A case study on cooperative problem solving processes in small 9th grade student groups

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***Abstract*— It is one of a teacher`s challenges in lesson planning to consider all levels of learning involving students` team skills while taking the actual subject content into account. This descriptive study examines how the student-centered approach can be utilized as supportive classroom climate and how it can be combined with cooperative team tasks for solving computational thinking problems using an easy accessible computer-coding environment. Drawing on existing concepts and research methods this study applies a case study approach with mixed methods to investigate students` development of team-attitudes and characteristics of team cooperation. It turned out, that students identified the quality of cooperation in their teams as beneficial and productive while from an outside point of view their teamwork seemed to be unorganized and not cooperative. These contradicting results were clarified in a classroom meeting, where it became clear, that the student-centered classroom climate still could have influenced students` team attitudes in a way that students felt comfortable to express themselves in their, sometimes not so nice, youth language during problem solving tasks but while be able to solve problems effectively.**

Keywords — computational thinking; student-centered learning; mixed research methods; computer science education; team attitudes;

I. INTRODUCTION

Cooperative learning in small student-groups supports learning processes and students` skills to solve problems [1]. In computer science education, problem-solving skills, as the evaluation of possible solution paths to a problem, are summarized in the term computational thinking [2]. This paper presents a study, which investigates the effect of a student-centered classroom organization as defined by the well-known American psychologist Carl R. Rogers [3] on students' team attitudes and problem solving characteristics in small student teams. In former studies, it was already shown that student-centered lessons provide a beneficial climate for promoting students` team skills [4], [5], [6]–[8]. As proof of concept this study applied in 9th grade student groups cooperative problem solving tasks. The process was investigated as mixed research approach [9], [10] and descriptive case studies [11] with three leading research questions aimed at students` perception of the teacher`s interpersonal attitudes, students` team attitudes and characterization of team processes. In this context, 9th grade students were actively involved in computational thinking coding challenges while emphasizing on collaboration, communication, problem solving, and teamwork-skills [12], [13]. The next section describes the theoretical background in our pedagogical approach and computational thinking. In the second section, methods, instruments and analysis methods for this study are presented. The third section describes results, which will be interpreted in the fourth section.

A. Theoretical Background

1) Student-centered learning

One of a teacher's concerns is to find an appropriate approach to organize lessons in a way, that students are motivated to acquire knowledge, develop enthusiasm and curiosity for the subject. Building such learning environment depends highly on the teacher`s interpersonal attitudes of authenticity, openness, acceptance, unconditional positive regard, and a deep understanding for students' feelings and meanings [14]. This learning environment is identified by a supportive interpersonal relationship between the teacher and students and was described by Carl Rogers' student-centered approach [3]. It is assumed, that students who are given freedom to explore areas based on their personal interests, and who are accompanied in their striving for solutions by a supportive, understanding teacher do not only achieve higher academic results but also grow with respect to their personal values, and social skills [15]. Therefore the teacher is providing a positive, warmth climate, which is required for students to be able to develop social skills and knowledge. In [16] it is emphasized that education has to go far beyond addressing exclusively students` knowledge in order to master the nowadays challenges as problem solving, flexibility, creativity, analytical thinking, critical skills and effective communication, openness and self-management. Evidence for that was proven in numerous studies, where in such classroom climate even a change in students` interpersonal attitudes was identified [17]–[22]. In a student-centered learning environment the development of both, knowledge-specific and interpersonal competencies are part of everyday classroom lessons [23]. Based on the idea, that knowledge, skills and personality can be seen as separate levels of learning, this paper assumes that the combination of all levels is effective if each level can unfold it's full range and all levels contribute to a significant learning experience [24]. For instance restricts pure intellectual learning or learning only for social skills an unfolding learning experience. In order to make such learning possible, the teacher has to cover all levels of learning in

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lesson planning. In a practical context, this means that classroom organization is about to engage learning in a facilitative positive climate, while promoting team skills in order to be able to transfer content knowledge. Former studies found out, that such student-centered classroom climate lead to more active participation in teams to construct knowledge for efficient collaboration and cooperation in teams [5], [8]. Students` learning experience significantly has improved in team skills, and students felt they have improved their teamwork competencies as a result of student-centered courses more than when attending traditional courses that included teamwork [15]. In summary, student-centered teamwork is a type of cooperative organization, where students have the opportunity to be an active part of decisions in their learning. This framework builds the pedagogical background for this paper.

