LEARNING THROUGH CONSTRUCTION IN IT COURSES

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In the Norwegian Center for Excellence in IT education (Excited), there are 19 IT study programs across two universities with six campuses. One of the goals of Excited is to gain more knowledge about "learning through construction"(LtC) in IT studies. The paper presents preliminary findings on characteristics of courses with "learning through construction" in bachelor and master courses with project-based learning in the spring semester of 2017. The LtC courses are characterized through a number of variables from a categorization model of project courses: teaching context, range of implementation, learning context, institutional context, personnel composition, grading, project variety, degrees of freedom of the process and in the deliverables. Our findings show that "learning through construction" is often used as a learning method in higher IT education because constructive skills are a highly valued learning outcome, and to develop such skills, it is necessary to practice. At the same time, the teachers conclude that the learning method is motivating for students and is stimulating creative thinking, and that project work is useful because the students will be better prepared for project work also after their studies. Our findings also shows that there are "learning through construction" courses on all study years of the bachelor and master study programs, and that some study programs have a maker focus in each semester. Some projects are individual work, but the majority of the projects are group work, often in small (2-4) or medium-sized (5-10) teams. Most of the time, the students organize the teams themselves, but in some cases the teams are set up by the faculty. When it comes to student autonomy, the students experience more freedom further into their education, as there are more flexible project processes in the later study years. The products of the student projects are typically software prototypes and product documentation/software design, more specifically the main product types are games and web applications. Some courses with learning through construction use external stakeholders in the student projects. The study also shows that the implementation of learning through construction projects varies across study years and study programs.

1. INTRODUCTION

The concept of "learning through construction" (LtC) involves project-based learning where the students get hands-on and relevant industry experience in a learning process where the students (often in groups) produce a product. In IT courses this typically is a digital product, e.g. an app, a game, a web site etc. "Learning through construction" involves a focus on skills as a valuable learning outcome. In the Norwegian Center for Excellent IT education (Excited), there are 19 study programs within IT. Among these study programs there are more than 70 courses, which mainly or partly has "learning through construction" as a pedagogical approach to learning. One of the Center's goal is to gain more knowledge about the concept of learning through construction in higher IT education, and the main aim of this paper is to look at the characteristics of such courses within the field of IT in tertiary education.

Learning through Construction can be regarded an approach with clear components from the theories of Problem-based Learning (PBL), but with focus on the importance of producing a digital product. In Kay et. al. (2000), PBL is summarized to consist of the following characteristics: open-ended, authentic, substantial problems that drive the learning; explicit teaching and assessment of generic and metacognitive skills; and collaborative learning in groups. Darus et al (2016) defines PBL to consist of the following elements: Self-Directed learning, Self-Reflective Students and the Perception of teachers as facilitators more than knowledge disseminators. Self-directed learning is described as independence and freedom of choice on the part of the students to determine their own learning objectives and activities.

In addition, LtC has clear components from Papert's theory of constructionism, where the focus is on "project development and the construction of knowledge resulting as a consequence of that activity, often in a computational context" (Stager, 2005). Comparing constructivism and constructionism, Stager (2005) explained: "While constructivism defines learning as the building of knowledge structures inside of one's head, constructionism suggests that the best way to ensure that such intellectual structures form is through the active construction of something outside of one's head, that is something tangible, something sharable". Papert and Harel (1991) warn about translating constructionism into "learning by making", which they describe as a simplified understanding of the concept. Ackermann's (2001) work on comparing constructivism and constructionism concludes that "Piaget and Papert are both constructivists in that they view children as the builders of their own cognitive tools, as well as of their external realities. For them, knowledge and the world are both constructed and constantly reconstructed through personal experience. Each gains existence and form through the construction of the other. Knowledge is not merely a commodity to be transmitted, encoded, retained, and re-applied, but a personal experience to be constructed. … Papert's constructionism, in other words, is both more situated and more pragmatic than Piaget's constructivism [or Vygotsky's socio-constructivism]." Papert's constructionism focuses more on the art of learning, or 'learning to learn', and on the significance of making things in learning." (Ackermann, 2001). Munkvold (2017) looks at learning through construction in a specific course called Game lab, focusing on the importance of producing an artefact and proving this an important element in regards to students' motivation in IT project based courses. He defines LtC as "the process of learning when creating a digital artifact (e.g. digital game, digital app or similar)".

