Key Memorable Events During Undergraduate Classroom Learning

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This paper presents a theoretical construct termed Key Memorable Events (KMEs): classroom events that are perceived by students as memorable and meaningful in support of their learning, and are typically accompanied by strong emotions, either positive or negative. As such, the proposed concept implies a hierarchy between different events and their contribution to the learning by focusing on those moments perceived by students as most significant. The concept is exemplified in context of large-group undergraduate-calculus tutorials. Theoretical and pedagogical implications are discussed in terms of lesson design, data analysis, and conceptualization of learning in the undergraduate classroom.

Keywords: Memorability, Classroom Learning, Instruction, Affect

Introduction

Undergraduate mathematics courses are typically taught in a frontal teaching style (henceforth referred to as FTS), and are often attended by large amounts of students (≥ 100), especially in first-year courses (e.g., Cooper & Robinson, 2000; Pritchard, 2010). The common practice of the traditional FTS at university has been criticized repeatedly, specifically regarding the one-directional non-responsive mode of communication this teaching style promotes. In this regard, it has been argued that FTS is focused on transmitting information (Biggs & Tang, 2011), and does not promote independent student thought (Bligh, 1972). Considering that emotions have been recognized to take an integral part in mathematical problem-solving behavior (e.g., Op't Eynde, De Corte, & Verschaffel, 2006), it has additionally been claimed that FTS does not reveal the human struggle for reaching mathematical discovery, and treats students as "non-emotional audience" who are granted no room for individual difficulties (Alsina, 2002).

While alternative teaching styles have been explored and their benefits acknowledged (e.g., Larsen, Glover, & Melhuish, 2015), FTS remains to be widespread, not prone to change, and will most likely not disappear in the near future (Cooper & Robinson, 2000; Koichu, Atrash, & Marmur, 2017; Nardi, Jaworski, & Hegedus, 2005). Therefore, it is important that research efforts will additionally be put into improving the system from "within", theoretically and practically. This includes gaining a better understanding of the following: how students learn during frontal undergraduate lessons, whilst additionally examining how the learning is shaped by student affect and the teaching that took place; how frontal undergraduate lessons can be designed to create and support a positive and meaningful learning-experience for the students; and how to identify the learning opportunities in class that enable students to be actively engaged learners during the lesson itself and in support of their subsequent independent learning at home. These goals are in line with Lester's (2013) call for attention to be given to the teacher's role in problem-solving instruction and how *large groups* of students learn problem solving in real classroom situations.

The current paper addresses these goals by suggesting a theoretical construct termed *Key Memorable Events* (KMEs): classroom events that are perceived by *many* students as memorable and meaningful in support of their learning, and are typically accompanied by strong emotions, either positive or negative. It should be noted that the *key* aspect here refers to the significance of the event to the *many* at classroom level. While the construct originated out of empirical

evidence (see Marmur, 2017, for further detail), the focus of this paper is theoretical, discussing the potential contributions of the notion of KMEs for lesson design, data analysis, and understanding of classroom student-learning. Nevertheless, some data are presented to illustrate the construct.

Theoretical Background

In the literature there is a variety of concepts that employ different frameworks and terminologies for addressing what we may globally refer to as *key events* during the process of student learning. Such events are situated in the affective and/or cognitive domain, and may have a substantial impact on both the short- and long-term learning. Though the separation between cognition and affect is not always clear-cut, addressing the literature according to these two perspectives can shed light on the nature of these events.

From an affective perspective, Goldin (2014) refers to *key affective events* as events "where strong emotion or change in emotion is expressed or inferred" (p. 404). Rodd (2003) claims that "undergraduate learning is frequently triggered by those unique events which contribute to an individual's agency or self-motivation" (p. 20). In line with this claim, Weber (2008) demonstrated how a single and strong positive experience of success may have a considerable effect on a student's success in a high-level calculus course, by altering the student's attitude and type of engagement with the material for the continuation of the course. This "direct path" to attitudes and beliefs through a single powerful experience has also been reinforced by Liljedahl's (2005) discussion of "Aha!" experiences during problem-solving activities.

From a cognitive perspective, different researchers have focused on crucial moments in student thought-processes during problem-solving activities. Nilsson and Ryve (2010) focus on what they refer to as *focal events*, i.e. those parts of student reasoning that are noticeably salient. They explain that such events steer our educational attention towards "the problems that stand out as central in the students' thinking in a certain phase of a learning activity" (pp. 245-246). In an analysis of a collaborative-learning situation, Damsa and Ludvigsen (2016) identify *key moments* in the group interaction, i.e. "an action or sequence of actions at the epistemic level that triggered subsequent actions and leading to a particular relevant development regarding the shared object" (p. 5). Their analysis of such moments was based on the more general theoretical approach provided by Webster and Mertova (2007) of considering *critical events* as an analysis tool in research on teaching and learning.

