Influence of Flipped Classroom on Technical Skills and Non-Technical Competences of IT Students

Mark Cieliebak
Zurich University of Applied Sciences (ZHAW)
Winterthur, Switzerland
mark.cieliebak@zhaw.ch

Andrea Keck Frei
Zurich University of Teacher Education (PHZH)
Zurich, Switzerland
andrea.keck@phzh.ch

***Abstract*—Flipped Classrooms is a teaching method that has become increasingly popular in recent years. In a didactic study, we taught a computer science class in parallel groups with Flipped Classroom and with classical teaching, and evaluated the teaching method's influence on student skills. The results show that at the end of the term, the two groups of students display similar technical skills, while non-technical competences were significantly more improved when using Flipped Classrooms.**

***Keywords*—teaching method evaluation; flipped classroom; inverted teaching.**

I. INTRODUCTION

Flipped Classroom (also known as "Inverted Teaching") is a teaching method where lecture and homework are "flipped": first, students prepare the topic of the next lecture at home, e.g. by reading part of a text book, watching e-lectures, or working with e-learning-modules. Then, in the lecture, students work with the teacher to clarify open questions, discuss the topic and solve exercises. Knowledge-transfer mainly happens in the first, preparatory phase, leaving time and space for more communicative and collaborative activities during the lecture. Under the teacher's guidance, students establish cognitive connections to their prior knowledge - in traditional lectures, this task is left to be achieved by the students at home, after the lecture. Flipped Classroom lectures are highly interactive and students assume more responsibility for their own learning than in traditionally taught classes. For a successful implementation of the Flipped Classroom method, completion of the preparational tasks is crucial [4], and can be supported by online check-up questions, to be answered before the lecture.

Flipped Classrooms have become very popular in recent years. They go back to the 1990's, when Eric Mazur introduced Peer Instructions in his physics lectures at Harvard University [9]. Since then, the concept has evolved into an established teaching method that is now used successfully at elementary schools, high schools and universities worldwide. Hundreds of guidelines, reports, books, conference proceedings and research papers have been published on Flipped Classroom. For an extensive literature and research survey, see [1] and [6].

At Zurich University of Applied Sciences (ZHAW), Flipped Classrooms are already used in various courses, e.g. in computer science, mathematics and physics. The feedback for Flipped Classrooms is very positive, from both students and lecturers, and more and more lecturers start using it in their classes. However, it was long unclear how well Flipped Classroom actually "works", apart from being perceived as a new and fun way to learn. How does this teaching method affect skills and competences of the students?

Most of the studies on Flipped Classroom focus primarily on the design of Flipped Classroom (in-class vs. out-of-class activities), media in use (e.g. literature vs. videos), or students' perceptions [1, 6]. Studies evaluating the educational outcomes from Flipped Classrooms indicate that students show increased academic performance (measured in examination results) and increased student satisfaction, compared with their peers in traditionally taught classes [8]. There are currently no long-term studies about causal effects of Flipped Classrooms. Most studies consist in short-term evaluations over one or two terms [6]. For instance, Moravec et al. used pre-class training material (worksheets/videos) to replace part of a lecture on biology by student engagement [10]. They showed that student scores in an exam for the corresponding topics had improved in comparison to previous years, when all material was presented during the lecture. Day and Foley conducted a study where they split a course on User Interface Design into two groups: one using traditional lectures, one using a variant of Flipped Classroom [5]. Their results show that the group with Flipped Classroom (called "web lecture") scored higher grades in weekly homework assignments and exams than the group with traditional lectures, and that they had "strong positive attitudes" about the new teaching format.

Despite these promising results, there are still many open questions regarding the effects of Flipped Classroom: How are non-technical competences (their further development is one of the goal of technical study courses at ZHAW) affected by the teaching method? How much time do students spend for preparing a Flipped Classroom? Does Flipped Classroom also improve technical skills in a university of applied sciences, where traditional teaching already has a high level of student interaction? To shed more light on these questions, Zurich University of Teacher Education (PHZH) was asked to evaluate Flipped Classrooms in a didactic study and compare them to traditional teaching. This study was conducted in spring 2014 in a course on "Algorithms and Data Structures" at ZHAW. The results of our study allow us to assess the effectiveness of Flipped Classrooms in higher education.

