Socially embedded mathematics-related emotions at university: The case of Lumi

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Abstract: Emotions have a significant role in learning mathematics. However, research has reported limited evidence on emotions within the university mathematics setting and on the situational nature of emotions. Furthermore, recent studies on university mathematics learning have emphasised the role of "the social" from different theoretical perspectives. Therefore, in the present study, we draw on the social and embedded theory of mathematical affect and consider emotions as socially situated states. With a case-study approach and a reflexive thematic analysis, we provide an explorative illustration of how a mathematics major (here named Lumi) frames their mathematics-related emotions as embedded in the social structures in their university mathematics setting. The findings describe Lumi's emotions as embedded within the social structure of university mathematics, more temporal social communities, and the artefacts influencing the building of interpersonal relations within these structures. The main finding is that the dynamic changes in emotions involve changes in the social setting. The findings also suggest that there is no need to eradicate negative emotions. Instead, there is a need to develop learning environments with norms and values that support students in communicating and creating various social structures that support their belonging to university mathematics.

Keywords: emotions, situated perspective, university mathematics, case study.

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1 Introduction

During the last years of affective research, variables such as beliefs, attitudes, emotions, and values have been widely discussed in terms of their impact on mathematics teaching and learning (see e.g., DeBellis & Goldin, 2006; Di Martino et al., 2023; McLeod, 1992; Schukajlow et al., 2023). However, there is limited research on emotions in the university mathematics settings (Göller & Gildehaus, 2021) and on the situational nature of emotions (Schukajlow et al., 2023). Therefore, in the present study, we consider emotions as socially situated states (see Hannula, 2012) and use Lumi, a first-year mathematics student, as a critical case (Patton, 2015, 266) to illustrate mathematics-related emotions as embedded in the social context.

Previous research shows that affective variables play an important role, for example, in directing attention, cognitive processing (Hannula, 2012), learning strategies (Pekrun et al., 2002), as well as study retention, study satisfaction, and performance (Hannula et al. 2019; Pekrun et al., 2002). Specific to the university mathematics setting, it is notable that the secondary-tertiary transition comes with a kind of emotional turning point for many students; having experienced mainly positive emotions in mathematics in school, entering mathematics at university is often related to negative emotions, such as frustration and helplessness (Göller & Gildehaus, 2021). For many students, these new negative emotions can be intense and closely related to identity tensions (Gildehaus & Liebendörfer, 2021; Gildehaus et al., 2024), motivation, and self-regulated learning (Göller & Rück, 2023; Lahdenperä et al., 2022). Therefore, it can be concluded that emotions play a key role also in learning mathematics at university.

There are different possible perspectives for researching emotions. Many researchers differentiate between positive and negative, and between activating and deactivating emotions (Pekrun et al., 2002; Schukajlow et al., 2023). Taking this together, there are positive activating (e.g., joy, hope), positive deactivating (e.g., contentment, relief), negative activating (e.g., anger, fear), and negative deactivating emotions (e.g., hopelessness, frustration) which mostly show either positive or negative relations to participation and performance in mathematics (Schukajlow et al., 2023). Another typical distinction in emotion research is the object. In their mathematics education research overview, Schukajlow et al. (2023) present a hierarchical model of objects, emotions can focus on; emotions focusing on general teaching and learning are on the highest level, whereas the lowest level includes emotions about specific mathematical tasks.

However, these perspectives do not provide tools for addressing the social context of learning mathematics. In recent years of university mathematics education research addressing other theoretical constructs, the role of the social has constantly occurred, for example, in the form of social inclusion and exclusion, successful social interaction, and social support structures in learning (Gildehaus & Liebendörfer, 2021; Gildehaus et al., 2024; Lahdenperä & Nieminen, 2020; Lahdenperä et al., 2022). Furthermore, university mathematics students in the same context can report very different emotions (see e.g., Gildehaus et al., 2024) and their mathematics-related emotions can be triggered by different contextual variables (Martínez-Sierra & García-González, 2014). Therefore, to understand mathematics-related emotions at

university, it seems timely to move beyond the valence and level of activation and the object of emotion and draw on theory considering emotions from the situational and social perspectives.