2) Computational Thinking

Problem solving competencies and the ability to identify, analyze, abstract and solve problems is defined by computational thinking concepts and is an approach how solutions for problems can be systematically approached, solved and captured for reuse. For instance, in [25], [26]–[29] describe computational thinking as the process of framing problems and their solutions as an iterative and interactive process between the model of computation [30]. Furthermore cooperative problem solving is seen as one of the core aspects as defined by the Irish National Council for Curriculum and Assessment (NCCA) in the specification of Coding where teamwork is a skill required for students to learn collaboratively and to reflect on their work [31]. Moreover, in [32] the importance of team competencies in computer science as core competencies in solving coding problems is underlined. Taking this into account, the present study emphasizes on cooperative teamwork using an easy graphical coding environment called *Python Turtle* as programming language for developing small programs for drawing graphics by coding as for example the house as depicted bellow. The code on the left hand side is a snippet of that house and represents a rectangle with the size of 100px.

```
forward(100)
left(90)
forward(100)
left(90)
forward(100)
left(90)
forward(100)
```

Fig. 1. Code snipped and result of coding task

While these commands seem simple, *Python Turtle* can still be a powerful tool and challenging for solving complex tasks as this environment uses all structures that Python has.

TABLE I. LESSON PLAN

#	Topic	Method
1	Introducing Python turtle	Lecture
2	Easy examples (shapes)	Pair work
3	Introducing advanced concepts	Lecture
4	Challenge (snowflake)	Team work
5	Summarize what learnt	Lecture

The lesson plan above shows a rough structure of the lesson plan applied for in this paper's described research. The focus on problem solving took place about over a period of two months. It followed student-centered lesson patterns aimed at motivating students, providing easy accessible examples and providing challenging tasks in team and pair-work. The underlying lesson patterns for student-centered computer science lessons were taken from [33]. Details of the lesson plan are left out here as this paper emphasizes on describing the research process and it's results.

B. Research Questions

The research goals of this study are students' team attitudes, their understanding of cooperation in groups and the characteristics of students' interaction in groups and described as research questions:

Taking student-centered classroom organization as precondition into account:

RQ1: To what degree perceive students the teacher`s student-centered attitudes?

RQ2: Is there a difference in students' team attitudes before and after the intervention?

RQ3: What are the characteristics of students' interactions and cooperation during computational thinking problem solving processes?

II. METHOD

Based on a case study approach as suggested by [9]–[11] this paper presents a research approach suitable for small student groups. The study design integrates a mixed-methods approach, including pre-post design questionnaires, reflection sheets, interaction analysis and a classroom meeting in the context of qualitative, descriptive research.

A. Research Design

Data were collected from three independent computer science classes at a 9th grade high school in Austria, each group divided in two groups A and B due to limited available computer workstations in computer labs. The A groups were taught by the participatory researcher involved in this research project with a total of 41 students across all classes. Another teacher, who was not involved in this research project, taught the B groups. As the B groups had no emphasis on cooperative problem solving tasks, they were not considered as control groups for research question 2 and 3. However, the B-groups were included as control groups for research question 1 as the teacher`s attitudes are focused on interpersonal qualities and independent from content taught. Thereby it was possible to identify external influences of students` perception in order to isolate interpersonal developments to the A-groups compared to B-groups. The table below shows an overview of the intervention groups and control groups.