This paper is structured as follows. In Section 2, we present the setup of our study and describe the methods we used. The results of our study comparing traditional teaching with Flipped Classroom are presented in Section 3. Section 4 provides conclusions on Flipped Classroom and its applications, and details how to implement a Flipped Classroom are given in the Appendix.

II. METHOD

Goals. The purpose of this study was to examine the impact of Flipped Classrooms on engineering students' technical skills and non-technical competences. The study addressed the following research questions:

1. Is there a difference between students in classes with Flipped Classroom and students in classes with traditional teaching regarding technical skills, methodical competences, self-organized learning and generic competences?
2. How much time was spent by the students in the two groups to work on the subject matter apart from the lectures (time for preparation and follow-up learning)?
3. What were the students' experiences with Flipped Classroom?

Study Design. To address these questions, a quantitative sequential design was used, comparing three parallel classes (59 students) in a course on "Algorithms and Data Structures" for first-year students at the School of Engineering at ZHAW. Students were assigned randomly to one of the classes. Two of the classes were taught with traditional teaching and one with Flipped Classroom. There were four lessons a week for 14 weeks; the first two lessons each week were organized as lectures, followed by two lessons of practical training with hands-on exercises. Every week was focused on a specific subject such as "Sorting" or "Graph Algorithms". Subject content was identical in all three classes, as was the final exam, and the three lecturers used the same teaching materials to a large extent.

At the first time point (t1) at the start of the term, students were asked about their technical knowledge, their individual learning and control strategies and generic competences by means of an online-questionnaire to be filled-in during a lesson. At the end of the term (t2), the same questions were presented again, and the students were additionally asked about their students' competences and their experiences with Flipped Classroom. Their technical skills were assessed by means of a written exam.

Sample. The overall number of respondents was 49 (63%), with 36 students answering at both t1 and t2. 13 students were in the class with Flipped Classroom and 23 in the two classes with traditional teaching. Students had a mean age of 23.8 years (range from 20 to 34). There were only two women in our sample (one in each group) and 45 students were German-speaking (which was the language of instruction). While most of the students (79%) had a vocational Baccalaureate, students with an academic Baccalaureate were overrepresented in the classes with traditional teaching (27% vs. 12%).

Questionnaires. The two questionnaires at t1 and t2 contained the following dimensions:

- **Technical skills.** At t1, the technical competences on algorithms and data structures were assessed using a set of multiple-choice questions. In addition, overall technical skills were rated based on grades in other technical lectures in the previous semester. At t2, the grades of the final exam (90 minutes) in "Algorithms and Data Structures" with a range from 1 (low achievement) to 6 (high achievement) were incorporated.
- **Generic competences**. Scales developed by Grob and Maag Merki [7], based on a 4-point Likert-like scale ranging from 1 "strongly disagree" to 4 "strongly agree", were used to measure the capacity for action and independence, the assumption of responsibility, social competences, volition, self-reflection and persistence at t1. Cronbach's alpha for the six sub-scales was over .83.
- **Learning and control strategies.** Individual learning and control strategies were assessed at t1 and t2 by means of a Learning and Control Strategies Inventory (ALK-I) by Straka et al. [12], with Likert-type response choices ranging from 1 "strongly disagree" to 6 "strongly agree". Cronbach's alpha for the sub-scales ranged from .47 to .86 (t1), and from .53 to .87 (t2).
- **Evaluation of university teaching.** At the end of the term (t2), the instructional quality of lectures was assessed by means of Staufenbiel's questionnaire (FEVOR) [11]. A Likert-type format with choices ranging from 1 "strongly disagree" to 5 "strongly agree" was chosen, to match the scales from BEvaKomp used at t2 (see below). In addition, students were asked to rate their own engagement in the class (preparing lectures, attending lectures and practical training classes, learning etc.) and to assess the degree the teaching method suited them, using a 4-point Likert-scale ranging from 1 "strongly disagree" to 4 "strongly agree".
- **Students' competences.** The "Berlin Evaluation Instrument of Self-Rated Competences" (BEvaKomp) [2] was used at t2 to measure students' self-related gains in knowledge processing, methodology, communication and cooperation competency, and personal competency. Choices ranged from 1 "strongly disagree" to 5 "strongly agree". Cronbach's alpha for the sub-scales was over .81.

