Competitive and Collaborative Approach
Towards a More Effective Education in Computer Science *

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Abstract To provide a computer scientists with good materials and interesting topics in a class does not mean that their education is of a high quality, students need to be motivated and evolve skills needed in a real-life employment. Social skills, communication, team work, collaboration and competition are valuable aspects they should know in order to be professionals in their future career. In this paper we look into experiences in competitive and collaborative learning in education and programming olympiads to improve a quality of education in our course. We provide criteria we applied for our course and present a student evaluation on the approach. Our approach showed increased motivation in students’ interest in the course. In addition students could handle a larger workload in the class as they were motivated to be better compare to others.

1 Introduction

Computer science has multiple disciplines where some may change and evolve quite quickly which is the trend of the industry where a five years old computer is seen as an archaic one. Computer science education in addition prompts for competition as many programs with different functionality, performance and interface are build by computer scientists every day. Schools produce a lot of students in the area but not all of the students are recruited as professionals, but rather as beginners in various

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companies. The goal for teacher is to prepare professionals that can succeed in the employment. It is not only important to train students in the knowledge of technologies, techniques, models and processes, but it is also important to build student’s social skills, communication capabilities, competitive nature and the ability to collaborate in a team which is in fact often the case in the employment. In this paper we present a competitive and collaborative approach towards more effective education in computer science. Based on previous research in the education we believe that our students can gain new abilities for their future career. In our computer science course we apply the research results and our rich experience we have from ACM International Collegiate Programming Contests (ICPC) [15]. We describe the way we applied the competitive and collaborative learning in our course and provide an evaluation and experience we received from the course.

This paper is organized as follows. In Section 2 we describe the background of computer science, competitive and collaborative learning in the programming olympiads and previous research in the approach. Next, we describe the way we applied the approach in our class in Section 3. Section 4 provides our experience and evaluation of the course. The last Section 5 concludes our work.

2 Background

Computer science has a long history which might be considered going back to ancient Summer and Babylon where a first tool we consider from that era abacus was invented. Simply rational behind this tool are lines drawn in sand with pebbles. Similar design is used even these days at modern machines [1]. The modern computer science as we build on started in 1936s with Church-Turing thesis where Alan Turing build a powerful computational model Turing machine [2]. Turing machine is an accurate model of general purpose computer and can do everything that a real computer can do. In addition, from this model we also find certain problems that cannot be solved by computers and are beyond the theoretical limits of computation. These days’ computer science spreads over a multiple disciplines such as theoretical computers science, algorithms, design patterns, databases, software engineering and many others. Education in these areas often involve math, graph theories, mathematical logic and statistics. For computer science courses often a lecturer follows a table-driven student evaluation. This often statistically distributes students in groups for grading. Table-driven system works and is proven by time, but we are raising a question if this is the right education direction for computer science.

Parallel to the institution education exists multiple competitions among institutions where students compete with each other or in groups and the best results are rewarded. In various locations we may see multiple programming olympiads [3] [13] [14] where among the well known world wide that we have extensive experience with is the ACM International Collegiate Programming Contest (ICPC) [15].

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2 Both authors are members of the competition organization where one since 1994
The ICPC contests are very popular instrument for the Association for Computing Machinery (ACM) [16] for younger generation besides it’s known scientific conferences. In the ICPC competitions students form institutional teams and compete with other teams by solving small algorithmic exercises where the team with the most solved problems in shortest time and with less wrong answers wins. There are in addition annually multiple contest tears where teams compete in specific regions, super regions and the best team can compete in the world finals. These competitions started back in 1977 and the participation has grown to several tens of thousands student from almost 2000 universities. The participation is high even that some universities requires fees. The key question might be what motivates students to attend the competition. With no doubt there is a competition among students and also collaboration within a team which involves student to student interaction. In addition the competition started with its own symposium Collaborative Learning Institute (CLI) at the world finals [17].

Our motivation is to apply similar key factors to motivate students in our computer science courses and compare the results with standard table-driven student evaluation.