2 Theoretical perspective

In our quest to move towards the social, we turn to Hannula (2012) who called for considering emotions as embedded in social contexts. In doing so, we address the situational specificity of emotions by taking a social perspective on mathematical affect and seeing a student as an inherently social autopoietic entity (see Hannula, 2012). This perspective emphasises the links between cognition and affect, such as the role of emotions in learning outcomes, and the links between affect and social, such as the need for social belonging (abid.). We consider emotions embedded within dynamic social structures. This indicates that besides individual students, we consider university mathematics communities as social structures. Hannula (abid.) identifies three dimensions relevant for analysing different social structures: resilience, magnitude of the group, and group members' level of belonging. For example, the social structure of (university) mathematics is well-established and durable, has many people involved, and especially for a first-year student, the level of belonging to this social structure can be low. In contrast, the social structure formed when studying together with a peer can be temporal, involves only two people, and typically comes with a strong level of belonging (cf. Solomon, 2007).

According to our interpretation of Hannula (2012), one of the central ways of forming social structures is communication. An individual navigates within and between social structures building interpersonal relations, and negotiates about shared norms, values, and understanding. This negotiation process changes both the individual and the social structure, as norms and values can gain legitimacy only when individuals within the social structure follow and embody them through their behaviour (abid.). For example, both students collaborating and not collaborating can be norms within different social structures of university mathematics. In both cases, a student can (try to) either collaborate or choose to work on their own. Depending on the context, this is framed as accepting the norm or trying to negotiate the norm and, by behaving accordingly, to change the respective social structure.

Besides communication and negotiation, Hannula (2012) emphasises the importance of the social structures' material and symbolic resources (tools and artefacts). These symbolic resources influence communication and have embedded

meanings within the social structure. For example, in a social structure of university mathematics, the MATLAB software used in mathematical modelling can serve as a tool, and mathematical proofs can serve as artefacts representing the validity of mathematical arguments.

The reason for the call for situational and social perspectives on emotions can be viewed in the light of the early stages of affect research. McLeod (1992) presented the taxonomy of affect as a continuum involving emotions, attitudes, and beliefs. The continuum can be described from the perspective of three changing constructs, namely intensity, temporal stability, and cognitive involvement. Although there have later been some critical examinations of the temporal stability dimension (Liljedahl et al., 2012), emotions can be placed at the one end of the continuum as the most intense, the least stable, and with the lowest cognitive involvement (McLeod, 1992). Due to the low temporal stability, emotions have typically been surveyed either retrospectively or prospectively (Schukajlow et al., 2023) and are, in general, the least researched areas of affect (Martínez-Sierra & García-González, 2014). Although emotions are volatile and perhaps challenging to research, they are important in the field of affect, not only for their unique relevance but also for their dynamic connections to other affective variables (Hannula, 2012; Martínez-Sierra & García-González, 2014; McLeod, 1992). This highlights the importance of finding ways of addressing emotions in all their situational specificity. The socially embedded perspective of the present study offers one avenue for this. Similar to Skott (2009), it entails that it is not ‘an anxious student’ but ‘an anxious student in a specific social setting’ with mathematics-related emotions emerging in and through social interaction.

2.1 Research objective

In their research overview, Schukajlow et al. (2023) call for more research on the situational nature of affective constructs, referring to emotions embedded in tasks, social environments, and sociocultural contexts. Our overall objective is to respond to this call and provide an explorative illustration of the situated nature of mathematics-related emotions within the university mathematics setting. With a case study approach, we draw on the social and embedded theory of mathematical affect (Hannula, 2012) and ask how university mathematics students’ emotions are embedded in their social environment.

3 Methods

3.1 The context, the case, and data collection

Lumi studies at a mathematics department in a research-intensive university in Finland. The department in question has engaged in educational development and most of the first-year courses had been implemented with innovative pedagogical practices, including inquiry-based and flipped learning approaches, as well as a strong emphasis on social elements such as students' engagement in peer learning and mathematical discussions (for more information on the context, see e.g., Lahdenperä, 2022, 36–40).

Lumi is a first-year student in a mathematics degree programme. Mathematics studies are proof-based from the beginning and so far, Lumi has studied mostly courses on analysis and linear algebra, as well as an introductory course on set theory, functions and logic. Lumi was selected as a critical case (Patton, 2015, 266) from a previous research project (Lahdenperä, 2022) which, although not directly addressing affect, motivated the present intention to delve into emotions. Lumi participated in an in-depth semi-structured interview (duration of about 1 hour) in which they reflected on their studying and learning during the first semester at university. For example, Lumi was asked how they studied in the courses, what kind of goals they had, and what supported and hindered their learning. Lumi can be regarded as a critical case for understanding socially embedded emotions as in the interview, they were verbose in describing their emotions and they took advantage of the multiple social learning opportunities offered within the mathematics department. Lumi gave active consent to participate in the research. The interview was conducted by the first author, who was not involved in teaching Lumi's first-year courses. The interviews were transcribed verbatim. Passages given here are translated from Finnish into English by the first author.

