisciplinary nature; the innovation should be able to balance the different process parts with respect to function, design, durability, production conditions, and business administration. This requires knowledge of, and interaction between, different disciplines where different perspectives and approaches are utilized. The student groups receive a project, (in form of briefs) from the problem owners (industry or society), that is supposed to be solved within these groups. The students act as problem solvers weighing and balancing each subject and the final solution, proposed by the students, consists of a wide-ranging solution taking the involved subjects into consideration.

- **Faculty members, curriculum, and administrative task**

While the students carry out their interdisciplinary project, the students are enabled and facilitated by the university in different ways; faculty members, curriculum, and administrative staff. While the students are carrying out their projects, faculty members hold lectures and provide tutoring both individually, and in groups of faculty members coming from different disciplines. At several occasions aligned with the different development phases of the project, an interdisciplinary team of faculty members within different subjects provide tutoring for the student groups. The program curriculum states that the students should be able to demonstrate an understanding of the increase in value of interdisciplinary collaboration. This is further developed in the course syllabus where it is stated, for instance, that the students should plan and carry out an interdisciplinary process and project and discuss the connections between the contributions of different fields of competence in an interdisciplinary project. As the students belong to different faculties, it is necessary that the administrative staff are working together in order to solve the practical problems that appear, and to prevent future problems. There are several different administration functions, such as grade reporting and schedule arrangements, involved and the functions ensure that all students have the same conditions.

RESULTS AND CONCLUSIONS

The CDIO approach advocates integrated learning experiences and the use of disciplinary competencies for solving interdisciplinary problems. This is reflected in the body of knowledge represented by the CDIO library: most of the articles reviewed in this study are describing interdisciplinary or transdisciplinary activities, as defined in Meeth. Terminology confusion seems to exist though; interdisciplinary activities are referred to as cross-disciplinary, multidisciplinary as well as interdisciplinary, and few articles include a definition of interdisciplinarity. This indicates a need for better understanding of the interdisciplinary concept in the CDIO community.

Most activities identified in the articles, whether in course, project, or course module form, are curricular activities. This implies that in order to successfully implement interdisciplinary activities, these should be regulated in the curriculum. The interaction could be between subjects, skills and courses within the discipline, i.e. in a cross-disciplinary or multidisciplinary mode, or between students representing different disciplines in multidisciplinary, interdisciplinary or transdisciplinary mode. Faculty staff acts as designers and enablers of these activities, both in terms of curriculum development on strategic level and activity creation and activity execution on the operational level. The practical example given above illustrates the importance of an effective administration for succeeding with interdisciplinary activities. This implies that faculty members, both administrators and teachers, have to work in interdisciplinary teams. Industry interaction is found especially in activities that are interdisciplinary and transdisciplinary, and which involves students from several programs and faculties. Industry related problems are by nature more complex which requires higher levels of interdisciplinarity.

This article is based on the meaning and contents of interdisciplinarity. However, developing interdisciplinary programs implies breaking the traditional university structure in which ordinary ways of developing programs are outdated. Hence additional research needs to be conducted on how to realize an interdiciplinary program as well as for identifying resources needed and success factors. Another interesting aspect for further studies is the students' learning with regards to interdisciplinarity and how it is possible to measure that the students attain interdisciplinary knowledge.