Teaching Methods: Traditional Teaching. With "traditional teaching" we refer to a lecturer-centric teaching method, where the lecturer presents the study matter during the lecture. Students take notes. Typical media used in the two classes were presentation slides and blackboard. Note that interactive elements (active questioning, discussions etc.) occur also in traditional teaching classes at ZHAW, but they are less frequent than in Flipped Classroom.

Teaching Methods: Flipped Classroom. In a Flipped Classroom, as it was used during this study, the following main activities took place every week:

1. *Preparation*, where the students get to know the topic (at home, 90min);
2. *Quizzes*, where the students answer simple online questions about the topic (at home, 10min);
3. *Plenum*, where students and teacher delve deep into the topic (classroom, 90min);
4. *Exercises*, which the students solve on their own (classroom and homework, 180min).

Details how each activity was implemented during the study are given in the Appendix; for more information on how to set up a Flipped Classroom, best practices and lessons learned, see [3].

Analysis. Taking sample size into consideration, data was first analyzed using descriptive data analysis (frequencies, means). T-Tests, Mann-Whitney U-Tests and Wilcoxon Tests were used to test statistically significant group differences and changes from t1 to t2.

III. RESULTS

Gain in technical skills was similar with both teaching methods. Students' prior knowledge in algorithms and data structures was very similar in both groups at t1. At the end of the term (t2), students in the group with Flipped Classroom had achieved slightly higher grades than students in the classes with traditional teaching (mean 4.85 vs. 4.77). However, this difference is not statistically significant (t=0.376, df=45, p=.709).

Learning and control strategies improved more with Flipped Classroom. Analyzing gains in competences between t1 and t2, we see some interesting group differences, as shown in Figure 1. The students in the class with Flipped Classroom had increased their learning and control strategies in a higher amount than the students in classes with traditional teaching. At t2, students in the Flipped Classroom group could better link new subject matter to their prior technical knowledge, and were better able to plan and organize their learning, observe and adapt their learning than at the beginning of the term (t1). The increase in competence is statistically significant for the domains "rehearsal / memorizing" (t=-3.105, df=12, p=.009) and "metacognition" (t=-3.481, df=12, p=.005). Students in classes with traditional teaching, on the other hand, had only improved their competences in three domains (and in a smaller degree than the Flipped Classroom group), and their competences had even deteriorated significantly in one domain (organization) (t=2.418, df=22, p=.024).

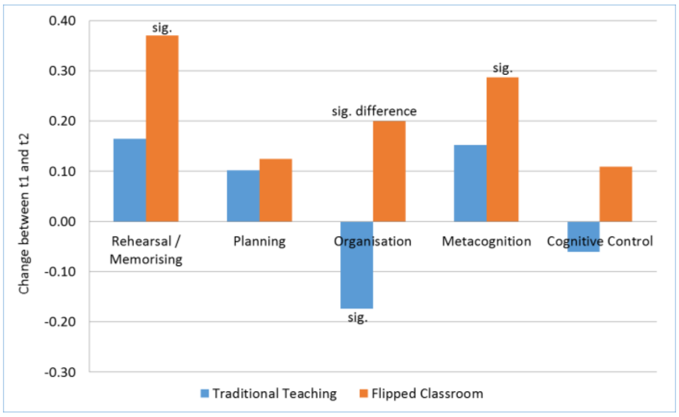

Fig. 1. Change of learning and control strategies between t1 and t2. Measured with choices ranging from 1 "strongly disagree" to 6 "strongly agree". Values > 0 indicate an increase of competence. "sig." = statistically significant.

Students in Flipped Classrooms achieve higher gains in personal competences. We see similar results looking at students' competences, displayed in Figure 2: For knowledge processing competences, methodology, communication competences, and personal competences, students in the Flipped Classroom group report higher gains in competences than students of the other group. However, the group difference is only statistically significant for personal competences (productive attitude towards learning, enthusiasm for the subject) (Mann-Whitney U= 104, p=.037 exact significance).