3.2. Data analysis

Our theoretical perspective led us towards focusing on Lumi's interpretations of their interpersonal relations and negotiations with and within various social entities. Lumi's interview was analysed using reflexive thematic analysis (Braun & Clarke, 2021). In reflexive thematic analysis, researcher subjectivity is seen as an analytical resource (Braun & Clarke, 2021). This is compatible with our aim of understanding

Lumi's emotions as states, and their embeddedness in the social environment as reported by the student themselves. The first author engaged with the interview thoroughly by reading it multiple times. In the analysis process, we used Lumi's own words describing both specific emotional states (e.g., happy, anxious) and behaviour (e.g., smiled, enjoyed) as reflexive thematic analysis codes to develop the initial themes. The final themes illustrating "patterns of shared meaning united by a central concept or idea" (Braun & Clarke, 2021, 14) were constructed through an iterative and recursive process heavily informed by the first author's contextual understanding. The final themes are university mathematics as a social structure, social communities, and lectures, problems, and exams as artefacts within university mathematics. To further understand Lumi as a critical case, the authors coded multiple interviews to engage in an active and critical reflection of the findings and the process itself beyond the case presented in this paper.

4 Findings

4.1 University mathematics as a social structure

The largest and the most resilient social structure Lumi builds interpersonal relations with is that of university mathematics. Lumi is happy to enter this new social environment; as they said, *I just went there as a happy learner*. Typical of research situated in the context of first-year university mathematics, Lumi considered mathematics at university as quite different from the mathematics they knew in school. Although novel and unexpected, Lumi readily enacts the new norms and values of this new social structure. They see building interpersonal relations within this new social environment as enjoyable, and something to be happy and enthusiastic about:

> It was nothing like high school mathematics, it was so different […]. First, you got to grow a fraction arbitrarily and it felt just awesome, like I had never done anything like that before.

However, figuring and negotiating those new social structures, was dominant in Lumi's interview and often related to either very positive or negative emotions. Specifically, positive for Lumi occurred the *positive surprise* that one of the new norms in this context was providing more social structures of belonging than Lumi actually expected:

> When I came here, I thought that the lecturer will have their back towards the auditorium, and then you write until your hand dies. I was prepared for that, and then I got something completely different. I'm maybe like happy and positively surprised, this is like fun. These experiences I've had many.

One other experience of these *many* that Lumi described here was that of asking stupid questions, even during the lectures:

> I enjoy a lot when I get to ponder, and I feel that my strength as a mathematician is just this that I sometimes ask even stupid questions, like I'm not afraid to ask and say that hey, I don't get it. And it then helps your learning.

This idea of a stupid question was linked to a figured norm of understanding as a central way of belonging to university mathematics, what Lumi emphasised and accepted as a valuable norm. Hence, they recognised that asking a stupid question (a question that could show that you are currently not understanding) could be unaligned with the university mathematics norms and pose a potential threat to their belonging to this social structure. However, within the participative given context, they (re)negotiated and enacted the new norm that asking stupid questions could also be a strength, as something providing a necessary step towards understanding and belonging. Thus, they changed, at least temporarily, their figured social structure of university mathematics, in line with overall positive emotions of enjoyment.

In contrast, negative emotions, such as frustration occurred in a context where Lumi could not identify a mode of belonging; they could not always directly identify the shared understanding, unless it was directly explained. Lumi then regarded unsuccessful negotiations of shared understanding as frustrating and confusing. As Lumi describes, *I felt a lot of feelings of frustration* and *my head was just more in knots, like what just happened*. Lumi noted these tensions themselves and attempted renegotiations *like are we students really expected to know these things?*

Here, this dichotomy of Lumi's emotions seems pivotal. The new social structure of university mathematics *felt awesome* whenever they were successful in building interpersonal relations and negotiating about shared understanding. However, Lumi often experienced frustration and confusion when not sharing the understanding. For Lumi, "feeling awesome about mathematics" was a shared norm they did not try to renegotiate and therefore, it was necessary for belonging to the social structure. Accordingly, Lumi's negative emotions signalled threats to their belonging towards university mathematics.