Similar approaches were already applied in many study disciplines. In [5] authors look at how students interact with each other and with materials. Authors discuss that often the student to student interaction is ignored and the course focus is solely on teacher student interaction. Authors describe three patterns for student to student interaction. The first pattern is a competition to see who the best is. Second, there is an individual work where students do not need to pay attention at other students. The last pattern is a team cooperation where they explore each others contribution to the goal. From these patterns the competition is the key. In addition research in the U.S. shown the key motivation for students is a competition where they want to be better than others. This in fact might not apply for other schools as in the Czech Republic where our experiment is applied. In addition to competition the cooperation among students will support the overall work as the individual success is support to the whole team. Authors suggest “that the team cooperation encourage each other to do the assigned work, and learn to work together regardless of ethnic backgrounds or whether they are male or female, bright or struggling, disabled or not”. The work then details on five conditions that support cooperative learning as more productive than the competitive one. These conditions are:

Listing 1 Five conditions to support cooperative learning

1. Perceived positive interdependence
2. Face-to-face interaction
3. Personal responsibility to achieve the group’s goals
4. Use of the relevant interpersonal and small-group skills
5. Group processing of current functioning to improve the group’s future effectiveness

Authors suggest to keep the team size small. Where the size impacts the individual accountability. In addition role assignment in the team might be beneficial for larger teams. From the individual accountability perspective it is important to let
students to teach the others about what they learned. This in addition supports students social skills. The authors discuss in the conclusion that in result of cooperation of students build and maintain stable marriages, families, careers, and friendships.

Similar work was done also at Berkley [4] where the research shows that the students learn best when they are actively involved in the process. Also students that collaborate in a group seems to be more satisfied with their course. In addition the work provides a road map to similar approaches to the collaborative learning such as peer learning, study groups, team learning, etc. This work provides a general recommendation and strategies for a collaborative environment where the focus is at assigning a team roles. Useful is a discussion how to deal with student and faculty concerns that may raise during the course.

Recent work applying competitive and collaborative learning in senior secondary schools is from Nigeria [6] where they investigate the effect of the cooperative and competitive learning on academic performance of students in mathematics. The findings revealed that cooperative learning strategy is more effective than the competitive one and that males performed significantly better than females in both learning strategies. From this research we consider that also ethnical and cultural aspects may play role and as we see from the ICPC competitions there is significantly more male contestants than female ones, in addition there is a huge community and interest in the competitions in Asia or Russian Federation compare to the interest in Europe or Africa. This in addition means that the applicability of Competitive and Collaborative learning will fit better to disciplines where is a majority of men which in our region are technical universities and computer science.

In order to prepare students for professional employment [7] provides a team-like cooperation in a competitive business-like environment. Students then cooperate and compete by structuring learning activities that require them to cooperate in teams that compete against one another. This paper also provides definitions of terms competition and collaboration (originally [8]):

Competition:
- a social process that occurs when rewards are given to people on the basis of how their performances compare with the performances of others doing the same task or participating in the same event

Cooperation:
- a social process through which performance is evaluated and rewarded in terms of the collective achievements of a group of people working together to reach a particular goal

The work discuss combination of both cooperation and competition approaches with the positive aspects of motivational competition through inter-group competition between collaborative team. Where the rational in the real world is that a competition is evident throughout our society, our lives, and our recorded history. Authors see the benefits to the students whose outcomes often exceed content-driven and application-based objectives which also prepares them better for the professional career. Computer science is an area that matches with its professional ex-
pectation to this type of learning. In the next section we describe results of the application at our course.

3 Experiment

Based on our previous experiences with ICPC competitions, multiple interesting articles on the competitive and collaborative learning and the real life competitive trends in computer science employment we decided to apply the approach in our course Architectures of SW systems at Czech Technical University which is an eligible course for the 6th semester for Bachelor degree. The size of the course was 56 students, where 39 students passed the course. The course was structured in optional lectures and mandatory practice, which is a way all the courses at our institution are structured. The lectures consisted of a talk on topic of software architectures [12] (a), design patterns [9] (b) and enterprise design pattern [11] (c) and documentation [10] (d) which in fact covers content from four text books. Practices where divided in even and odd weeks, where the students either handed out a small demonstration program on a specific architectural type (e) with documentation (f) or read a large research paper and prepared for a discussion (g). Every odd week students were given a programming challenge (h) to solve where the first few correct implementations were progressively rewarded with points. The requirements were very high for an eligible course.

To apply the collaboration, students built teams of two members where they were working together on the architectural programs (e) and documentation (f), presentation of an enterprise pattern (c) in front of all the class and programming challenges (h). Students could define their own strategy to work on tasks together or sharing the tasks as individuals. Students were also evaluated individually during the research paper discussion (g) (in English) and two tests (i).