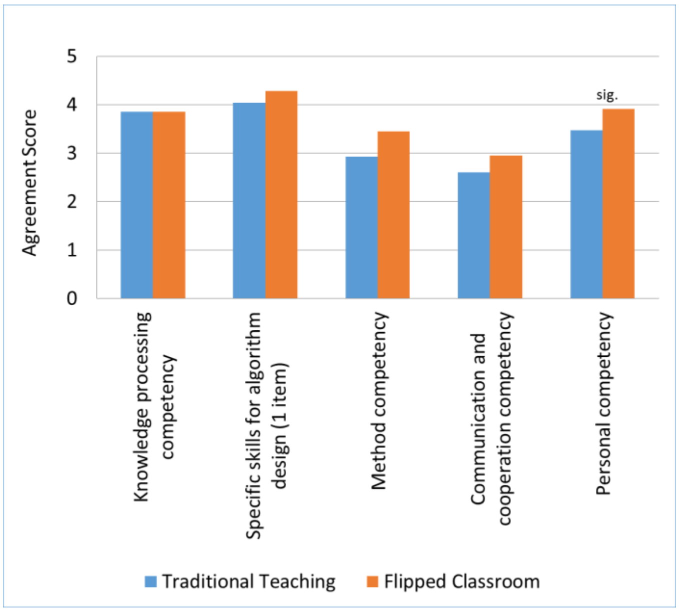

Fig. 2. Assessment of students competences at t2. Measured with choices ranging from 1 "strongly disagree" to 5 "strongly agree".

Students in Flipped Classroom use more time for preparing lectures. Students in the group with Flipped Classroom reported a significantly higher amount of time used for preparation than the other students, as shown in Table 1 (111 minutes vs. 22 minutes on average every week) ($t=3.056$, $df=15.1$, $p=.008$). Time for follow-up learning, on the other hand, was similar in both groups (28 minutes vs. 32 minutes). The highest amount of time was invested in solving the technical exercises (homework): on average 354 minutes in the Flipped Classroom group, and 140 minutes in the group with traditional teaching. This difference is statistically significant ($t=4.399$, $df=16.9$. $p=.000$).

TABLE I. STUDENTS' WORKLOAD (IN MINUTES PER WEEK)

	Teaching Method	Average Workload	Standard Deviation
Preparation time for lectures	Traditional	22	38
	Flipped Classroom	111	105
Follow-up time for lectures	Traditional	32	40
	Flipped Classroom	28	37
Time for solving exercises at home	Traditional	140	84
	Flipped Classroom	354	170

Students in Flipped Classroom were slightly more satisfied with 'their' teaching method. All students had prior experience with the teaching method Flipped Classroom from their first semester at ZHAW. Feedback concerning the class "Algorithms and Data Structures" was very positive in both groups: Figure 3 shows that all students were very satisfied with the teaching method used by their teacher, and that they attended lectures and exercises regularly.

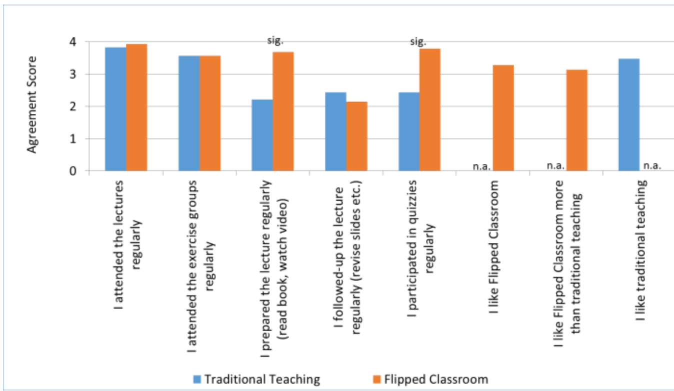

Fig. 3. Student engagement and teaching method assessment at t2. Measured with choices ranging from 1 "strongly disagree" to 4 "strongly agree". n.a. = not asked.