Projects are common in the IT industry, and it is therefore important that IT students experience project work during their education. Development-oriented courses e.g. programming, software development etc. are courses where one often finds project-based learning. It is also important to note that project-based learning involves several aspects. Sindre et al (2015) present a classification of project-based learning, describing different variables of project learning: 1) Teaching context: According to Sindre et al (2015) the teaching context of project-based learning can mean that a project is the entire course, or a smaller part of a course which also includes more traditional teaching like lectures over a textbook. 2) Range of implementation: A project can range from one to many courses, and then either courses being taught in the same semester, or courses being taught in subsequent semesters. 3) Learning context: A project takes place after students have learnt relevant theory about necessary technology and methods (top-down approach), or instructor introduces the theory within a project framework (bottom-up approach). 4) Institutional context: A project can be implemented locally to one organization (typically the university), or involve other organizations (e.g. cross-institutional), furthermore projects' might also involve stakeholders (e.g. companies). 5) Personnel composition: A project can focus on individual team projects, or even larger constellations with large teams composed of smaller teams. Also, teams could be homogeneous (consisted of same course/field students) or heterogeneous. 6) Grading: Projects typically use Pass/Fail or a more granular grading scheme. In a team project, the policy could either be to give the same grade to all team members, though possibly with exceptions for extreme cases of non-contribution, or grades could be individual in spite of the deliverable being a team effort. 7) Project variety: Same project for every student/team, or unique projects, self-selected by the students, 8) Degrees of freedom of the process: The project process can range from a well-specified (e.g. what methods to be used, steps to be undertaken and deadlines) to a more flexible one, where the only thing that matters is the final deliverable, and 9) Degrees of freedom in the deliverables: Projects deliverable can range from very strict and well-defined, where instructors have specified in much detail what problem is to be solved and what should be delivered; to a more flexible one, where each team is completely free to decide what to develop as long as it relates to the learning goals (Sindre et al, 2015). This classification model was important while collecting data about the maker projects in IT courses. This is also partial focus in this paper, as we would like to compare our findings to the classification of Sindre et al (ibid).

In addition to comparing our findings to Sindre et al's categorization of project learning, we will also analyze our findings in the context of Bloom's revised taxonomy (Anderson et al, 2001), where learning is described in two dimensions; the cognitive process dimension and the knowledge dimension. The cognitive process dimension includes 1) Remember, 2) Understand, 3) Apply, 4) Analyze, 5) Evaluate,

and 6) Create, while the second dimension consists of factual, conceptual, procedural and metacognitive knowledge. Learning through construction involves design and construction and can be categorized into the cognitive process dimension "Create", and is considered as higher order thinking skills. LtC will often be categorized into Procedural knowledge of the knowledge dimension. Procedural knowledge is described as "how to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods", including knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods, and knowledge of criteria for determining when to use appropriate procedures (Anderson et al, 2001).

2. METHOD

To gain more knowledge about learning through construction we identified and mapped «learning through construction» courses within 14 study programs at NTNU and Nord University (9 bachelor programs, 4 master programs and 1 one-year program across all the six campuses. 2 bachelor programs and 3 master programs are not included so far). The study programs are taught at 6 different campuses, in addition to one online study program. To identify courses with an element of LtC, we contacted the study program coordinators who pointed out the courses with learning through construction in their study programs. This led us to find more than 70 courses within the 14 study programs, that to different extends were using an LtC approach.

To map the different properties of the LtC courses, we contacted the teachers responsible for the relevant spring courses, a total number of 33 courses. We have not been able to get in touch with a few university teachers, and in the study, we have mapped 33 out of 37 identified LtC courses. Together with the teachers, a questionnaire was filled out, mapping the different properties of the different courses. The questionnaire consisted of 37 questions, including some open-ended question, some multiple-choice questions, and some single choice questions. The questionnaire worked as a well-structured interview guide, where the researcher made notes on topics not represented in the questionnaire. The teacher was then asked to fill in these notes in the "Additional comments"-question of the questionnaire. It took approximately 30 minutes to answer the questionnaire. The teachers were in most cases interviewed online, using skype for business and the shared screen functionality.

3. FINDINGS

The following chapter will first present some general background information about courses with learning through construction projects. Then the findings will be structured based on the nine categories defined by Sindre et al (2015): 1) Teaching context, 2) Range of implementation, 3) Learning context, 4) Institutional context, 5) Personnel composition, 6) Grading, 7) Project variety, 8) Degrees of freedom of the process and 9) Degrees of freedom in the deliverables.

3.1 General information about learning through construction courses

Our findings shows that there are "learning through construction" courses on all study years of the bachelor and master study programs, and that some study programs have a maker focus in each semester.

The size of the courses with learning through construction varies from 5 ECTS to 30 ECTS, and the number of students in these courses varies from 9 to more than 400 students.

Figure 1: Class sizes of courses with learning through construction in our study

20 out of 33 courses with learning through construction have more than one university teacher contributing in the course. The table below shows that it is not unusual to have several university teachers involved in "learning through construction" courses, even in courses with a low number of students, but that the use of teaching assistants naturally grows as the class size increases.

Class size	Nr of teachers	Nr of teaching assistants
9-20 students	1-4	0
21-35 students	1-5	0-1
36-60 students	1-4	0-2
61-99 students	2-3	0-2
100-199 students	1-5	1-6
200-299 students	-	-
300 + students	2	7-14

Table 1: Class size and number of teachers and teacher assistants in the course.

The teachers report that the students get feedback on their project work in various ways. In some courses, the students are expected to ask for help when needed, while a number of courses have weekly meetings scheduled with the teams or the team leaders. In some courses, there are regular meetings every second week, while in one 2nd year course there are daily meetings every morning in an intensive project period of 3 weeks. A number of courses have regular supervisor meetings, but often based on a number of hours assigned to each project, e.g. 25 hours of supervision per project. In several courses there are teacher assistants available in labs at scheduled times during the week. There are also courses where one teacher reports that the students do not get any feedback, and another teacher reports that the students get written feedback via mail or an LMS when they ask for feedback. In some projects the students are expected to hand in intermediate deliverables, on which they get feedback. There are also examples of use of peer review among the students, e.g. that teams presents their work to the class, and that the class provides feedback.

