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Using preservice teachers' reflections about a project-based statistics course to investigate knowledge creation in collaborative settings

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In project-based courses, students learn new knowledge through 'knowledge creation in collaborative settings'. We studied how personal, social and cultural aspects interact in such learning situations. Our empirical basis was a project-based course in statistics in primary teacher education. Participants (n=21) wrote reflective, post-course reports, in which we identified five 'drivers' of their learning. These were: (1) awareness of adaptable teaching conventions; (2) discussing with and explicating to others; (3) competencies relevant later, (4) knowledge of how statistics is used in society; (5) knowledge about oneself. The drivers connected the personal, social and cultural aspects in different ways. For instance, personal learning connected to the social through the group work, and to the cultural, such as teaching conventions and the societal role of statistics. These cross-connections were powerful drivers of learning and can be used for designing other courses.

Keywords: Collaborative learning, preservice teachers, project-based learning, societal role of mathematics, statistics education.

Introduction

In many countries, there are calls for reforming mathematics education to reduce teacher-centredness and the drill of mathematical rules. It is advised to foster meaningful relations (1) among learners, (2) across mathematical constructs, and (3) between mathematics and the world outside school. However, various barriers hinder reform, such as in-service teachers maintaining traditional teaching formats and examinations not being adjusted to reforms (Fullan, 2014). Also, teacher education (TE) offers limited backing to reform. On the one hand, TE still struggles to bridge the theory-practice divide and ease the *transition shock* when preservice teachers (PSTs) enter the teaching profession. Consequently, novice teachers have much to cope with and implementing reform is among the last things on their minds. On the other hand, in TE the knowledge about reforms is often only taught theoretically in lectures. The teacher-centred format of instruction then, in fact, contradicts the taught content. As a result, many PSTs have few experiences of how they themselves could learn new knowledge through reform practices. Nevertheless, such participatory experiences are well suited to learn about educational reforms, their benefits, and possible ways to implement these into one's own teaching (Darling-Hammond & McLaughlin, 2011).

We work in initial TE for primary mathematics and initiated a reform by redesigning a mathematical course into a *project-based* course (Holmes & Hwang, 2016). Contents and organisation of the course are explained below in 'Context of the study'. The reform aimed at offering PSTs first-hand experiences of learning new mathematical content within collaborative settings. In this way, they would learn *experientially* about a reform approach and not theoretically from lectures. The instructional format of project-based learning builds on the assumption that students can learn from each other in a dynamic process with peers. This process is known as *knowledge creation in collaborative settings* (KCCS) and will be elaborated below in the Theoretical Framework.

Some research on teachers' KCCS focuses on how digital tools (e.g., chat messages, shared online resources) can mediate the collaboration (e.g., Matranga & Silverman, 2022). Other research on teachers' KCCS is known as *lesson studies* (e.g., Quaresma et al., 2018) or *learning studies* (e.g., Mårtensson & Ekdahl, 2021), whereby teachers collaboratively design lessons, research these, and create knowledge relevant for their teaching. The resulting knowledge is pedagogical, practical and situated, and of a different type than mathematical knowledge, for instance regarding reasoning conventions and explicit formalizations of concepts. Although participants in lesson/learning studies also develop mathematical knowledge 'on the fly', this is not the primary objective. In our study, we took a different angle, namely by studying PSTs' KCCS of subject matter knowledge. Thus, our study was on KCCS within initial TE without applying lesson/learning study, and without focus on digital tools facilitating the knowledge creation. More concretely, the aim of our study was to study PSTs' reflections on their own learning processes within this collaborative setting, and what they perceived as aspects that contributed positively or negatively to their learning of statistics.

Context of the study

Our study was connected to an on-campus statistics course in a 5-year master's program for primary TE. The participating PSTs had chosen to specialize in mathematics education. For this, their 4th year consisted of two school practicums with a focus on mathematics teaching plus six 10-ECTs courses on mathematics and mathematics education, among which the statistics course. This statistics course aimed for content knowledge (with concepts like *significance* and *correlation*) and for pedagogical content knowledge (with concepts like *tally marks*, *categorizing*, and *data visualization*).

