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Analysis of differences between teachers' activity during their regular and constructivist lessons

Janka Medová, Kristína Bulková and Soňa Čeretková

Constantine the Philosopher University in Nitra, Faculty of Natural Sciences, Department of Mathematics, Nitra, Slovakia; jmedova@ukf.sk, kristina.bulkova@ukf.sk, sceretkova@ukf.sk

Different aspects involved in the constructivist teaching mode were assessed in the eight observed mathematics lessons conducted by four upper-secondary in-service teachers. Four among these lessons were identified as 'regular' by the teachers themselves, the other four lessons followed the same constructivist lesson plan designed by the respected educational expert. The main differences were found in the way how the students were working and achieved their independent learning capabilities. The lessons following the constructivist lesson plan were clustered together by the means of hierarchical cluster analysis. The regular lessons were more influenced by the teachers' personalities than the constructivist lessons.

Keywords: Teacher behaviour, teaching styles, professional development.

Introduction

The traditional transmissive “chalk-and-talk” methods have already been criticized continually, while concurrently the student-centred pedagogies have frequently and gradually been approved for several decades (Steffe & Kieren, 1994). Teachers face a lot of issues and challenges when implementing awaited constructivist approaches (Appleton & Asoko, 1996). Teachers lacking any experience in the constructivist classroom often struggle with the setting up such a learning environment that is demanded for the constructivist perspective (Windschitl, 2002).

According to Schoenfeld (2010) the teachers' decisions during the lesson are influenced by their resources (i.e., knowledge, material just being available), goals (e.g., such aims which they are trying to achieve) and orientations (e.g., their beliefs, values, biases). Teachers' professional knowledge can be seen as an outcome of their overall different experiences they have been involved in, including both formal and initial training, as well as professional development and informal forms of learning through their own practice or media. The overall teachers' knowledge has been constructed and developed gradually. Such process has been always influenced by their prior beliefs, pre-knowledge or originating knowledge and experiences of the knowers (Smith, 1993). As such, different people experiencing the same intervention will achieve and develop their own and usually quite different constructions of that experience (Lachance & Confrey, 2003).

Theoretical framework

Beerenwinkel and von Arx (2017) describe the constructivist-oriented teacher as a person who activates the overall students' pre-knowledge and provides them with some suitable issues and problems, often related to their everyday context. During the problem-solving activity of students, the teacher creates a space for independent learning, encourages rethinking and seeks to demonstrate certain scientific approach to generating such knowledge.

According to Widodo & Duit (2004), there are four categories comprising the significant indicators for the constructivist teaching: (a) construction of knowledge (CK); (b) personal relevance (PR); (c) social interaction (SI), and (d) independent learning (IL). Beerenwinkel and von Arx (2017) defined evident facets for each of the listed indicators that are suitable for quantification. Construction of knowledge can be assessed according to status in the learning process, activation of pre-knowledge, providing problems, evolutionary development of knowledge, revolutionary development of knowledge, thinking aloud and demonstration of the scientific approach to knowledge generation. Personal relevance is based on exploring the interest, accounting for needs, everyday-life context and transfer to other subjects. Social interaction can be quantified according to extent of student-student interaction, student-teacher interaction with the whole classroom and student-teacher interaction while individual work or group work. Independent learning is manifested in space for independent learning, encouraging the rethinking, fostering the metacognition, benefit from independent learning and metacognitive abilities.

In our study we focused on the differences between the regular lessons of Slovak mathematics teachers and the lessons conducted by the same teachers based on the lesson-plan prepared by the relevant expert in constructivist teaching and learning. We stated the following research questions: (i) In what facets of constructivist teaching does the regular lesson differ from the lesson based on the lesson-plan prepared by the relevant expert? (ii) What are the relations between the episodes from regular and constructivist lessons of investigated teachers? (iii) What are the (implicative) relations between the facets of constructivist teaching observable in the lessons of investigated teachers?

Materials and methods

Within the project PRIMAS supported by the European Union FP7 the course aimed at the professional development (CPD) of mathematics teachers was implemented at the authors' university. The CPD focused on the implementation of inquiry-based learning and thus also constructivist teaching in upper-secondary schools. Several authors (e.g. Jaworski, 2006) see inquiry as fitting with the constructivist view of knowledge and learning.