The teachers reported that "learning through construction" is often used as a learning method in higher IT education because constructive skills are a highly valued learning outcome, and to develop such skills, it is necessary to practice. At the same time, the teachers conclude that the learning method seems

motivating for students and stimulates creative thinking, and that project work is useful because the students will be better prepared for project work also after their studies.

3.2 Teaching context

According to Sindre et al (2015), the teaching context differs from courses where LtC is the teaching model for the entire course to courses where the LtC project is just part of the course. The diagram below summarizes the findings from the study:

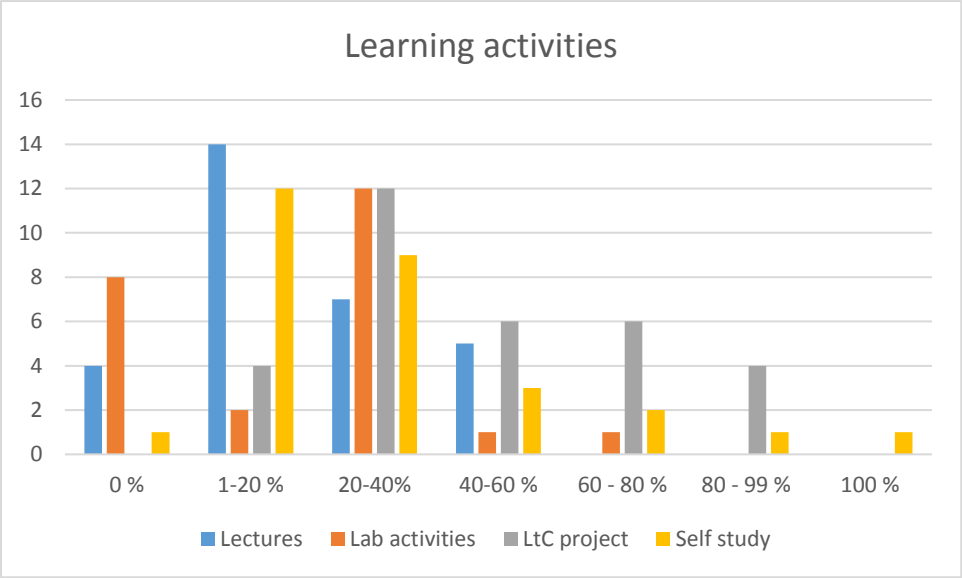

Figure 2: Learning activities in LtC courses

The diagram illustrates that LtC projects are often a part of a course and do not define the entire course content. Looking specifically on the grey part of the pillars (which illustrates LtC projects), we see that in most cases LtC is just part of a course, and that there are other learning activities in the courses, e.g. lectures, lab activities and self-study. However, there are courses where the maker project is 80-99% of the course, but also courses where the maker project is only 1-20 % of the course. This relates to the "teaching context" of Sindre et al.'s categorization, which describes that a project can be the entire course, or be a smaller part of a course, which also includes more traditional teaching like lectures of over a textbook.

The teachers of the courses with learning through construction also reports that the courses often have additional learning activities as well, e.g. guest lectures, workshops, seminars with industry representatives, supervising meetings, group leaders meeting, writing an individual essay, mandatory assignments, student presentations, inspiration talks, experience exchange among students, as well as interaction and dialogue with a supervisor and a customer. However, some of these learning activities are closely connected to the project work.

There are examples of courses (e.g. programming courses, software engineering courses, web technology courses), that possibly could have been taught without any learning through construction projects, using teaching methods like lectures, lab activities with right/wrong answers etc. However, there are some project courses, which are planned with a maker purpose.

3.3 Range of implementation

According to the classification of Sindre et al (2015), a project can range from one to many courses and also span over more than one semester. In our survey, we found that out of 33 courses, two teachers mention that they sometimes collaborate with other courses on the LtC projects. One respondent specifically mentions this connected to the NTNU project "Experts in teamwork" (Experts in Teamwork

is a master's degree course in which students develop their interdisciplinary teamwork skills. The course is compulsory for all students in master's programs and programs of professional study at NTNU.). In the remaining 31 courses, none collaborates with other courses on the LtC projects in specific.

3.4 Learning context

According to Sindre et al (2015) the learning context is described looking at when the theory is integrated into a project-based course, defining a top-down approach when a project takes place after students have learnt relevant theory about necessary technology and methods, and the bottom-up approach when the instructor introduces the theory within a project framework.