Conceptualizing KMEs

In continuation of the theoretical approaches presented above, this paper wishes to put emphasis on the aspect of the *memorability* of a classroom event, as the memorability of an event may shed "unified" light on both dimensions of cognition and affect related to student learning. The New Oxford American Dictionary (Stevenson & Lindberg, 2010) defines the adjective *memorable* as "worth remembering or easily remembered, especially because of being special or unusual". It additionally suggests the following as possible synonyms: unforgettable, significant, notable, noteworthy, important, special. These definition and synonyms suggest that *memorable events* are not merely events that can be recalled from memory upon request, but that these are events that additionally hold significance and meaning for a person who experienced them. For example, one can imagine the moment when "the penny dropped" (i.e., the moment when some important aspect of the material became understood and things fell into place) to be a memorable event for a student, and that for him/her this event was also filled with emotions, such as the

excitement of success in understanding a complex concept, followed by a raise of self-confidence.

The suggested focus on memorability of events finds further support in the neuroscientific domain, which informs us that the brain does not store all information it encounters. As articulated by Wolfe (2006), the brain is in fact "designed to forget" (p. 36). Focusing on memorable events may supply insight into student short- and long-term learning processes, since, as claimed by Wolfe, memorability means that information is stored in permanent and rich networks, thus enabling its future retrieval. In this regard, "emotional events often attain a privileged status in memory" (LaBar & Cabeza, 2006, p. 54), taking a crucial physical part in filtering which information from the environment will be "saved" for future use (McEwen & Sapolsky, 1995). For example, neuroscientific experiments reveal that the triggering of negative emotions may jeopardize the functioning of the working memory during mathematics problem-solving (e.g., Ashcraft & Krause, 2007), or even induce physical reactions that can alter the memory altogether (e.g., McEwen & Sapolsky, 1995). On the other hand, lessons designed to evoke student emotion may lead to stronger memories, and can consequently serve as a hook for learning (Wolfe, 2006). In summary, this demonstrates neuroscientific reinforcement for the link between memory, emotions, and learning, and its relevance to education research (see also Hinton, Miyamoto, & Della-Chiesa, 2008).

When considering student learning-experiences in the undergraduate classroom, I propose to imagine a two-dimensional representation, where on one axis there is a detailed list of consecutive classroom events, and on the other axis a list of the different students attending the lesson. Accordingly, we may treat the location (X, Y) in the resulting table as the meaning and importance given to event X by student Y in terms of his or her learning experience at that moment in time. However, as supported by the theoretical background presented above, if we conceptualize the flow of a lesson as a sequence of classroom events, these events will not all be at the same level of importance to students, and some events may be more significant than others. These will be referred to as *memorable events* (see Figure 1: Key Memorable Events).

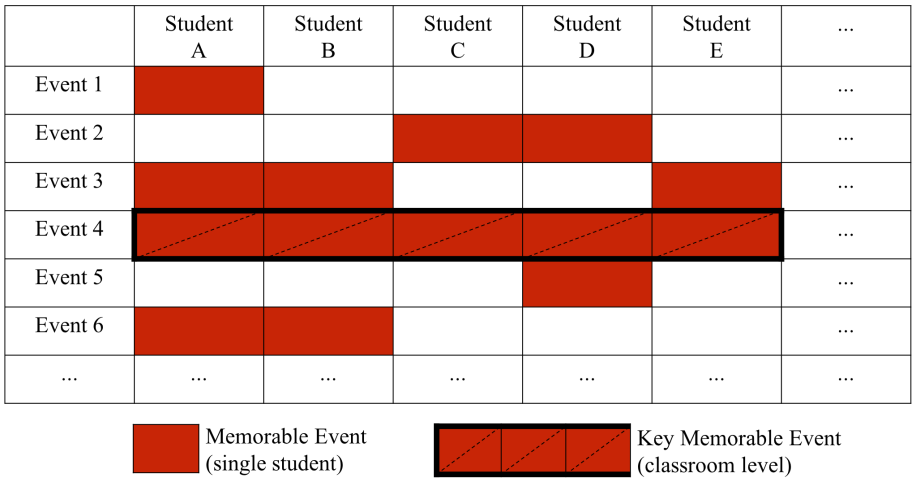

Figure 1: Key Memorable Events

Continuing this representation, I suggest two complimentary approaches that may be used for addressing and analyzing the nature of the learning in class. We may consider the learning of a *single student* through the progression of classroom events, leading us to a conceptualization of a single student's learning trajectory, in Simon's (1995) framework, or the student's affective

pathway, in Goldin's (2000) framework. On the other hand, and what is here emphasized, is the focus on a *single event* and how this event affects the different students in class in similar ways. This approach may supply insight into how a specific pedagogical act impacts the students as a *group* by recognizing repetitive themes students report on regarding this event. Repeating this approach with different events during a lesson may result in an overall categorization of how various instructional acts relate to the students' learning as a whole. Accordingly, this approach emphasizes the immediate relation between the teaching and the overall classroom learning.

Focusing on the memorability of events on the group level, it should be acknowledged that what may be memorable to one student, may not be memorable nor significant to another. The term *key memorable events* is thus used to refer to those events in the lesson that are perceived by *many* students in class as memorable and meaningful in support of their learning (see Figure 1: Key Memorable Events). Whereas an operational definition should additionally quantify the phrase "many students", this conceptual definition could nonetheless be easily implemented methodologically by means of stimulated-recall interviews (see Marmur, 2017) in order to identify classroom events that are memorable and key.