TABLE II. STATISTICS OF INTERVENTION GROUPS

Group	Students	Boys / Girls
G1	14	6/8
G2	15	10/5
G3	12	6/6

TABLE III. STATISTICS OF CONTROL GROUPS

Group	Students	Boys / Girls
G1	15	4/11
G2	13	9/4
G3	13	5/8

The benefit of three available different student groups was to be able to carry out multiple case studies, each group as separate investigation but also to get overall comparable results for interpretation across all groups.

The study was carried out during one academic year from September to June. From March to May each one of the A-groups experienced the same intervention with a focus on collaborative problem solving using *Python Turtle*. The reason for placing the actual problem solving tasks to a later time during the academic year was, that former research results identified that the students` perception of teacher`s student-centered attitudes developed over a longer period of time [17], [34]. The case study approach is based on three principles: using multiple sources of evidence to get different views on the field, a case study protocol and database where collected data is stored for maintaining a chain of evidence from research questions to interpretation of results. This allows tracking the way back from a conclusion to the initial design of a research instrument. Students` perception of the teacher`s interpersonal attitudes was measured at three times at the beginning of the academic year, in between and at the end. During the collaborative problem solving intervention from March to June, research instruments were focused on evaluating students` team attitudes and the characteristics of students` collaboration in teams.

B. Instruments

1) Questionnaires

Students` perception of the teacher`s student-centered qualities was examined with a questionnaire by [17] at the beginning, during and at the end of the school year. Students´ level of team orientation was measured with a standardized questionnaire which was already applied by [6] for investigating the impact of the student-centered approach in college classes. In order to observe differences before and after the intervention, the questionnaire was distributed as pre-/post-test.

2) Reflection sheets

In order to identify the characteristics of students' interactions, students were asked after the beginning of the intervention phase to state their attitudes and beliefs of cooperation in groups on reflection sheets. Categories were built based on these results and at the end of the intervention phase students were asked again to state their beliefs of cooperation in groups. Reflection sheets were used for measuring students` thoughts and interests on their view on team cooperation. Former research experiences using this instrument suggest meaningful and deep insights as described in [35]. In particular, students responded before the intervention for a written reflection about their understanding on team cooperation on this question:

What does team cooperation mean for you? State at least three sentences what your personal opinion is.

3) Students´ interaction

Students` communication while problem-solving task using *Python Turtle* as programming language was audio recorded. The challenge for students was to draw a house using a drawing pencil controlled by basic commands. By using the commands *forward(), left(), right(), penup(), pendown()* students designed an algorithm for drawing a house. The transcribed audio recording was categorized in characteristics codes for team cooperation based on [36].

4) Classroom meeting

In order to get deeper insights and characteristics of classroom processes beyond what the remaining research instruments have measured, a classroom meeting as a type of group-discussion defined by [37], [38] and further specified in the student-centered context by [4] provides a way to check collected data back with students directly to resolve unclear outcomes of other research instruments. Students` statements were noted during and immediately after the meeting.

C. Data Analysis

The underlying approach of this study`s data analysis is driven by the explanation of what has been measured and the interpretation of data from different point of views. Collected data was triangulated across research questions in a process of clarification that each outcome was either confirmed, unconfirmed, revised or provided further explanations. This approach of analysis has the benefit that outcomes can be viewed, arranged and interpreted from the qualitative and descreptive point of view.

Research question 1: According to [17] a teacher is high-valued in student-centered qualities if the results are above 3.0. Outcomes of each intervention and control group were compared with descriptive statistics in order to find tendencies to the given threshold of 3.0. Additionally, students' comments on the teacher`s interpersonal qualities were noted during the classroom meeting,

Research question 2: Results of students` team attitudes were analyzed for a high esteem of teamwork and cooperation and the level of active participation during team processes [7]. The pre- and post-test results were compared descriptively for identifying variations before and after the intervention. As qualitative support of these outcomes, reflection sheets were coded for the frequency of mentioned team attitudes and compared with outcomes from the second data collection after the intervention.