Assessing teaching quality (see figure 4), students in the Flipped Classroom group rated most aspects slightly higher than the other students and were in statistically significant higher agreement with the statements "the teaching method supports the understanding of the subject" (Mann-Whitney $U=91.5$, $p=.023$ exact significance) and "the lecturer is seldom digressing from the subject" (Mann-Whitney $U=86$, $p=.011$ exact significance).

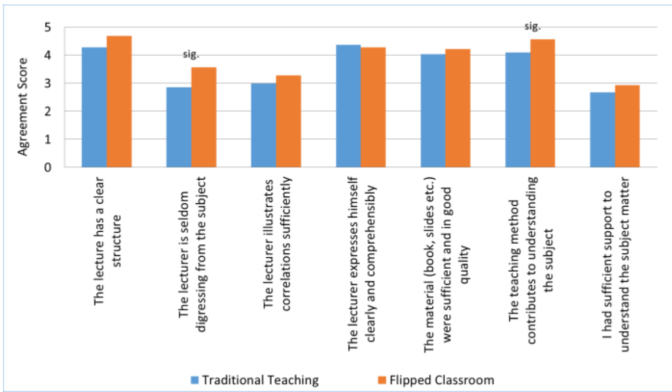

Fig. 4. Assessment of teaching quality and effectiveness at t2, based on student opinions. Measured with choices ranging from 1 "strongly disagree" to 5 "strongly agree".

Students appreciate advantages of Flipped Classroom, but do not want to use it for all classes. In addition to the structured online-questionnaires used above, we collected informal feedback and comments of the students on Flipped Classroom. These can be summarized as follows: According to the students, the main advantages of Flipped Classroom are having more time during the lecture for in-depth discussion and analysis, to address individual students' needs, and to explain interesting aspects in more detail. Nevertheless, students were aware of the high amount of time they invest preparing lectures, and therefore did not consider Flipped Classroom suited to be used for all lectures of a term at the same time. Students report being more active and to maintain a higher interest in the subject than in other classes without Flipped Classroom.

IV. CONCLUSION

We presented the results of a didactic study which compared Flipped Classroom with classical teaching, with the following main findings: Time for preparation is higher in Flipped Classrooms; effects on technical skills of the students were similar for both teaching methods; and improvements of non-technical competences were higher for Flipped Classroom. These findings are in majority in line with other studies on Flipped Classroom [6; 8]. In contrast to other studies, we didn't find significant group differences for academic performance. However, this might be an effect of the small sample size, as the descriptive results showed better grades for the Flipped Classroom group. All in all, the results of our study indicate that Flipped Classroom is a viable alternative to traditional teaching. At the same time, it has to be taken into consideration that we analyzed effects only over one term, and that the classes did not only vary in teaching method, but also in other parameters (lecturer, effort spent for exercises etc.). It would be worthwhile to conduct a study throughout a whole program approach, as so far there is limited evidence on long term outcomes.

Acknowledgments

We would like to thank Geri Thomann, who helped to setup and conduct this study, and Christian Heitzmann and Karl Rege, who taught the two classes with traditional teaching.

Appendix: Implementation of a Flipped Classroom

We explain the main components of a Flipped Classroom, as it is used in computer science education at ZHAW. Of course, there exist many variants of Flipped Classroom, and lecturers usually adapt the basic principles to their needs. Here, we describe how Flipped Classroom was implemented in "Algorithms and Data Structures" in spring 2014, which was used to conduct this study.
Every week the following main activities take place: *Preparation*, *Quizzes*, *Plenum* and *Exercises.* We now describe these activities in more detail.

Preparation. We are using an online learning management system (OLAT, www.openolat.com) where we provide the students with all relevant information for the lecture. In particular, for each week we supply the following data:

- Topic of the lecture
- Motivation, why this is relevant
- Learning targets
- Introductory video (2-3 minutes)
- Learning material that needs to be prepared (book chapter, video tutorial or other online resources)
- Links with additional material and information

Serious preparation of the learning material should take 60-90 minutes for the students. For the lecturer, effort for preparing a lecture in Flipped Classroom is comparable to traditional teaching – except if videos are created.