4.2. Social communities

While trying to build interpersonal relations with and within university mathematics, smaller and less stable social structures became relevant for Lumi. This was mostly the one-to-one and small-group interactions with their peers, as well as learning collaboratively in general. Lumi's level of commitment was strong towards these social structures, and they were useful especially when belonging to university mathematics was threatened. Lumi's interpersonal relationships with these entities supported them in enacting the norms and understanding of university mathematics. Thus, with regard to their emotions, Lumi framed this as something *very beneficial, because then you didn't need to get frustrated if the problems didn't start to unfold*. To continue, Lumi considered interpersonal relations within these social structures as supportive for their belonging to university mathematics and framed it as joyful and *feeling mathematical*. An important role was that of the tutors, who seemed to mediate between the smaller community and the overall social structure of university mathematics, by providing just as much hint to guide the students towards understanding and consequently, towards belonging:

> The tutor gave me a small hint that I was missing but I got to do it by myself so that the joy of discovery was not wasted, like the accomplishment, when you got it solved, that made me feel very mathematical.

At some points also collaborative learning in general occurred as *supporting factor* in belonging to university mathematics, and in line with that, they were framed as enjoyment and feeling good:

> [T]he collaboration, when you worked together and the tutors were there, like the culture […], you definitively notice it and enjoy it.

Yet, also on this community level, it happened that Lumi did not find a social structure to belong to, even if their belonging to the social structure of university mathematics was threatened. These instances occurred, for example, when the small group in which students solved weekly problems could not support in negotiating shared understanding within university mathematics. As posing a threat to their belonging, the instances were deemed frustrating. Lumi stated:

> When pondering about the problems together in a small group, it was like now I sit here […] and […] get nothing out […]. The frustration, this is the feeling I remember the most authentically from the sessions.

However, this frustration could not exclusively be addressed by finding an understanding and belonging. It could also change into relief when another form of shared belonging within the smaller social structure was found:

> I sat next to one of my course friends [in the lectures] and we like shared this feeling, we were just confused, like we didn't understand. It was also kind of therapeutical, like there was someone else who doesn't understand. And then we then together tried to create the basis for understanding, like what is going on here. It felt great to discuss the matters.

These dynamic changes of emotions happened when Lumi was trying to negotiate the relevant understanding on their own. Here, Lumi was not able to enact the norm of understanding being necessary for belonging to the social structure of university mathematics. Also, Lumi was not able to re-negotiate the norm. Lumi then changed their social setting by building interpersonal relations within smaller social communities. Here, experiencing the threatening emotions together with a peer, while sharing the norm of understanding being necessary for belonging, offered relief.

4.3. Lectures, problems, and exams as artefacts within university mathematics

Lumi described lectures, tasks, and exams as artefacts having a role in communication with and within the social structures and in negotiating the norms, values, and understandings. The representations of these artefacts came evident through emotions. For example, lectures built around student discussions were *fun* and regarded as *providing very fruitful discussions*. In this way, the lectures embedded the meaning of negotiating understanding within university mathematics without threatening Lumi's belonging via negative emotions, which again seems to underline their participative character in this context.

The mathematics problems influenced Lumi's building of interpersonal relations with the social structure of university mathematics in two ways. First, the problems embedded the meaning of clarifying the norms and values of university mathematics. Lumi framed this as enjoyment:

> I enjoyed [the problems] because it was very easy to see what we were expected to learn.

Second, the mathematics problems represented mathematical understanding and, when successful in solving them, strengthened Lumi's belonging to the social structure of university mathematics. This was framed as happiness:

> I was happy […], I had a smile on my lips and it felt awesome that you got [the problems] right.

> It was a happy course […]. I had six flowers in a row [used by the teaching team to mark good solutions], it was just awesome, and then I felt that I know how to do these, I understand these different types of tasks. […] I felt certain.

However, the mathematics problems were not always accompanied by positive emotions, specifically when their representation of understanding was not clear. Lumi stated that *it was so frustrating because the problems were so challenging* and therefore, negotiating understanding with university mathematics was challenged. In some settings, Lumi went further in framing themselves as not good enough a mathematician for not being successful in solving the problems:

> Sometimes, it was like you didn't come up with a proper solution […], like you couldn't be satisfied with your own work.

Finally, Lumi framed exams as artefacts providing a way of communicating with university mathematics. The enacted norm of working hard protected Lumi's belonging to university mathematics, and this balanced out some of the earlier negative emotions. Lumi stated:

> Although I had a lot of these feelings of uncertainty and being lost, if you did the work, you then were successful in the exam. Like, the exam was good in a sense that it favoured the hardworking students.