The structure of the course followed the spiral model of teachers' professional development, consisting of the following three repeating steps: Reflection - Analysis - Implementation. The course was aimed at the transformative learning of the participating teachers as mentioned by Thompson and Zeuli (1999). Firstly, the teachers reflect on the lesson they labelled as 'regular'. Later in the course, the teachers went through this cycle for three more times. They did specific changes in their practice, videotaped their lesson, reflected on it and came with specific conclusions that might influence their further practice. The first change was in the way of questioning. The second lesson should follow expert-prepared lesson plan. Detailed lesson plans including typical student questions and suggested answers were chosen with the aim to offer teachers tools that they were not familiar with prior to the study. Any and every positive experience in implementing constructivist approach is very good motivation for their further practice. The third lesson was planned by teachers themselves according their experience from previous cycles.

In order to answer the research questions we analysed eight videotaped lessons taught by the four participants of CPD that implemented the same lesson plan named *Counting trees* (Mathematics Assessment Resource Service, 2015). Two lessons for each participating teacher were analysed. The first of the lessons were recorded after the first 90-minute session of the CPD. The teachers were required to record their regular mathematics lesson following the national curricula. The second analysed lesson was the one following the *Counting trees* lesson plan. The teachers did not get any special support to this particular resource. On the other hand, the constructivist lesson was carried out after completing the 52 out of the 60 group contact lessons of the CPD. The subsequent sessions reflecting on the lessons were conducted in researcher-teacher pairs.

The lessons were divided into smaller episodes according to the activity during the lesson (i.e., teacher lecturing, group-work, etc.). The time for each episode was recorded. Each episode was labelled by pseudonym of the given teacher, number of lesson (1 - regular, 2 - constructivist) and phase of lesson. The defined facets were assessed for each episode. The levels were defined from 0 (the facet was not manifested in the observed lesson) to 3 (the facet regularly occurs in the observed lesson). The facets describing the personal relevance got almost for each observation the zero value, so we decided to omit this indicator from the further analysis.

The weighted arithmetic mean for each facet was calculated and the mean value of the lessons was compared by the means of paired *t*-test (De Winter, 2013) performed in R environment (RCoreTeam, 2018). The hierarchical cluster analysis was performed using the Euclidean distances and UPGMA clustering method. The cophenetic correlation coefficient was used to determine the most accurate clustering method. The statistical implicative analysis (SIA) (Gras et al., 1996) using package *rchic* (Coutrier, Pazmiño Maji, Conde González, & García-Peñalvo, 2015) was applied to explore the implicative relations between the facets of constructivist teaching.

Results

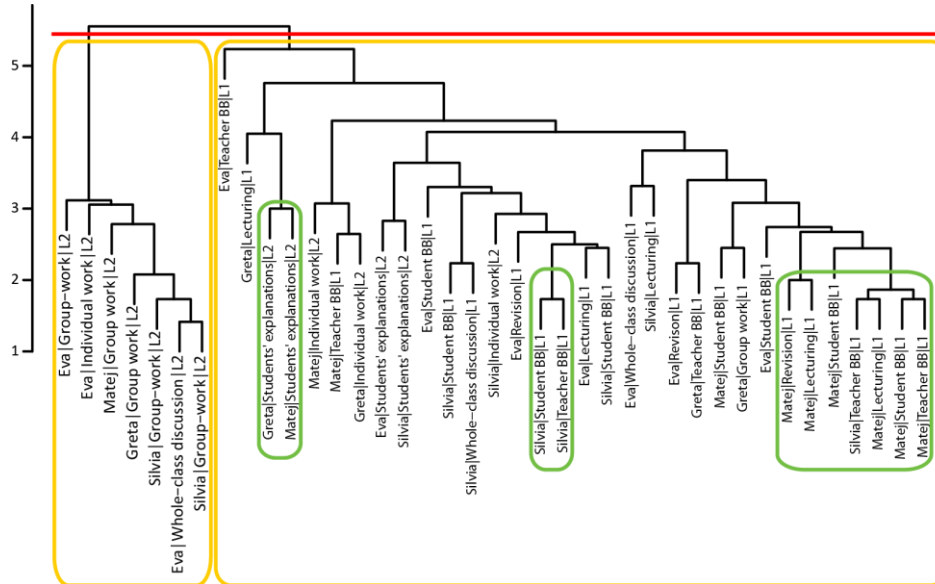
Four of the observed facets significantly differed between the regular and constructivist lesson. The means, *t* statistics and *p* values are summarized in Table 1. The evolutionary development of knowledge (CK4) and teachers' thinking aloud (CK6) were more prevalent in the course of the regular lessons. Surprisingly, the revolutionary development of knowledge (CK5), typical for the constructivist classroom was not significantly higher in the lesson based on the constructivist lesson plan.