A *project-based* course builds on projects, in which students collaborate in small groups on an authentic, situated inquiry for an extensive period of time, after which they present their findings, orally or in writing, to outsiders (Holmes & Hwang, 2016). The statistics course consisted of ten projects, each of which was scheduled to take one full day. In the morning, PSTs worked on their inquiry and created a *slideshow* to present their findings in a plenary session in the afternoon. The projects aimed for PSTs to gain understanding of concepts from statistics, of the role of statistics in society and research, and of primary statistics education. Examples of project titles were *Refugee Statistics*, *Qualitative Research on Vulnerable Families*, and *Designing an Interdisciplinary School Project*. Project work took place in groups of 2-4 PSTs in small rooms with the first author available for consultation. Group composition was random and renewed every two weeks. If a PST could not be present, he/she had to individually write a project report. Since this was judged as cumbersome, course attendance was high in comparison to the two parallel courses.

Theoretical framework

The statistics course described above aimed at PSTs' KCCS, with neither a lecturer explaining statistics concepts nor seminars for solving exercises. In this paragraph, we clarify terminology, background, and theoretical perspectives to KCCS. To start with, the term *collaborative setting* points at an environment, in which people work together. Contrary to a *cooperative setting*, in which individuals have their own goals, in a collaborative setting the participants share common goals.

The term *knowledge creation* refers to the social practices that advance the knowledge in a community similar to how scientific research groups work. Knowledge creation requires talking, explaining,

writing, and other actions to determine gaps in the knowledge in the community, setting goals, investigating problems, creating ideas new to the community (not necessarily original), and evaluating whether the community's knowledge is advancing (Hakkarainen et al., 2013; Scardamalia & Bereiter, 2021). Knowledge creation can be hierarchically situated with a more-knowledgeable other as leader (e.g., a teacher), but when it happens in *collaborative settings*, participants work in a not-so-hierarchical group and share common goals.

KCCS is a type of *collaborative learning*, which is an umbrella term for all learning that is not individualized. Collaborative learning has benefits over individualized learning, such as higher motivation, fewer errors, more creativity, initiatives, and responsibility, increased confidence, and more efficient use of higher-level skills (e.g., reflection, planning) (Murray-Harvey et al., 2013). Such strengths are outcomes. However, the outcomes do not explain dynamics in the processes, and what important aspects in these processes assist participants in developing knowledge new to all.

In the present study, we aim to contribute to theorizing how individuals learn through KCCS. So far, many theories of learning fall short for giving meaning to key aspects in KCCS (Hakkarainen et al., 2013). Piaget's theory presumed learning to be a highly individual and mental endeavour, which does not account for the benefits of collaboration. Vygotsky's theory presumed a more-knowledgeable other guiding learners, which does not apply to KCCS since the knowledge to be created is initially absent among the peers. The same applies to other theories of participatory enculturation, whereby apprentices watch and copy the experienced elders without necessarily collaborating with each other. These theories do not consider the crucial role of non-hierarchical peer-groups in learning processes of individuals. The above implies that the complex dynamics in KCCS needs further theorizing. For this, we build on Hakkarainen et al. (2013) who explained that three aspects of human activity are involved in KCCS. These aspects are (1) the *personal*, which is the individual with his/her own background, perceptions, and pre-knowledge, (2) the *social*, which are the inter-personal activities and the concrete environment where the knowledge creation takes place, and (3) the *cultural*, which is the wider setting that frames the personal and the social, including traditions, conventions, mediating artefacts, and the historically developed knowledge-to-be-learnt. According to Hakkarainen et al. (2013), strong connections between these three aspects can be fertile for an individual's learning. For this paper, we studied dynamics in these cross-connections. Our research question was: *What relations across personal, social, and cultural aspects can be discerned in the dynamics in KCCS that, according to the PSTs, drive their personal learning?*

Methods

21 PSTs (15 female, 6 male) participated in the study. Following Murray-Harvey et al. (2013), we asked PSTs to write a reflection report after the course. These were the empirical base in our research. However, unlike Murray-Harvey et al. (2013), we did not offer guidelines or criteria, and informed PSTs that any reflection report was OK. We aimed to offer PSTs full openness for reflections, hoping for fresh insights. Also, we considered 4th year PSTs as pedagogically knowledgeable and well able to reflect on their learning experiences in university courses. Consequently, two PSTs submitted a superficial report of five lines; a majority submitted a one-page report, and three PSTs wrote more than 800 words. PSTs were asked permission to use their work for research and all were anonymized.