Research question 3: Students` interaction was analyzed in categories proposed by [36]. (I) Informative, (RS) Reasoning in language, (EV) Evaluating work or action, (Q) Asking

questions, (A) Answering questions, (OR) Organizing processes, (JA) Expressing agreement, (JD) Expressing disagreement, (RP) Repeating spoken language, (AF) Expressing feelings. The qualitative counterpart of the interaction analysis is given by the classroom meeting. Students were faced with results of the interaction analysis and dialogues of audio recording and asked to reinterpret the statements during the problem solving process. Furthermore, students had to revise their transcribed dialogues to compare the recorded interactions with students' reactions for explaining and clarify communication patterns during interactions.

III. RESULTS

A. Research question 1: Students` perception of teacher`s interpersonal attitudes

When students were first asked in October, both, the intervention group students and control group students had a similar level of perception of the teacher`s attitudes. Only on the level of the teacher`s authenticity students of the intervention groups rated the teacher 2.98 while students of the control groups rated the other teacher with 2.30. During the school year, the intervention group's perception of the teacher`s student-centered attitudes tended to increase, while students' perception in the control groups remained the same.

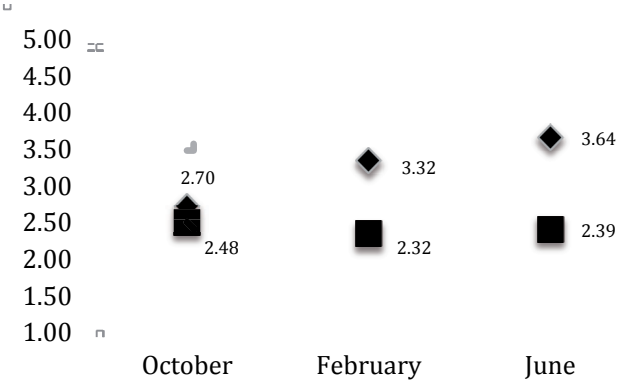

Fig. 2. Average value representation over all intervention- and control-groups

B. Research question 2: Team attitudes

1) Questionnaires

Most of the questionnaire's items improved slightly towards higher team attitudes and only a few decreased. Even though, some items showed a clear increased result of team attitudes over the period of time, most of the items have only little variation between pre-/ and post-test. When summarizing the average data values of all items, it can be identified, that the improvement of team-attitudes showed only a marginal improvement.

TABLE IV. AVERAGE RESULTS ACROSS ALL ITEMS

	Pre		Post	
	M	SD	M	SD
Group 1	1.98	0.92	2.18	0.99
Group 2	1.92	0.98	2.08	1.09
Group 3	1.95	0.90	2.08	0.95

2) Reflection sheets

Based on the results of students` reflection sheets before the intervention phase, 9 categories were coded and counted how often they were mentioned. Further written students` reflections were coded again after the intervention and counted into the 9 categories as initially defined.

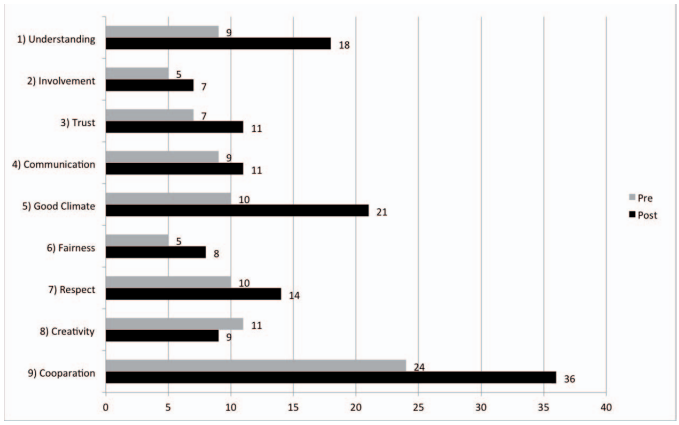

Fig. 3. Results of feedback sheet analysis: *What does team cooperation mean for you?*