The competition was given by the grading, where the final score would be assigned by the best score and distributed to equally from A to F based on the result of others. Simply who will have better score than others will have a better grade than others. The points were assigned in the manner as shown in Table 1. An individual could receive up to 45 points and in a team up to 61 points. Teams had multiple tasks (c)(e)(f)(h) so they received a soon feedback on their work. In addition the

<table>
<thead>
<tr>
<th>Task ID</th>
<th>Task</th>
<th>Points per task</th>
<th>Points total</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c)</td>
<td>presentation of an enterprise pattern</td>
<td>10+10</td>
<td>20</td>
<td>Team</td>
</tr>
<tr>
<td>(e)</td>
<td>architectural programs</td>
<td>4x2</td>
<td>8</td>
<td>Team</td>
</tr>
<tr>
<td>(f)</td>
<td>architectural program documentation</td>
<td>4x3</td>
<td>12</td>
<td>Team</td>
</tr>
<tr>
<td>(g)</td>
<td>paper discussion</td>
<td>5x1</td>
<td>5</td>
<td>Individual</td>
</tr>
<tr>
<td>(h)</td>
<td>challenges</td>
<td>7x3</td>
<td>21</td>
<td>Team</td>
</tr>
<tr>
<td>(i)</td>
<td>two tests (a)(b)(c)(d)(g)</td>
<td>20+20</td>
<td>40</td>
<td>Individual</td>
</tr>
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presentations (c) were graded by 10 point from the audience and 10 points from the teacher, so there existed also a communication and feedback from other teams. Students were directly involved in the education process as the tests contained questions form their presentations. Every team presentation was awarded with applause from the audience. Challenge winners were honorable announced every first upcoming lecture.

4 Experiment Evaluation

Our previous experience with the same class at Charles University where a table-driven evaluation took place showed that students were not interested much in the course and only a subset of topics were applied: (a)(c)(d) and a project. The application of competitive and collaborative approach brought more motivation to the course and allowed to extend the content of the course. The class with a lot of tasks and additional challenges made students feel a pace environment which they may face in real SW development. We mentioned earlier that students participated in the education process in form of patterns presentations. In our institution it is common that only a small group of students attend the lectures. In here it was about 35 students attending every lecture, because they seemed interested in the student presentations, their feedback and point evaluation of the other teams, second of all the results of challenges were announced at lectures.

Students had to collaborate in the team together in order to receive more points than other teams, often students split their tasks and solved them individually such as one did implementation part and one did documentation. If one team member in this case failed then both were punished with a low score on the other hand a good results were rewarded with full score, multiple tasks allowed a soon feedback for the team so they could improve in the next task. We believe that it is good to apply rather small projects with a soon feedback rather than a large project with the feedback at the end of the course. Many students had a problem with research papers as English is their second language, but often they said that after the first paper the rest was much simpler, in addition they had a chance to improve their English and lose the initial fear to talk. At the end of the course many student were able to understand the text and answer the questions.

From the perspective of our course we have applied all three patterns of communication in our course. First, students were collaborating in teams and evolving social skills, planning and collective strategies. Second, teams were competing in order the receive good grades and do better than others. Third, they had their individual responsibilities in reading and tests.

Our feeling form the lecturer perspective is that the students were positively motivated by the announcement of the challenge winners in the lecture and also by the applause for their presentation. With the students involved also in the grading process we believe that this motivated students to attend the lectures and learn multiple
disciplines which some of them might have learned in a passive way, such as the team work, planning and education other colleagues.

At the end of the course we passed evaluation forms for the class where individual elements were evaluated. All students that passed the class (A, B, C, D or E) could
Fig. 6 Popularity of projects

Fig. 7 Popularity of presentation

Fig. 8 Popularity of tests

Fig. 9 Attendance of practices

Fig. 10 Attendance of lectures

fill out the evaluation. Students that canceled or failed the class (3) did not attend in the anonymous evaluation. Fig. 1 shows the grades distribution for the class.

Fig. 9 and Fig. 10 shows the attendance in the lecture and the practices. The evaluation of the student tasks from Table 1 can be seen on Fig. 4, Fig. 5, Fig. 7, Fig. 8 and Fig. 6. Fig. 3 and Fig. 2 shows how students likes team and competitions work.
5 Conclusion

In this paper describe application of competitive and collaborative learning known from programming olympiads and previous research in our computer science course. We have defined a specific tasks for students that were evaluated in this manner. At the end of the course we evaluated the course based on anonymous student feedback. From the feedback we see that majority of the students like to have a competitions for the grades and to work in teams where most of the A and B students liked the team work and most of the A students also liked the competition. Very popular among students shown to be challenges which directly support competition and also the presentation which is a place where students influence the education of others. Student projects shown to be positive as they played a role for both team and competition part. Tests and research papers had more balanced feedback in which we rather see a success because not many student like to do tests and read papers in foreign language. Something very positive we see is the attendance at lectures with is optional and in this case the distribution almost matches the practices attendance, we believe this has something to do with student presentations and their opportunity to influence the points of the presenter and also with the expectation from the challenge honorable mention. We believe that competitive and collaborative learning in education as we present in this papers have a positive effect on the course and will be applying it on our upcoming courses.

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