The student-student interactions occurred more often in the constructivist lessons as there was actually a large space devoted to the group-work during the lesson. The level of student-teacher interactions did not differ significantly, neither for the individual, nor for the group communication. Fostering metacognition features (IL3) and benefits from the independent learning (IL4) were the two characteristics of individual learning that did differ significantly between the two lesson types.

| Facet | Description of facet | Lesson 1 | | Lesson 2 | | <i>t</i> | <i>p</i> |
|-------|--|----------|-----------|----------|-----------|----------|----------|
| | | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | | |
| CK1 | Status in the learning process | 0.82 | 0.47 | 0.03 | 0.01 | 2.00 | 0.092 |
| CK2 | Activation of pre-knowledge | 0.99 | 0.55 | 0.36 | 0.68 | 0.43 | 0.354 |
| CK3 | Providing problems | 0.40 | 0.03 | 0.18 | 0.17 | 0.30 | 0.395 |
| CK4 | Evolutionary development of knowledge | 0.75 | 0.27 | 0.06 | 0.07 | 2.95 | 0.049 |
| CK5 | Revolutionary development of knowledge | 0.36 | 0.07 | 0.36 | 0.22 | -0.01 | 0.496 |
| CK6 | Thinking aloud | 2.15 | 0.87 | 1.19 | 0.56 | 4.12 | 0.027 |
| CK7 | Demonstration of the scientific approach to knowledge generation | 0.25 | 0.14 | 0.00 | 0.00 | 1.50 | 0.137 |
| SI1 | Student-student interaction | 0.18 | 0.02 | 2.05 | 0.19 | -6.17 | 0.013 |
| SI2 | Student-teacher interaction (classroom) | 1.67 | 0.23 | 0.85 | 0.42 | 1.98 | 0.093 |
| SI3 | Student-teacher interaction (individual work or group work) | 0.84 | 0.82 | 1.62 | 0.07 | -2.22 | 0.079 |
| IL1 | Space for independent learning | 0.51 | 0.25 | 2.03 | 0.07 | 1.53 | 0.133 |
| IL2 | Encourage rethinking | 0.64 | 0.14 | 0.68 | 0.58 | 0.20 | 0.432 |
| IL3 | Foster metacognition | 0.38 | 0.02 | 1.62 | 0.01 | -11.34 | 0.004 |
| IL4 | Benefit from independent learning | 0.22 | 0.04 | 1.39 | 0.27 | -2.85 | 0.052 |
| IL5 | Metacognitive abilities | 0.62 | 0.15 | 1.00 | 0.28 | -0.49 | 0.337 |

M = mean, *SD* = standard deviation, Lesson 1 = the regular lesson, Lesson 2 = the *Counting trees* lesson

Table 1: Mean values of the levels for the facets describing indicators of constructivist teaching



Name of the teacher|Episode of the lesson|Number of lesson; BB means solving a task on the blackboard; L1 regular lesson, L2 *Counting tree* lesson.

Figure 1: Dendrogram grouping the episodes from the observed lessons

The observed variables from our analysis of the observed lessons were grouped into two clusters (Figure 1). The first one contained the variables representing episodes of constructivist lessons: the students work in groups (Eva, Greta, Matej, Silvia|Group-work|L2) with students' individual work (Eva|Individual work|L2) and whole-class discussion (Eva|Whole-class discussion|L2). The second cluster comprised of several smaller subclusters

grouped by the same type of an episode of lesson and by the style of teaching conducted by the observed teacher. For example, one subcluster contained almost all episodes of the observed lesson Matej1 (see Fig. 2 in green square). Some of teachers connected discussion in groups with the work on the project. In the first cluster, also one variable for individual work (Eva|Individual work|L2) is grouped. We assume that the teacher encouraged students also during their individual work.