Some items developed positively in all three groups with at least 5 more mentions at the post-test. These were: 1: Understanding, 5: Good Climate, 9: Cooperation. Slight improvements with a plus of 3 mentions showed the items 3: Trust, 6: Fairness, 7: Respect. One item (2: Creativity) decreased in the post-test slightly with -2 mentions at two groups and remained unchanged at one group.

C. Research question 3: Characteristics of students` team cooperation

1) Interaction Analysis

After audio recording students interactions (about 7-10 minutes each) the dialogues were analyzed and assigned into categories. The table bellow shows, that student interactions mainly had the characteristic of dominant organizing processes, reasoning- and thinking-processes, asking and evaluative processes.

TABLE V. RESULTS OF INTERACTION ANALYSIS

Category	Code	Description	G1	G2	G3	S
Informative	I	Providing information	8	5	2	**15**
Reasoning	RS	Reasoning in language	10	18	13	**41**
Evaluating	EV	Evaluating work or action	7	9	8	**24**
Asking	Q	Asking questions	9	6	13	**28**
Organizing	OR	Organizing or/and controlling behavior	21	25	17	**63**
Agreeing	JA	Expressing agreement	1	13	2	**16**
Disagreeing	JD	Expressing disagreement	1	1	1	**3**
Repeating	RP	Repeating spoken language	3	1	1	**5**
Feelings	AF	Expressing feelings	9	4	5	**18**

2) Classroom Meeting

The classroom meeting was initiated for a clarification of contradicting results at the end of the intervention phase. During the first session, students were challenged with

differing results of reflection sheets and interaction analysis, that students saw themselves as understanding and cooperative, but the outside view showed dominant and controlling behaviour. Students were asked to improve the transcribed interaction protocol with less domination and controlling by a single team member towards a cooperative problem-solving interaction where all team members can contribute equally to the process. While students edited the transcription of the recorded interaction in groups it turned out that students were surprised about their language they used and how they still were able to accomplish the task successfully. In the second session a role-play of transcribed and improved interactions was carried out with students in order to uncover and experience differences. One group played the original transcribed text of the interaction analysis and the other group played the improved version. At the end students` reactions were differing and illustrated reflective conclusions of the students and new insights.

This statement points out that the students know each other that bad language is not considered as insulting someone.

I feel so comfortable in this computer science class that I have such a trust in our classroom group so I know that such language maybe sometimes not so nice sounding but we know is okay for us.

This student mentions that the language that they use is a sort of a common communication style, which is automatically used in classroom settings even though the improved dialogues sound nice.

When I have to compare both interactions, I would say that the modified one is better for team work. But I know from my experience, that interaction with my colleagues in the classroom never looks like that. For some reason, I don't mind during lessons when we talk in that way to each other. And I think that we still were very productive and cooperative.

This student sees the sense of using more a respectful language but also sees that the other language is a respectful in their way.

The role-play opened up my eyes a little. I realized that we sometimes would need more respect in talking to each other. On the other side I see that it is difficult to keep this respectful style in conversations. It is more like for having fun during lessons when I talk to my colleagues in that way. I do not intend to control someone. It is just like my conversation style.

Here it is mentioned that they all work well together and sees no reason to change the way of talking with each other.

We see that we accomplished the task very well. We also see that we never argued or had some fight with each other. Further no one did obviously feel hurt about the conversation style. Why should we change in this strange sounding conversation style as in the role-play?

This student is aware of the language they use and even sees advantages in using the improved communication patterns. However, he doesn`t see a correlation between teamwork performance and the style of communication.

