Designing Collaborative Learning Activities in a Physics Course

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Abstract—**The short paper describes and evaluates a collaborative learning activity that was implemented in four physics classes in different university programs. The activity consisted of two assignments for groups of four to seven, where students find a common set of solutions to a given number of problems. After a short introduction of collaborative learning and the related literature, we present the setup of the activity and particularly address some of the pitfalls of group work, how we tried to overcome them and our experience gained. Based on student passing rates, the course evaluations and our own observations we conclude that the group assignment provided a powerful learning experience with positive effects on the student performance, attitudes and interpersonal relationships.**

Collaborative Learning, Group learning, Group work, Physics education, Collaborative problem-solving

I. Introcuction and Background

RESEARCH suggests that collaborative learning activities (CLAs), where students work together in small groups toward a common goal [1], [2] outperform traditional lecturing [3], [4]. Positive effects were reported on students' academic achievement, self-esteem, attitudes and interpersonal relationships [2], [3], [5]-[7] critical thinking, problem solving skills [8]-[10], levels of meta-cognitive thinking [11], transfer [12] persistence [10], retention [13]. In practice, CLAs remain a challenge as the activities need to be aligned with the course's learning objectives and issues like free-riding, student resistance, and bad group dynamics might undermine their aim [14]. Thus, the description and evaluation of implemented CLAs can help teachers and researchers to identify ways to tackle some of the issues that can occur in concrete group work assignments. This paper attempts to contribute to this discussion and adds to the body of empirical, cumulative case study research on CLAs.

II. Aim and Case Description

In this short paper, we describe and assess a CLA that was implemented in four physics courses in different programs during 2016 and 2017. Each of the courses had a lenght of 7-8 weeks was followed by at least 100 students. After a description of the implemented CLA and the underlying pedagogic design ideas, we will present and discuss preliminary evaluation results and finish this short paper with some conclusions.

III. The Group Assignment

A. General setup

The CLA consists of two group assignments with the first conducted after three weeks and the second after six weeks. The groups are composed by the course management and announced before the beginning of the course. During the assignment, students meet in group rooms under exam like conditions and collaboratively work in groups of four to seven to find a common set of solutions to a given number of problems. The degree of difficulty of the problems lies thereby somewhat above the final exam. The time to solve the problems is three hours for all groups, which is deliberately relatively generous in order to allow time for thinking and discussion.

B. Participation rules and group sizing

Participation in the group assignments is non-mandatory, but encouraged through the possibility of getting bonus points in the final exam (see next section). However, to be eligble to participate in the CLA, students have solve hand-in problems prior to the group activity and achive a minimum score on those. We have found that almost no students fail to get to qualify. A likely explanation for this high passing rate is the comparatively ease with which weaker students can get help from other students and/or are able to find solutions to the problems on the internet.

Despite the proposed group size of four to seven, there is some variation in the number of students actually participating in the activity. This is, for example, due to the fact that students come to the first assignment without enough preparation, but very few – partly caused by the anti-freeriding mechanisms outlined in *section D* - come to the second if they are not up to par. Thus, there is a risk that the nominal number of students in a group is reduced significantly. This can be problematic if a group of five is reduced to two students as certain group phenomena that contribute to the students' learning success are unlikely to occur in dyads [15]. One way of solving this is to tell the students in advance that they should contact the course management immediately if this happens to give a chance to merge groups.

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C. *Accreditation of bonus points*

Student groups who have 80% of the maximum number of points in the two assignments can get 4 bonus points in the final exam. The achievable maximum in the final examp is 24 points and the treshhold for passing is 10 points. In this setup, the group assignments can have a strong impact (up to 40%) on the final grade of a passing student. As despite all efforts the risk of free-riding the group work cannot be eliminated (see next section), there is a risk that students can pass the course without being able to solve problems on their own. In some of the courses we therefore implemented a rule stating that a student only can use 30 % of the points achieved in the actual final exam as bonus points.

D. *Reducing free-riding*

As with many group activities, free-riding could be problem [14], [16] as each group member gets the same reward. To minimize this effect two measures were taken. First, the number of questions to be solved increases with group size, creating peer pressure on students to prepare and contribute. As outlined in section B there are indications that this measure showed indeed some effect. Secondly, in order to prevent one "strong" student from doing all the problems while others are passive, the problems typically involve some time-consuming calculations that are unlikely solvable by one individum in time. However we found that this aspect is not too critical, since the students generally had difficulties to predict the time it will take to solve a problem. As a positive effect, we observed that the students used the whole group as a resource and divide the work among themselves.

IV. Evaluation and Discussion

Our preliminiary research confims that the group assignments in this case study had positive effects on several of the factors identified in the introduction. Academic achievement has stayed around the same or improved. In one course (Physics for Computer Engineering Students) the pass rate of students increased from 22% to 80% (even though there were some other contributing factors). However, in some courses the pass rate was the same or had gone down slightly, but this has been in courses where the pass rate previous years already had been over 90 %. An potentially interesting finding in this regard is the effect of a course's reputation within the program. We observed that in programs where the course had the reputation of being very hard, participation and student effort in the lectures and group activities appeared to be generally higher than in programs, where the course had very high prior passing rates and thus the reputation of being easier. It will be interesting to see whether this effect will also be observable in the future as higher passing rates might change the reputation of the course in a particular program.

In terms of students' attitudes towards the CLA, the course evaluations show a very positive perception. In the qualitative comments part of the evaluation, we found that many students brought up the group assignment as one of the things that should definitely be maintained in the course.

Further, from the observation of the group exercises we learned that the way how the groups organize the work varies. Some groups chose to do all problems together while others divide the problems among them and finish with a common discussion in which they decide what solution they hand in. In both cases is the discussion during the work, particularly the one when the group decide what the correct solution, a very powerful learning experience.

Finally, we also observed a positive effect on interpersonal relationships as the activity served as a way for students without study friends to get a social network.

V. Conclusions

In this paper, we described the implementation of group assignments in a physics class and shared our experiences from several course iterations. The improvement in performance in course instances with prior low passing rate, the consistently good survey results combined with our own observations lets us conclude that this implementation of a CLA is a powerful tool to improve physics education. The specific measures that were implemented to encourage active participation and avoid free-riding were widely successful and relevant. Although generizability is limited we think that verions of this CLA can also successfully be implemented in other courses, particularly within the field of STEM education. To even better understand the social dynamics and their impact on individual learning, we will expand our research through the analysis of video recordings of five groups per course.

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