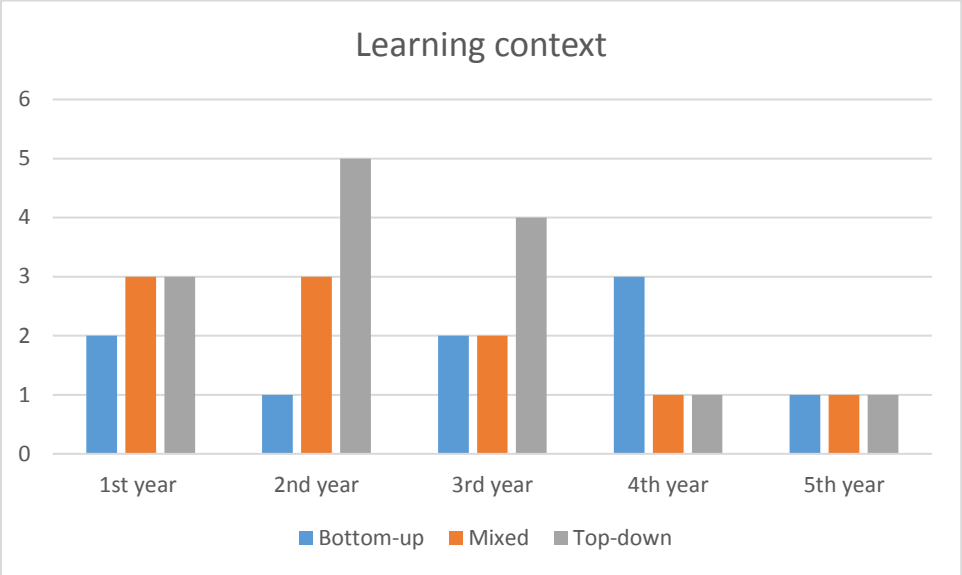

Figure 3: The different approaches to theory in the LtC courses

The diagram illustrates that there are more courses with a top-down approach than a bottom-up approach. However, several teachers reported that there in reality often was a mixed approach, which means that e.g. the overall theory is first introduced, and then specific theory related to the project. One teacher reports that "the students use what they have learnt earlier and often they have to learn new technologies / theory through self-study".

3.5 Institutional context

Sindre et al (2015) describe institutional context as following: "A project can be implemented locally to one organization (typically the university), or involve other organizations (e.g. cross institutional), furthermore projects' might also involve stakeholders (e.g. companies)." Our study shows that external stakeholders are involved in 18 out of 33 courses and customers are involved in 15 out of 33 courses.

3.5.1 The involvement of external stakeholders

The involvement of external stakeholders in the LtC projects are found at most of the study years. The diagram below shows that during the first study year there are as many courses with external stakeholders as without. During the 3rd study year, there are no courses with external stakeholders and in the 5th study year, there are external stakeholders involved in all LtC courses.

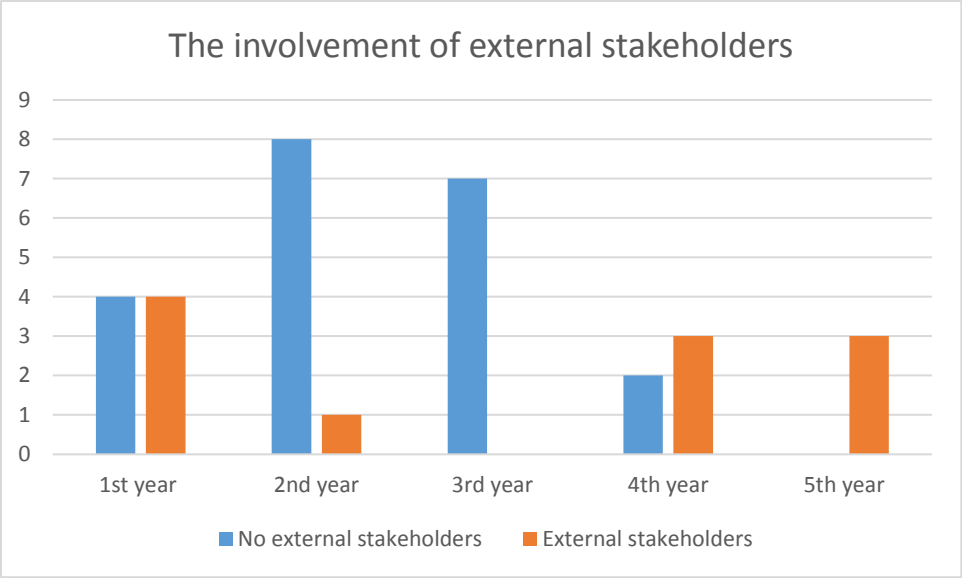

Figure 4: The involvement of external stakeholders throughout the study years

As the class size of the LtC courses vary from 9 students to more than 400 students, it is interesting to study if class size matters when it comes to the involvement of external stakeholders in the university courses. However, the diagram below shows that external stakeholders are involved in both small classes and large classes.

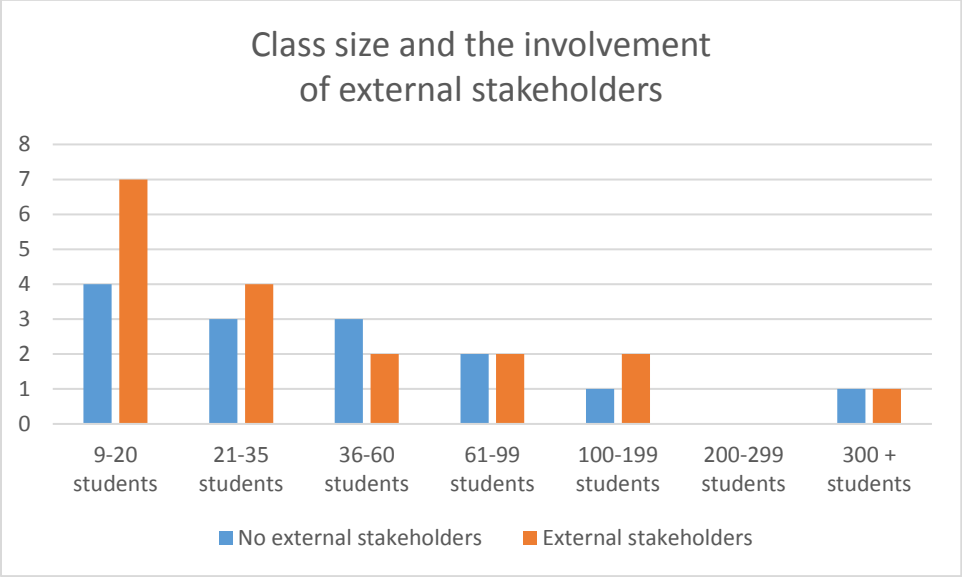

Figure 5: Class size and the involvement of external stakeholders

A teacher of the largest class reported that he had spent much time recruiting persons in the industry to use as mentors for the students. However, his course had more than 400 student. Even though he was able to recruit 43 persons from the industry, he was not able to benefit from these volunteer people from the industry, due to lack of resources and due to the high number of students in the course.