The fifteen facets of constructivist teaching were grouped into the three clusters (Figure 2). In the first cluster, only two didactical variables were grouped: CK6 (thinking aloud), and SI2 (student-teacher interaction in the classroom). The second cluster contained the following five grouped variables: SI1 (student-student interaction), IL3 (fostering metacognition), IL4 (benefit from the independent learning), IL1 (space for the independent learning), and SI3 (student-teacher interaction during the individual or group work). The third cluster comprised of the following three didactical variables: CK1 (status in the learning process), CK4 (evolutionary development of knowledge), CK3 (providing problems), CK7 (demonstration of the scientific approach to knowledge generation).

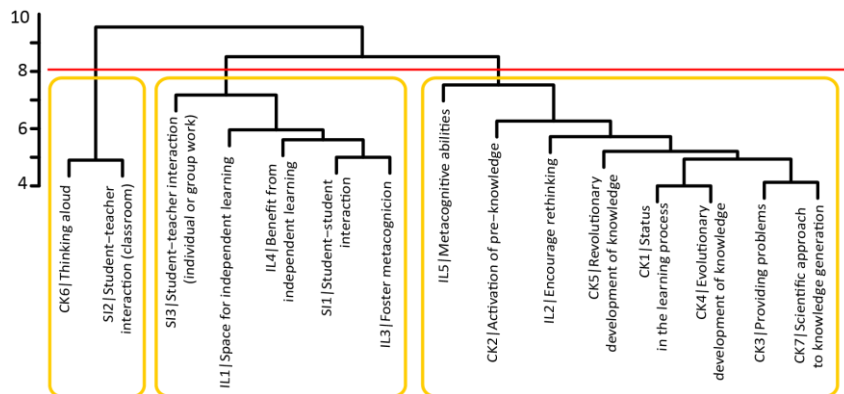


Figure 2: Dendrogram of different facets of constructivist teaching

The statistical implicative analysis produced the three R-rules (Figure 3). The first connected subgraph $IL2 \rightarrow CK6 \leftarrow SI2 \leftarrow CK2$ represents the aspects influencing the teachers' thinking aloud.

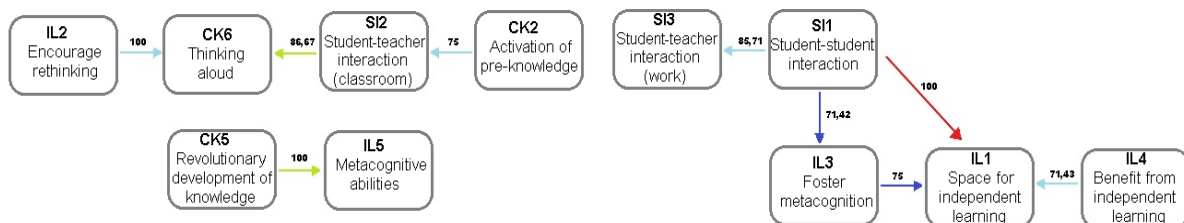


Figure 3: R-rules of the different facets concerning to constructivist teaching

Based on the results of the *t*-test we can conclude that since the lessons varied in their structure, the actual and real difference was mainly in the way how the students had been working. The teachers did not engage in “think aloud” too much and more time was devoted to the individual work of students. Student-student communications were observed more frequently which implied greater benefits for students as a result of independent thinking during constructivist lessons.

The variables grouped in the first cluster imply that the discussion in classroom about the given problem or topic is encouraged by teacher's thoughts aimed at revising or expanding a knowledge structure or framework. Students had real opportunities to reflect on their observations (or perceptions) related to the discussed issue (e.g., creating a definition, possible strategies, or solutions). Teachers' thinking aloud about the topic influenced the intensity of the interaction in the classroom between the teacher and students.