Data analysis: before analysing the reports in light of the theoretical aspects (the personal, social, and cultural), we categorized the various reflections in PST's reports according to themes. For this thematic categorizing, we used Grounded Theory (Corbin & Strauss, 2015). First, the first author read all reports asking: "what are recurring themes that PTSs report as 'driving' their learning in the course?" (open coding). This led to four *drivers*. Thereafter, the second author used the four and examined line-by-line six randomly selected reports (axial coding); she found a need for a fifth driver. To these thematic drivers, she put illustrating excerpts. Both authors discussed this analysis and agreed on the five drivers. Thereafter, the second author validated the themes to all reports, finding new excerpts and no need for new drivers (saturation). The five drivers were named: (1) awareness of adaptable teaching conventions, (2) discussing with and explicating to others, (3) competencies relevant later, (4) knowledge of how statistics is used in society, (5) knowledge about oneself. Thereafter, we analysed the excerpts in each thematic driver in light of connections across personal, social, and cultural aspects that PSTs reported as driving their learning within a KCCS. For instance, excerpts in the driver 'awareness of adaptable teaching conventions' testified of PSTs' gained insights (personal learning) into advantages of learning in self-directed peer groups (the social) as an alternative to teacher-centred instruction that had so far been taken for granted (cultural conventions).

Results

We identified five drivers that PSTs reported as contributing to learning. The first driver was 'awareness of adaptable teaching conventions'. In their reports, PSTs described the course as "*this was a very new way of working*" (S04) and they compared to conventional teaching situations: "*We are very used to gaining knowledge by listening to others*" (S10). Many noticed differences to conventional teaching: "*Giving weekly presentations is not something I have encountered in previous courses. Throughout teacher education, we mostly encounter lectures where we listen and take notes or work on tasks assessed by subject teachers. The fact that this course was put in a different form has shown me that as a teacher you do not always need to teach in the same way as other colleagues*" (S13). PSTs described their engagement in the course as *active, first-hand, figuring out on our own, or solving assignments in our own way*. Moreover, PSTs were positive about this new learning experience, in particular about the responsibility to choose own ways to tackle assignments: "*...for my part, it was a positive experience that we could read articles and subject texts that we as students had found ourselves*" (S04). Also, it was judged positive that they themselves played an important role in the course: "*I thought it was very rewarding to be such an active part of the teaching*" (S03).

In this driver 'awareness of adaptable teaching conventions', PSTs connected their personal learning to the groups' responsibilities (own methods, own resources), thus to the social. Also, the *new* learning experience created an awareness, or even surprise, about existing teaching conventions and that we change them, thus connecting to cultural conventions and historically developed traditions.

The second driver was 'discussing with and explicating to others'. In their reports, PSTs related of how their exchanges in the group work and the plenary contributed to their learning. In the groups, explaining to others and getting explanations from others both contributed to new knowledge. "*There is a low threshold for talking and asking each other things you wonder about, so I understood things more quickly*" (S06). And: "*Working in groups was incredibly nice as we had a good time socially*"

(S09). Some PSTs also experienced working in a small group as efficient: *“(in groups) one can find answers to various questions in parallel and ask and learn from each other. In a group we can find more aspects than I would have done alone (or this would have taken longer)”* (S04). Moreover, the exchange with peers made the knowledge creation go deeper: *“It can be useful to listen and collaborate with others who work and think quite differently from yourself. Then you have to think more critically through what you yourself think and say, and you learn to see things in new ways”* (S04). And: *“(It) contributed to deeper understanding. We students could decide for ourselves how we wanted to work, which meant that we gained more connection to the work”* (S14).

Some PSTs expressed that the requirement to translate the group findings into a presentation to others in the plenary improved the quality of the knowledge creation: *“Because of the presentations, we had to spend time researching something we must fully understand. This affected how we solved tasks. Instead of solving a task and then think it is finished, we had to think through whether we understood what we were going to present. This made us become more familiar with what we presented. We may have talked about less, but what we talked about we have understood better”* (S10).

Thus, in this second driver ‘discussing with and explicating to others’, the PSTs connected their personal learning strongly to both the dynamics in the small groups and the plenary presentations. In the small groups, they not just listened to each other, but they were challenged to exchange and convince each other, which deepened their learning process. On top, having to present in the plenary required them to reflect on how to explicate it to outsiders from their group. It may have helped that in the small groups they felt comfortable with each other. Thus, we see the PSTs explicitly connecting their personal learning strongly to the social. The other aspect, the cultural, was not obvious in this theme of PSTs’ reflections. Nevertheless, it was implicitly present in the knowledge, which was historically and culturally developed before PSTs could interact with it.