The teachers report that the external stakeholders are taking on very different roles to provide authentic tasks for the student groups, taking on the roles as mentors, guest lecturers and sponsors, in addition to inviting to work place visits and providing testing arenas for the students' products.

3.5.2 The involvement of customers

In a "learning through construction" project, it might be useful for students to get experience on working with customers, as this is the situation they will meet in industry after their studies. Some LtC projects

use real customers, others use fake customers (e.g. the teachers play the role of a customer), while some projects are executed without customers. In some courses, some groups may work with customers, while other groups do not.

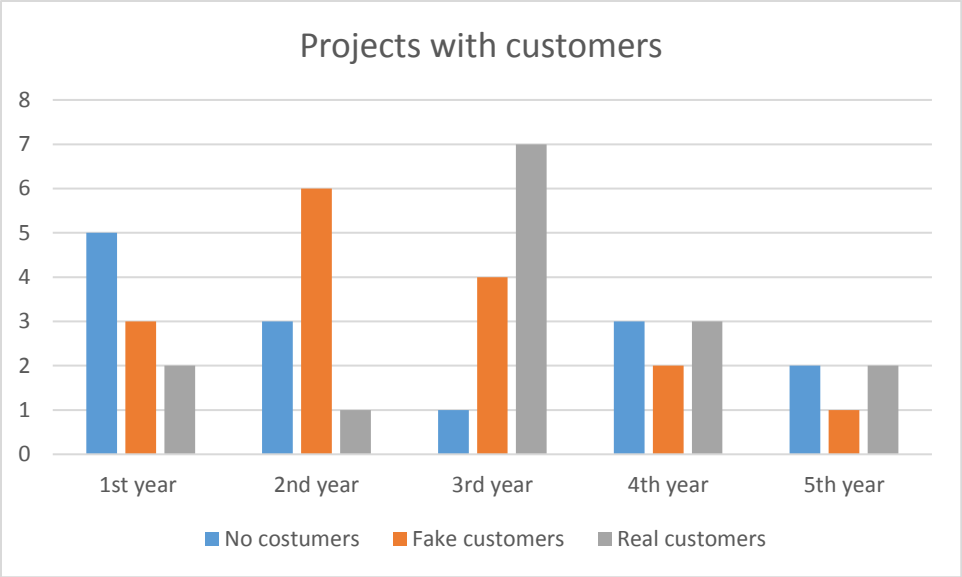

Figure 6: The involvement of customers in the LtC projects during the 5 study years

The diagram shows that there are some projects with external customers and some projects without external customers throughout all the five study years. We also see that the courses with projects involving real customers increases in the third year and then decreases again during the 4th and 5th year. The first-year courses with external customers are courses with 30 and 80 students.

3.6 Personnel composition

Group size varies within the different courses. From the 33 courses mapped, 11 courses give the opportunity of individual LtC projects, 17 courses give the opportunity of dividing the groups into 2-4 persons and 10 courses give the opportunity of dividing the groups into 5-10 persons. In addition, one course defines that the project might be individual or may consist of two persons, one course defines the

group size to be 4-6 persons and one course defines the group size to be exactly 5 persons. None of the groups are put together of more than 10 persons.

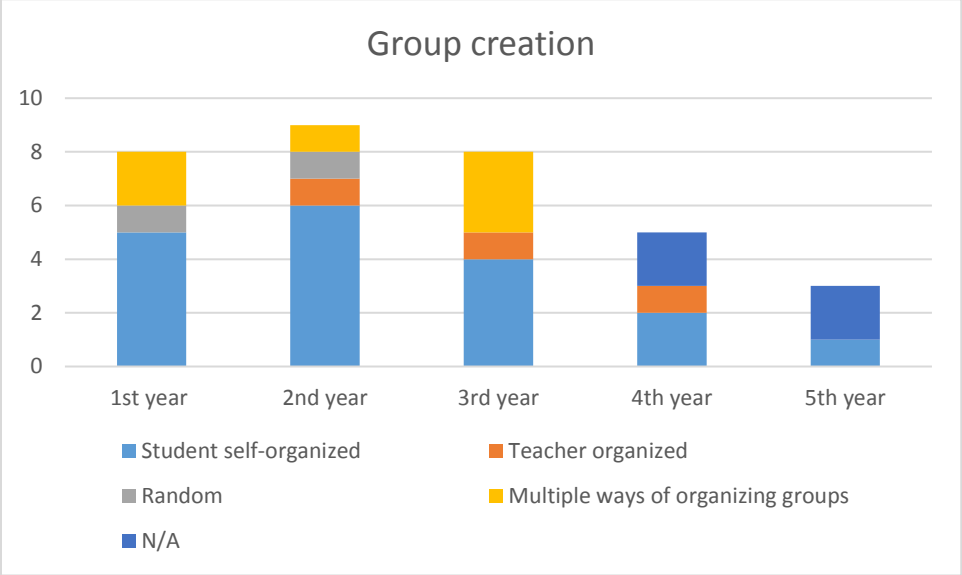

Figure 7: How are groups created in the LtC projects?