The variables in the cluster 2 represent the aspects of group-work in the classroom. The teacher supporting interactions between the students in groups, helps students share their opinions about the given topic and strategies in the solving process. The independent work gives some space to the students for managing time, tools, and strategies to achieve their assignment. Especially as far as the group work, the mutual discussion can bring several diverse ideas as far as the methods, form of collaboration, or managing of timing, and developing their soft or mathematical skills. The teacher enters into a conversation or group work only as a facilitator.

Based on the cluster 3, any knowledge, that is new for the students, can be easier integrated by linking it or by the reinterpretation and reinforcing of an existing previous knowledge. The scientific approach in the learning process may keep and support the quality of any new information for its integration into the knowledge structure. The grouped variable CK5 (revolutionary development of knowledge) confirms the teacher's role as a facilitator in the learning process, where the teacher gives comments, stimulating cognitive conflicts. In this sense, the variables IL2 (encourage rethinking), CK2 (activation of pre-knowledge) and IL5 (metacognitive abilities) represent such a new knowledge, that is activated through the discussion process, where the students can explain their arguments and thinking and the teacher encourages them to do so.

Results of the SIA indicate that the pre-knowledge covering a topic is activated in the discussion process headed by the teacher. Such discussion factually does represent an interaction between the teacher and the students in the classroom. Encouragement of rethinking is clearly an influential aspect to thinking aloud. The second rule (SI1→IL3)→IL1 contains the strongest implication: SI1→IL1, meaning, the mutual interaction between the students is conditionally a factor for their independent learning. Especially, while they are involved in group work in the classroom, students have a space to discuss their opinions independently from the teachers' leading. The teacher is only a guide who can help with some ideas in small groups (SI1→SI3). We concluded that for the independent work it is necessary to create a space for discussions between the students focused on developing the relevant questions, ideas or solutions. Discussion is interrupted by the teacher only with some comments enhancing the discourse. Finally, the rule CK5→IL5 represents how cognitive conflicts offered by the teacher can help the students to explicate their thinking, learning or problem solving.

Discussion

The study builds on the characteristics of constructivist teaching described by Widodo and Duit (2004) and further elaborated by Beerenwinkel and von Arx (2017) for science

education. The framework was implemented and used as a base for our quantitative analysis of eight mathematics lessons. Four lessons were usual for the teachers, and four were based on constructivist lesson plan designed by an expert. Students' activity was changed and the teacher had to adopt the new role of a mentor and facilitator of students' discussion.

Teachers in Slovakia frequently engage in lecturing practices. On the other hand, this style of teaching-lecturing is not seen too frequently in countries such as Israel or Japan where independent work of students connected with between-desk-teaching is usual. It also differs from the situation in Finland where the whole-class discussion is the usual teaching approach (Gunnarsdóttir & Pálsdóttir, 2015). The second lesson provided students with more opportunities for independent learning. Taylan (2015) recognised independent learning in both, individual and group work if the mathematical discussion was carefully prepared. It was the case also in *Counting trees* lesson plan that suggested teachers' questions to start and support students to discuss. The teachers' thinking aloud apparently decreased in the constructivist lessons. Despite Ayalon and Hershkowitz's (2015) claim that different teachers can see the same task differently, the proposed lesson plan seemed to have similar effects in participating teachers' classes. It may indicate similar experience with setting up the constructivist learning environment. The participating teachers were involved in the CPD aiming at the constructivist teaching style. We can assume teachers' willingness to teach in the constructivist mode as they had chosen this kind of course.

Conclusions

The outcomes and results of the study confirmed actual differences between the usual lesson and a lesson based on constructivist lesson plan. The episodes of the constructivist lessons when students worked independently were clustered together. Clustering the episodes of the regular lessons depended more on teachers' personality than on the phases of the lessons. Teachers during their regular lessons appeared to hold the main authority in the classroom. Based on our observations, teachers' thinking aloud or interaction between the student(s) and the teacher were more prevalent in the regular lessons. On the other hand, when the teacher was following the constructivist lesson plan, a higher level of independent learning was observed. The carefully prepared lesson plan enables the teacher to implement lesson in a constructivist approach. Further research is needed to evaluate impacts of the actual experience with constructivist lessons on teachers' regular practice.

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