When I was listening to the modified role-play I felt more for the original conversation as it happened here. I really would like to have conversations like this. But I also see that we really like each other and we really like to work with each other in teams. This tells me that somehow the conversation style cannot have so much impact on our team abilities.

IV. INTERPRETATION

RQ 1: Perceive students the teacher`s student-centered attitudes? If the teacher's authenticity is perceived under 2.40 at the beginning of the school year, the perception of the teacher's authenticity remains under 2.80 during one school year. If the teacher's authenticity is perceived over 2.95 at the beginning of the school year, it increased up to 3.65 during one school year. Further, students of the intervention groups increasingly perceived the student-centered climate in average.

RQ 2: Is the students' team attitude different at the end of the school year? In average the students' team attitudes increased very little over one school year. Hence, it can be assumed that the student-centered classroom climate has little or no impact on students` team attitudes and creativity is not considered as an important factor for team attitudes. This complies with the findings of [6] where for college classes similar results were found - also on item level.

RQ 3: What are the characteristics of students' interactions and cooperation during computational thinking problem solving? Thinking- and evaluative processes are very positive aspects for group work, but dominating students used them for organizing and controlling. The interaction analysis showed that students` characteristics of cooperation differ slightly as they have stated in the reflection-sheets. As students saw themselves in reflection sheets as cooperative group with understanding and respecting of each other's contributions, results of audio-recorded interactions showed a different picture of controlling and organizing group processes by dominant members. The question was, why students perceived the positive student-centered classroom climate and described their team characteristics as cooperative but didn`t show in fact show these attitudes. This issue became even more interesting, when considering outcomes of the programming tasks which were accomplished effective within a short period time. Contrary to that, students also were interested to achieve results in using non-cooperative language or even without the help of others. This kind of youth language is expressed as controlling behavior and for adults understood as non-cooperative. Students are aware of the language they use and see it as an important factor for their successful communication. It can be assumed, that when students have to solve problems cooperatively they prefer to use their youth language for communication if the classroom climate is perceived as positive. It can be assumed, that this authentic behavior comes from the positive classroom climate as measured in the first research question.

V. CONCLUSIONS

This study evaluated the impact of student-centered classroom organization on students' team attitudes and characteristics of their interaction and cooperation. The outcomes are twofold: First, the chosen approach for small group classroom research

with mixed methods showed that if classroom research in small groups is structured as a long-term/short-term and qualitative/quantitative data collection approach, a broader view on the field is possible leading to deeper insights. Second, this study unveiled some characteristics of students` interaction, communication and problem solving approaches where it turned out, that even if students` teamwork processes can appear ineffective for adults, the actual process is still effective and the results are valuable.

A. Methodical Limitations and further work

The results of the current study have a number of limitations in data collection and analysis. Even though mixed methods and a research protocol provided a certain countercheck to avoid a bias during collection and analysis of data, certain limitations have to be taken into account for generalizing and reinterpreting data. Even the research instruments were designed and applied thoughtfully, the fact that the teacher of the intervention group was at the same time the researcher collecting data remains as weak spot of the study. The outcomes of the study, that there is a possible impact of the student-centered classroom climate on students` team skills and collaborative problem solving competencies at computational thinking processes requires further studies to underline these assumptions carefully by taking statistical methods into account. While this study`s goal was not to examine statistical significance of student-centered lesson organization on computational thinking problem solving processes, it`s outcomes are still noteworthy as they describe a phenomenon that occurred in this particular setting of this research project. In summary, this study has to be considered as contribution and example for research in small student groups in computer science education. With an instruments` composition of questionnaires, students` reflection sheets, a classroom meeting and a subsequent content analysis, which was compared with data of an interaction analysis, we see potential for further work to continue with the testing of the case study research protocol in practice for usability for other teachers and researchers in classrooms. Further studies should involve more teachers who apply these scenarios, more student groups and external observers and investigators to improve the rating analysis quality of the outcomes.

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