The diagram shows that most of the time, the students organize the groups themselves, but in some cases the faculty sets up the teams. In two of the courses the groups are organized randomly, and in some courses there are multiple ways of organizing groups (e.g. some groups are student self-organized, other groups are created by the teacher staff, some groups are created based on different roles in the teams, and some groups are formed around project ideas (students choose project ideas)). During the last two study years, there are several individual projects, where group creation is not applicable.

3.7 Grading

The "learning through construction" courses are assessed using a variety of assessment types, e.g. team / individual project report, oral exam, home exam, thesis, written school exam, portfolio and the project deliverable (digital or physical product), all graded with grades A-F, where A is at the top of the scale and F is fail. There are no examples of pass / fail grading in our study.

Our study did not include data on policies on if a team project gives the same grade to all team members, or if the team members are graded individually.

3.8 Project variety

The figure below illustrates that "learning through construction" projects use 2 approaches; some courses use the same project for all teams, while other courses allows students to work with unique projects. In addition, the teachers reported two other approaches: One course reports that they run two different projects, where one half of the class solve project 1 and the other half of the class solve project 2. Afterwards each group perform peer assessment on the work of an opposite project. Another teacher reports that the students in his course develop different modules to be put together into a larger system.

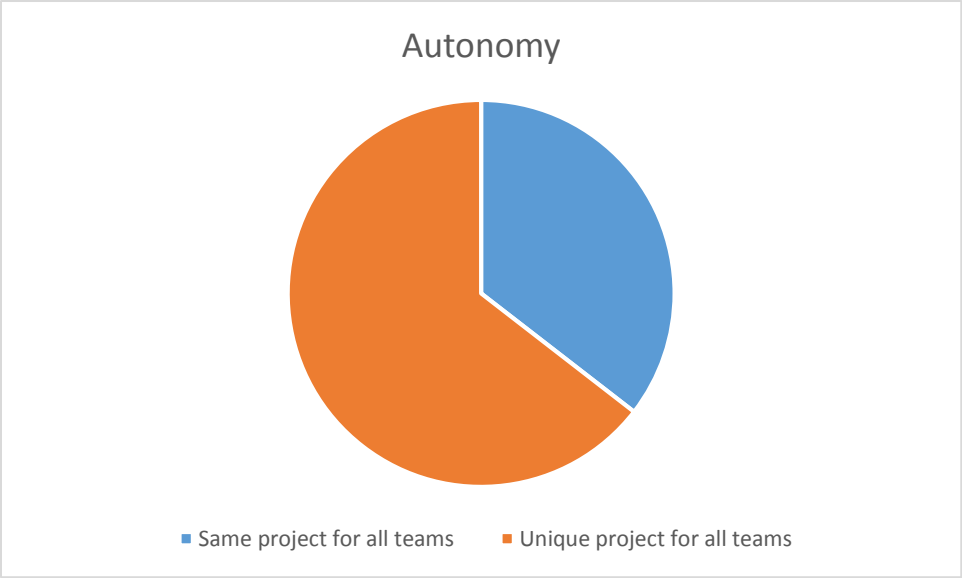

Figure 8: Student autonomy when it comes to same or unique projects for the student teams

It is interesting to study if the autonomy changes during the study years, and the diagram below shows that in the first year courses there are just as many projects where students work with the same case, as there are unique projects. During the last year of the bachelor degree program, there are more examples of project courses where students can define their own projects. During the 2 years of the master study programs, the students are mainly working with unique projects.