A third driver was ‘competencies relevant later’, which clustered reports of learning competencies useful after the course. On the one hand, PSTs expressed having learnt pedagogical knowledge for teaching: *“The project-based learning has given me new perspectives on teaching. I will take that knowledge with me in my future job as a teacher”* (S01). Some PSTs more specifically expressed having learnt how to teach statistics: *“I received many tips on how to teach statistics in a fun, exploratory and motivating way”* (S13) and *“The course contained statistics in a form that I can take with me straight to school. Before the course, I was very unsure of my skills in this field of mathematics and have therefore had a steep learning curve and learnt many new concepts. After this semester, I feel that I master statistics and take with me many good ideas and concepts to be able to create rewarding and interesting lessons for my future students”* (S19).

Also, several PSTs expressed that they had learnt presentation competencies useful to them as future teachers. *“Presenting (..) is good training for the teaching profession. It will be a life full of talk in front of a class and being confident about this I see as absolutely relevant and important.”* (S06). Moreover, the learnt competencies were also perceived useful in contexts other than teaching. For example: *“There were also challenges with working in randomly selected groups. Working life will also give us such challenges, so it is only an advantage to have practised”* (S06). Or: *“This was also good to prepare ourselves for writing the master’s thesis next year”* (S18).

In this third driver ‘competencies relevant later’, PSTs reported that they had learnt competencies, such as presenting and collaborating, which they expected to use in a future. Many of the named competencies (presentation, teaching, collaboration, writing) were communicational, which implies a social aspect. Simultaneously, the mentioned competencies seem not to be of immediate use but at some point in the future. This wider horizon beyond the personal and social brings in a cultural aspect.

The fourth driver was ‘knowledge of how statistics is used in society’, which clustered reflections on the content of the course. As one PST wrote: *“What I am left with the most after the course is the fact that behind the statistics there are lots of people. A person is not just a number. It made statistics very real”* (S06). Another PST wrote: *“I never was very interested in statistics, since I found it a rather boring topic throughout my schooling. During this semester, I have opened my eyes and seen how much statistics there is all around, and that there are incredibly many situations that you don't think about where statistics plays a big role. Statistics is a very important part of society, and I have become much more interested in it through this course”* (S15). A third PST reflected: *“I have spent a lot of time working on statistics, since I took a bachelor's degree in economics and administration, but many of the concepts and ideas have taken on a new meaning for me. I know what lies behind the terms and why we use them. In the past, these were only about calculations and numbers”* (S21).

In the reflections above, the PSTs connected their personal learning to a cultural aspect, namely how statistics is used in society. So, it was not so much the knowledge of statistical concepts, such as *significance* or *correlation*, which drove the learning, but rather the societal perspective on the widespread and sometimes hidden use of statistics that motivated them to engage in the assignments. We identified this as a cultural aspect, because the role of statistics materializes outside of the direct working environment of the PSTs. Nevertheless, we also note a social aspect in it because the PSTs related the role of statistics to people as in *“behind the statistics there are lots of people”*.

The final driver was labelled ‘knowledge about oneself’. It held reflections on personal growth and gained confidence, for instance in presenting: *“Myself and the others (...) have become much more confident in presenting our work”* (S13) and *“Standing in front of a class and presenting has been something I have never particularly enjoyed, and I was very nervous the first time. Throughout the course, I noticed a development, my nerves decreased with each presentation and presenting became something harmless”* (S17). Other PSTs reflected on themselves and their functioning in collaborations: *“I learnt that I can work with the vast majority of people (at least everyone in my class). I also experienced how in a group changes my role with regard to the role the others take. I thought that I was most comfortable as a group leader, but I have learnt that I can be comfortable in several positions and bring a lot of good to the table regardless of the position I have”* (S21).

Here, PSTs reflected that gaining knowledge about themselves supported their learning process. This knowledge was not inward looking, but about themselves in relation to others, such as in presentations in front of the class or in collaborating. In this theme, PSTs clearly connected learning about themselves to social situations, and not to cultural aspects.