Quizzes. After preparation phase, the students complete weekly a short online survey, where they answer 6-9 questions about the topic ("quizzes"). These questions are directly related to the learning material, and should be easy to solve if the students had previously studied the learning material. Answering the quizzes should take 10 minutes at most. We use multiple choice questions, and grading is done automatically by a software tool. The quizzes end with a mandatory question: "What did you not understand? If everything was clear, what did you find most interesting?"

Plenum. The weekly quizzes have to be solved until one day before the plenum. The results are reviewed by the teacher and show him which parts of the topics were well understood, and which have to be explained in more detail in the plenum.
A typical plenum has 90 minutes and consists of three parts:

1. Short introduction to the topic;
2. Clarification of open questions;
3. Solving small assignments.

Open questions are derived directly from quiz responses, in particular from the last question "What did you not understand?". In fact, it is often possible to put some of the responses directly on a slide and discuss them in the plenum (e.g. "Is it OK to solve small or medium size problems with the brute force method?" (translated)).
In the third and largest part of the plenum, each assignment takes 5-10 minutes to solve, and students work either alone or in small groups. For assignments, we use simple exercises or ConcepTests [9]. Students present their solutions of the assignments and discuss them in the plenum.

For each topic, we have a large collection of slides with examples, explanations, and assignments, which we prepared before semester start. During the semester, each teacher selects the appropriate slides for his/her plenum, and adds new slides or explanations if necessary (this reduces the amount of work for each teacher).

Exercises. After the plenum, students solve hands-on exercises on their own. Each week, exercises take 3-6 hours to complete, and cover the current topic in depth. Solutions are submitted for grading electronically (via OLAT), and reviewed by the teacher. Results of the review are discussed with the students individually in the following week.
Grading. Successful participation in quizzes and exercises over the entire semester makes up for 20% of the final grade (10% each). This is intended to motivate students to work continuously during the semester. In addition, there is a written exam of 90 minutes at end of semester (80% of final grade).

References

[1] J.L. Bishop and M.A. Verleger, "The Flipped Classroom: A Survey of the Research", Proceedings of the 120th ASEE National Conference, Atlanta, 2013.

[2] E. Braun, B. Gusy, B. Leidner, and B. Hannover, "Das Berliner Evaluationsinstrument für selbsteingeschätzte, studentische Kompetenzen (BEvaKomp)", Diagnostica, vol. 54(1), pp. 30-42, 2008.

[3] M. Cieliebak, "Flip your classroom - But be aware!", Lifelong Learning In Europe (LLinE), vol. 4, 2014.

[4] C. Crouch, J. Watkins, A. Fagen, and E. Mazur, "Peer Instruction: Engaging Students One-on-One, All at Once", Reviews in Physics Education Research, Eds. E.F. Redish and P.Cooney, 2007.

[5] J.A. Day and J.D. Foley, "Evaluating a Web Lecture Intervention in a Human-Computer Interaction Course", IEEE Transactions on Education, vol. 49(4), pp. 420-431, 2006.

[6] J. O'Flaherty and C. Phillips, "The use of flipped classrooms in higher education: A scoping review", Internet and Higher Education, vol. 25, pp. 85-95, 2015.

[7] U. Grob and K. Maag Merki, "Überfachliche Kompetenzen. Theoretische Grundlegung und empirische Erprobung eines Indikatorensystems", Peter Lang Verlag, Bern, 2001.

[8] N. Hamdan, P. McKnight, K. McKnight, and K. Arfstrom, "A Review of Flipped Classroom", Flipped Learning Network, 2013.

[9] E. Mazur, "Peer Instruction: A User's Manual", Addison Wesley, 1996.

[10] M. Moravec, A. Williams, N. Aguilar-Roca, and D.K. O'Dowd, "Learn before lecture: a strategy that improves learning outcomes in a large introductory biology class", CBE-Life Sciences Education, vol. 9(4), pp. 473–481, 2010.

[11] T. Staufenbiel, "Fragebogen zur Evaluation von universitären Lehrveranstaltungen durch Studierende und Lehrende", Diagnostica, vol. 46(4), pp. 169-181, 2000.

[12] G. Straka, J. Rosendahl, and K. Kiehl, "Arbeits-/Lern- und metakognitive Kontrollstrategien-Inventar (ALK-I)", Universität Bremen, 2005.