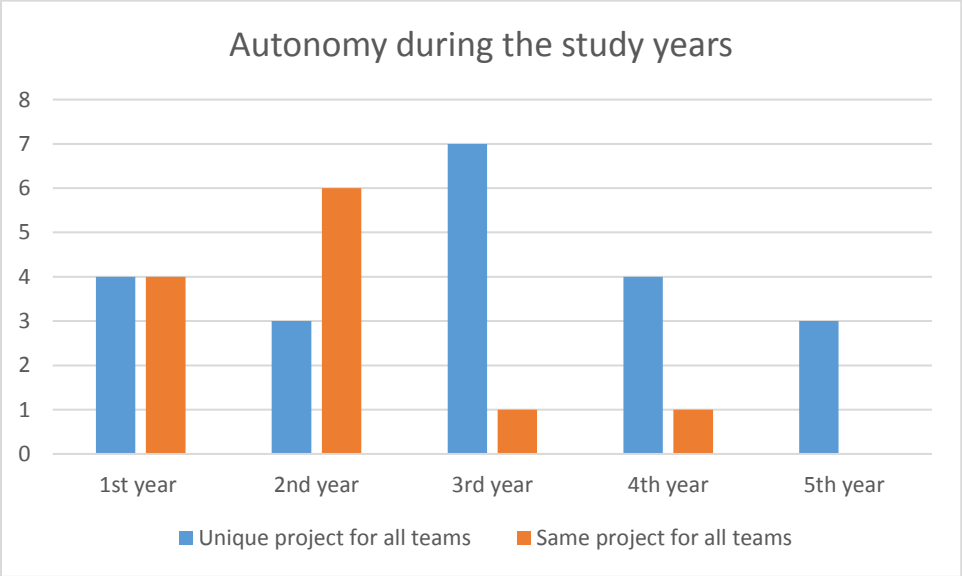

Figure 9: Student autonomy during the 5 study years

3.9 Degrees of freedom of the process

Looking at student autonomy, we see that the students are given more freedom further into their education, as there are more unique projects and flexible project processes in the later study years. Most first and second year courses have a well-specified or somewhat specified project process (concerning what methods to use, steps to follow, deadlines etc.), while during the last study years the project process is flexible (and where the only thing that matters is the final deliverable). However, there are examples of first year courses with unique projects per teams, but where the project process is still well-specified.

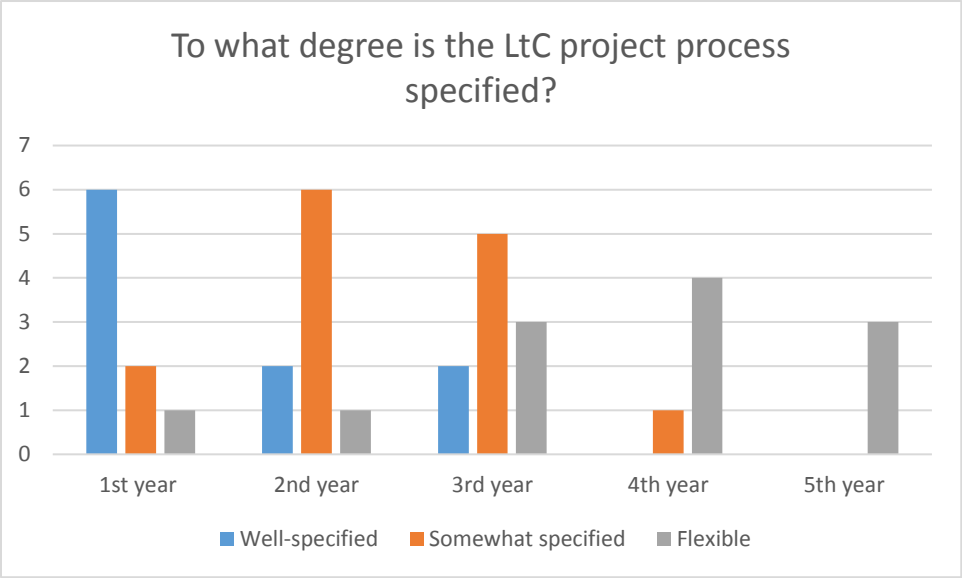

Figure 10: The degree of freedom in the project process (it was possible to check several options of this question).

3.10 Degrees of freedom in the deliverables

The products of the student projects are typically software prototypes and product documentation/software design, more specifically the main product types are games and web applications.

Projects deliverable can range from very strict and well-defined, where instructors have specified in much detail what problem is to be solved and what should be delivered; to a more flexible one, where each team is completely free to decide what to develop as long as it relates to the learning goals (Sindre et al, 2015). To measure this, we asked to what degree the LtC deliverables were defined by the teacher(s).

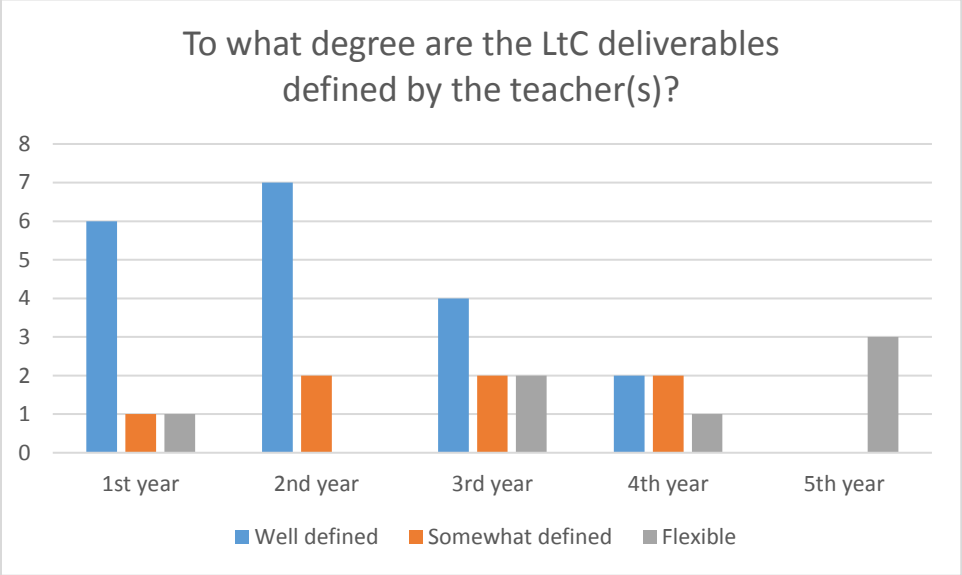

Figure 11: The degree of freedom in the deliverables.

The diagram shows that during the two first years of study, the project deliverables are mostly well defined by the teacher(s). Later in the study programs, there is a tendency that the students have more freedom concerning what to deliver.