Discussion and conclusion

With the aim to improve mathematics education, we offered PSTs reform-based learning experiences, assuming that first-hand experiences would concretize theoretical lectures about reforms (Darling-Hammond & McLaughlin, 2011). The reform was a redesign of a traditional statistics course into a *project-based* course (Holmes & Hwang, 2016). The PSTs' reflections on what 'drove' their learning were grouped into five themes, indicated as *drivers*. We analysed these on connections between the *personal* (an individual's background, perception, knowledge, etc.), the *social* (the inter-personal), and (3) the *cultural* (conventions, historically developed knowledge, etc.). The driver 'awareness of adaptable teaching conventions' clustered reflections on project-based learning being totally new, but also engaging and yielding an awareness that teaching conventions can be changed. The driver 'discussing with and explicating to others' was about the peer-collaboration yielding a dynamic, in which it was safe to ask, where PSTs were given responsibility to choose their own strategies, and they had ownership over results. Having to present findings thereafter was another driver for the knowledge creation. The third driver 'competencies relevant later' clustered reflections on gained skills in collaborating with new people, presenting, teaching, and studying. The driver 'knowledge of how statistics is used in society' related of critical insights that, for instance, 'people are not numbers'. The final driver 'knowledge about oneself' was about increased confidence to present and collaborate. Except for the driver 'the role of certain content in society', the drivers confirm earlier research (e.g., Murray-Harvey et al., 2013; Quaresma et al., 2018; Scardamalia & Bereiter, 2021). Figure 1 displays the three aspects in learning: the *personal*, the *social*, and (3) the *cultural*. In these, we positioned the five drivers, together with a few smaller themes, which PSTs had indicated as *driving* their personal learning through the KCCS (Hakkarainen et al., 2013). Figure 1 illustrates how the thematic drivers *connected* personal, social and cultural aspects of learning.

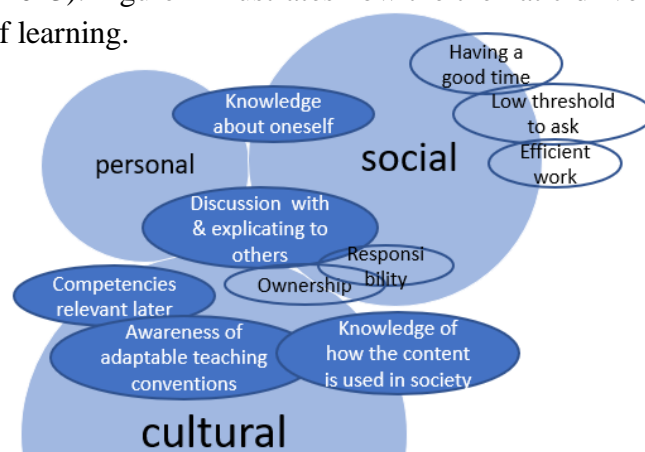


Figure 1: Drivers of KCCS and how they connect personal, social and cultural aspects of learning

We now return to the research question, *what relations across personal, social, and cultural aspects can be discerned in the dynamics in KCCS that, according to the PSTs, drive their personal learning?* In KCCS, the learning is not purely personal (driven by personal motives). KCCS bring a ubiquitous relation between collaborating peers, that is between the personal and the social, but additionally, connects to cultural aspects because the collaborative groups are outward looking. For instance, the knowledge created in the groups had to be presented to others outside the group. This also happens when teachers participate in a lesson/learning study; they will bring their collaboratively constructed knowledge to other colleagues and to classrooms. This urges group members to explicate the created knowledge, which otherwise may remain tacit. This made the driver 'discussing with and explicating

to others' an important one. Three other drivers also connected the personal learning to the cultural, namely 'gained awareness that instructional conventions can be changed', 'knowledge about oneself' and 'knowledge of how statistics is used in society'.

Some drivers can be taken as educational design principles. The course design involved rotating peer groups, the societal role of statistics, primary statistics didactics, and plenary presentations. These design principles directly relate to the drivers 'discussing with and explicating to others', 'knowledge of how statistics is used in society' and 'competencies relevant later'. Also, the course was designed to offer PST participatory experiences in a reform practice, which led to their 'awareness of adaptable teaching conventions'. However, further research is needed to find out whether the course indeed encouraged PSTs to implement reform in schools. Finally, 'knowledge about oneself' was not designed. Likely, the new social and cultural experiences that made them see themselves afresh.

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