> I experienced this feeling of confusion […] but then towards the end it started to clarify […], when you understood what's actually important and then put effort on learning those, then it felt like yes, I know the basics.

In that sense, the exam overcomes the problems as an artefact, providing the relevant artefact of testing the belonging to the institutional structures.

5 Discussion

We have considered emotions as socially situated states and, with a case-study approach, presented an illustration of how Lumi's emotions are embedded within the social structures found in the university mathematics setting. The findings demonstrate that Lumi is building interpersonal relations and negotiating norms, values, and understanding with and within two distinctive types of social structures, the large and resilient social structure of university mathematics, and the more temporal social communities of smaller magnitude. Lectures, mathematics problems, and exams serve as artefacts having embedded meanings for finding belonging within these social structures.

The social embeddedness of emotions shows, for example, in Lumi's framing of their new acquaintance, university mathematics. This novel social structure represents the secondary-tertiary transition as an emotional turning point. Lumi is not referring to any general mathematics but to this novel social structure with embedded positive emotions while building interpersonal relations with it. It is notable that here, in contrast to Göller and Gildehaus (2021), the secondary-tertiary transition entails positive emotions. As discussed, this could at least partly be implied by the overall participatory structure of especially the lectures in this context. Yet, Lumi still describes negative emotions as well, that in general shows similarities to the ambivalent category presented in DiMartino et al. (2022) as they report both positive and negative emotions depending on the social structure and context.

As communication is one of the central ways of creating these social structures (Hannula, 2012), we can view the unsuccessful attempts of building interpersonal relations and negotiating the shared values, norms and understanding as the social structure fades away. Lumi sees negotiating the norms, values, and understandings within all the social structures as a way of protecting the existence of and their belonging to the social structure of university mathematics. It is remarkable to what extent their emotions are directly linked with their perceived belonging to the social structure: strengthening one's belonging to university mathematics comes with enjoyment, happiness, and enthusiasm, and in contrast, when posing a threat to one's belonging, these negotiations are framed as confusing and frustrating. This entails that from a practical point of view, successful social interaction, in terms of providing ways of belonging, has a central role in supporting students' positive emotions (see Gildehaus & Liebendörfer, 2021; Lahdenperä & Nieminen, 2020; Lahdenperä et al., 2022). It also underlines the often-discussed dichotomy of mathematics (cf.

Gildehaus et al., 2024; Kollosche, 2015): Given that Lumi perceives themselves as either belonging or not, their emotions occur either very positive or negative, leaving little space for any in between negotiation. This also offers one possible explanation for the range of emotions students can report in the same context (see Gildehaus et al., 2024; Martínez-Sierra & García-González, 2014).

Research addressing the dynamic nature of emotional states in authentic settings is still rare (Hannula, 2012). Therefore, the main finding of the present study is the dynamic nature of Lumi's emotions. This becomes evident in the situations threatening their belonging to university mathematics. Lumi was first not able to understand university mathematics and found themselves in situations where they were not able to enact the norms and values established in the social structure of university mathematics. Although framing this as frustrating, Lumi was not willing (or more likely not able to) change the social structure of university mathematics by enacting a new norm stating that understanding is not necessary. Lumi then shifted from one social structure to another. Here, a dyadic relationship with a peer offered an alternative social structure to belong to, and the negative emotions were replaced with relief. It seems important that the new social structure is more temporal and smaller compared to the original social structure of university mathematics. Finding alternative commitment in these smaller social structures protects the belonging to university mathematics. In a theoretical sense, dynamic changes in emotions involve changes in the social setting. From a practical perspective, to support belonging to the social structure of university mathematics, we may support the creation of smaller temporal social structures. This is in line with Lahdenperä and Nieminen (2020) who argue that social communities can serve as an alternative or as a proxy for the larger scientific community. However, having the smaller and temporal structure of these communities in mind, we could also observe the relevance of tutors and collaborative engagement to provide support towards belonging to the establishes university mathematics social structure.

From a practical point of view, navigating between social structures and time allows students to frame university mathematics with negative emotions without losing their commitment to it. In this being, there is no need to try to eradicate negative emotions. Instead, it would be beneficial to understand how we can develop learning environments with norms and values providing possibilities for students to communicate and create these social structures supporting their belonging to university mathematics.

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