4. DISCUSSION

We see Learning through Construction as a learning method in higher education that aims to reach the Create category of Bloom's revised taxonomy (Anderson et al, 2001). Create is the sixth category of the cognitive dimension, and "requires creative thinking on the part of the student" (Anderson et al, 2001). An LtC classroom with a large degree of freedom when it comes to the process and the deliverables will end up with original, and in many cases unique, products. This fits into the Procedural knowledge / Create category of Bloom's revised taxonomy. "Although the process categories of understand, apply and analyze may involve detecting relationships among presented elements, create is different because it also involves the construction of an original product" (Anderson et al, 2001). This is a necessity for IT students to prepare and specialize for work in the industry.

Our findings on the learning context in courses with LtC show that the use of bottom-up and top-down approaches, as well a combination of the approaches are found in all study years. From the comments, it was obvious that the teachers were not comfortable with only two choices when it comes to the learning context; top-down theory approach or bottom-up theory approach. 10 teachers out of 33 reported to use a combination of top-down and bottom-up approach to theory, even if it was not an option in the questionnaire (this was added in an "other" option of the questionnaire).

Seen in the Bloom's revised taxonomy table (Anderson et al, 2001), LtC will often fit into the procedural knowledge dimension. In addition, a top-down theory approach which let students apply their earlier knowledge in a maker project, can be placed in the Apply category of cognitive processes. "Apply involves using procedures to perform exercises or solve problems" (Anderson et al, 2001). On the other hand, a bottom-up theory approach lets students, in a maker project, focus on creating, and theory will be presented when necessary. This theory approach can be placed in the Create category of cognitive processes (see table 2). This means that the teachers of LtC courses, and study program coordinators should be conscious about how theory is approached in LtC courses and in which courses the top-down, bottom-up and the mixed approaches are used, if the goal is to reach the Create category during the 3 or 5 years of the bachelor and master study programs.

The knowledge dimension	Cognitive process dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Meta-cognitive						
Procedural			A top-down theory approach			A bottom-up theory approach
Conceptual						
Factual						

Table 2: The revised Bloom's taxonomy table (Anderson et al, 2001) seen with LtC glasses.

"The creative process can be broken into three phases: problem representation, solution planning and solution execution" (Anderson et al, 2001). Teaching a learning through construction course, means that the teacher(s) should prepare for all three phases. In our opinion and based from the the empirical data in this project, the Sindre et al (2015) classification model seem to lack a focus on different phases of the project work, which could be useful for teachers who would like to use the classification model to improve their LtC teaching. It also seems that the classification model lacks a focus on formative assessment and how to provide feedback to students during the project work. Formative assessment and feedback in the project process is an important part of project learning, and it would have been an improvement of the classification model if variable 6 (Grading) was changed into Assessment (including both summative and formative assessment). Variable 3 (Learning context) of the classification model can, as previously mentioned, also include the mixed approach to theory (combination of top-down and bottom-up theory approach).

5. CONCLUSIONS

The paper presents the preliminary findings on characteristics of IT courses with "learning through construction" projects, which is the learning process when students are creating a digital artifact (e.g. digital game, digital app etc.) (Munkvold, 2017). The characteristics of LtC courses are described using the categorization model of Sindre et al (2015), including 9 variables: teaching context, range of implementation, learning context, institutional context, personnel composition, grading, project variety, degrees of freedom of the process and in the deliverable. In addition, we added some general findings about LtC courses, including course size (ECTS), class size and number of teachers and teacher assistants, as well as how students get feedback during their project work and why teachers choose to use LtC as a learning method in their courses.

Variables of project-based learning	**Summary of findings**
1. Teaching Context	16 out of 33 report that the LtC project counts for more than 40% of the course.
2. Range of Implementation	The great majority of the courses do not collaborate with other courses when implementing the LtC project.
3. Learning Context	14 out of 33 are reporting a top-down approach to theory. 10 are reporting a mixed approach.
4. Institutional Context	External stakeholders are involved in 18 out of 33 courses. Customers are involved in 15 out of 33 courses.
5. Personnel Composition	Group composition is mostly student self-organized. In only 3 out of 33 cases this is teacher organized.
6. Grading	All LtC courses are graded with A-F grades.
7. Project Variety	20 out of 33 have unique projects. Majority of unique projects in the 3rd, 4th and 5th study year.
8. Degree of process freedom	The degree of freedom in the process is increasing during the last years of education.
9. Degree of deliverables freedom	Mostly well defined in the 1st and 2nd year and more somewhat defined and flexible in the 3rd, 4th and 5th year.

Table 3: Brief summary of findings using the categorization model of Sindre et al (2015)

Even though it possible to find some typical characteristics of LtC in higher IT education, the study also shows that there are a wide range of variation, across study years and study programs, hence there does not seem to be a very standardized pedagogical method of teaching LtC courses.

Further research will include mapping fall courses with learning through construction to get an overview of the use of learning through construction as a learning method in all semesters of all the study programs. This will add the opportunity to look closer into the progression of maker projects in higher IT education. It would also be interesting to look further into the group organizing, as this might affect the learning outcomes of the students. Would the groups benefit from being grouped based upon their pervious grades, their fields of interest, their programming skills, their creative skills, etc.? Further research about LtC should also look at the students' experiences with learning through construction as a learning method and how the different ways of organizing it effects students' motivation and learning outcomes.

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