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BIOGRAPHICAL INFORMATION

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APPENDIX 1. SUMMARY OF LITERATURE REVIEW RESULTS

Author	Subject and level	Type of learning activity*	Type of interdisciplinarity*
Sunnerhagen et al. (2006)	Chemical biology. Master.	Examination form.	***Interdisciplinary*** context: students and examiners from different disciplines.
Wetterö et al. (2006)	Engineering biology. First year in a masters programme.	Full course "Engineering Project for Engineering Biology" with an ***interdisciplinary*** task.	Between subjects.
Leong-Wee and Pee (2007)	Engineering programmes. B eng.	Final year project.	***Cross-disciplinary*** staff team. (In the final year project combinations of different subjects/disciplines.)
de Roza (2010)	Engineering programmes. All levels.	***Multidisciplinary*** industry projects.	Staff and students cooperate with industry in projects.
Habash et al. (2010)	Mechatronics for all types of engineering students. B eng.	A mechatronics platform that is utilised for interdisciplinary teaching.	Using an ***interdisciplinary*** platform for integrating students. Between subjects. Students interact as well.
Haeck (2010)	Engineering programmes.	The whole university.	Academic staff should cooperate in creating ***transdisciplinary*** programmes.
Helenius (2010)	Service design and engineering (students from computer science, software engineering, information systems, telecom or digital media). Master.	Full ***multidisciplinary*** programme with ***cross-disciplinar*** intake of students.	Between students in the programme, also industry application. Between faculty members in the design of the programme.
Clement et al. (2011)	Biochemical engineering. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.
Elmquist and Johansson (2011)	Product development, production management. Master.	Joint courses and joint degree project.	Between students representing different disciplines. ***No explicit use of terms multi, inter, cross or transdisciplinarity.***
Ingeman-Nielsen and Christensen (2011)	Arctic Technology. B prof.	***Interdisciplinary*** course "Site investigations".	Between subjects.
Jørgensen et al. (2011)	Design and innovation. Bachelor (master).	Thematic semesters with integrated ***multidisciplinary*** projects.	Between subjects and in curriculum.
Karlshøj and Dederichs (2011)	Architectural Engineering and Civil Engineering. Master.	A ***multidisciplinary*** course in "Advanced building design".	Multidisciplinary team of professors, between students.
Kjærgaard et al. (2011)	Electronics. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.
Krogsbøll et al. (2011)	Civil engineering. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.

Rudd et al. (2011)	Officers' education, subject systems engineering. Undergrad.	***Interdisciplinary*** capstone projects outside the normal curricula.	Project level. Students made teams but mainly used their disciplinary knowledge.
Seidel et al. (2011)	Several faculties; Engineering, Business, Creative arts. B eng.	A ***multidisciplinary*** capstone course "Advanced innovation and new product development".	Between faculty staff. Students from five different faculties in the same course working with industry.
Spooner et al. (2011)	Engineering, industrial design and business students work on product design. B eng.	***Transdisciplinary*** projects.	Between students working with industry.
Nordahl and Busk Kofoed (2012)	Medialogy, which is an ***interdisciplinary*** science. Bachelor and master.	Full programme and projects that are ***interdisciplinary*** and ***transdisciplinary***.	Between subjects.
Al-Atabi (2013)	Chemical, electrical, electronic and mechanical engineering. B eng.	Voluntary programme consisting of several courses.	Seems like the students work in ***interdisciplinary*** teams.
Tarkanian and Caulfield (2013)	Material science. B eng.	Specific ***interdisciplinary*** project course. Mandatory for material science majors.	Between subjects.
Birk et al. (2014)	Food science B eng.	***Interdisciplinary*** course "Food microbiology".	Between subjects.
Elmquist et al. (2014)	Product development, Product development and materials engineering and Industrial design. Master.	Company based workshop, in an ***interdisciplinary*** course" Materials and design".	Between staff and between students solving an industry problem.
Kans et al. (2014)	Mechanical engineering. B eng, bachelor.	Different courses including ***interdisciplinary*** cooperation.	Between staff and between students.
Rebrin et al. (2014)	Metallurgy. B eng.	***Interdisciplinary*** project course spanning 5 semesters.	Between subjects.
Tien and Hajibeigy (2014)	Engineering; in the paper mechanical engineering and electrical engineering. B eng.	***Multidisciplinary*** project in the course "Multidisciplinary Engineering Design".	Between students representing different disciplines.
Lourenço Jr and Veraldo Jr (2015)	Engineering programmes. B eng.	***Interdisciplinary*** projects every semester.	Between subjects.
Nyborg et al. (2015)	Software technology, IT and Economics, IT Electronics. B eng.	***Interdisciplinary*** project courses, both within and across programmes.	Between students and subjects.
Palm and Törnqvist (2015)	Information technology. B eng.	Course module.	Between subjects and skills. ***No explicit use of terms multi, inter, cross or transdisciplinarity.***
Törnqvist (2015)	Various subjects at the faculties of Arts and science, the Institute of technology and the Faculty of health sciences. Later part of bachelor and master.	Full course "***Cross Disciplinary*** Projects".	Between students representing different disciplines aiming at solving an industrial/societal problem.

* The terms marked in bold italic is the term used by the authors of the original article