Two Examples

The two examples presented here are taken from a wider research project examining student learning in undergraduate large-group calculus tutorials. The first exemplifies the utility of KMEs as a guide for lesson design, whilst the second example demonstrates its utility as a methodological tool in explaining classroom phenomena.

Example 1: A "Designed" Setting

Marmur and Koichu (2016) presented an iterative process of lesson design aimed at creating an aesthetic experience for students in a "traditional-instruction" calculus tutorial. In the final successful iterations of the lesson, the incorporation of two surprising events of reaching a dead-end in the solution, prior to the surprising presentation of a non-routine solution, managed to serve as a teaching method leading to an aesthetic experience for many students.

Revisiting the data with the suggested terminology of KMEs, the students' strong and emotional responses to these "surprising events" revealed that these events indeed served as KMEs of affective nature for the students (as expressed in stimulated-recall interviews, as well as observed in class). The data suggest that this combination of KMEs not only supported the creation of an aesthetic experience, but was also most influential on the students' learning process in both cognitive and affective terms (see also Koichu et al., 2017). In affective terms, the students reported heightened involvement and enjoyment during the lesson, as well as a rise in self-confidence by being encouraged not to give up when initial attempts at solving a challenging problem are unsuccessful while working independently. In cognitive terms, the KMEs raised the students' focus, attention, and interest during the lesson; they exposed the students to an expert's thought process of how to reach a solution; and they enhanced the memorability of the material taught. Moreover, students reported to be actively engaged learners by attempting to accomplish a range of self-imposed tasks. These included independently testing alternative ideas to the solution; attempting to predict the next step in the solution; identifying difficult places in the proof to come back to; looking for connections between the problem taught in class and the corresponding homework assignment; and formulating problem-solving strategies from their current experience that they could use in the future. It should be noted however, that the students reported that this was not part of their routine behavior in class. Additionally, some students reported that this lesson impacted their after-class learning activity

in a non-standard way. This included deciding to independently re-solve the problem, as well as go through all material from the beginning of the semester. The latter was encouraged by the students' newly recognized need for what Schoenfeld (1985) refers to as *resources* – knowledge in support of solutions for non-routine types of problems.

Example 2: A "Regular" Instructional Setting

Marmur and Koichu (in press) juxtaposed two similar large-group undergraduate-calculus tutorial-lessons as a contrastive basis to examine how students' emotional states relate to the type of mathematical discourse conducted in class. Though both lessons contained a similar challenging problem the students did not understand, the students evaluated the lessons in opposite manners. While the lack of understanding in one of these lessons (Lesson-N) was (unsurprisingly) accompanied by negative student emotion of anger and frustration, the second lesson (Lesson-P) was (surprisingly) perceived by the students as special and good, even though they admitted key parts of the proof to be incomprehensible, and showed disbelief in their ability to solve such problems on their own.

In KME terminology, the difference was analyzed by the identification of a single KME of affective nature per lesson, that shaped the students' overall learning experience. The difference was related to the type of discourse initiated by the instructor during the identified KME. In the KME of Lesson-P, the instructor initiated a type of meta-level discourse on how to approach a challenging problem (termed *heuristic-didactic discourse*). According to the data, this KME demonstrated expert problem-solving heuristic-behavior in an approachable way to students, shaped the learning experience during the rest of the lesson, and additionally served as a neutralizing factor for possible negative emotions as a result of not understanding the solution. However, in the KME of Lesson-N, the instructor made a promise for heuristic-didactic discourse, yet did not fulfill this promise in the remainder of the lesson.

Discussion

The proposed concept of KMEs may supply insight into student learning at group-level, and could be utilized both as pedagogical tool for the improvement of undergraduate teaching (as in Example 1) and as methodological tool for analyzing real classroom situations (as in Example 2). As the second use requires a presentation of additional data outside the scope of this paper (see Marmur, 2017), I expand the discussion focusing on the first proposed use for teaching improvement, as well as a theoretical reflection on classroom student learning.

KMEs as a Guide for Lesson Design

Being that KMEs are conceptually regarded as events that are perceived as memorable and meaningful by *many*, I suggest that they may be utilized by instructors as indicators for events in the lesson that will most likely remain "invariant" in future "same" lessons taught to other students. Building on variation theory (Marton & Booth, 1997; Runesson, 2005) for lesson design, Watson and Mason (2009) claim that variation in lessons should be "foregrounded against relative invariance of other features" (p. 98). As suggested by their argumentation, the significance of understanding the invariant aspects of lessons is to be able to utilize them as "anchors" on top of which variation is created. Accordingly, KMEs may indicate a likely *invariance* in a lesson design, which provides crucial information for its further development and refinement. In practice, utilizing the notion of KMEs as such "anchors", may additionally allow lecturers and instructors to each time "fill" them with varying mathematical content.

In this regard, it should be noted that the creation of hierarchy between different classroom events in regard to student learning, as suggested by the KME concept, is not foreign to the way some researchers address the mathematics itself. For example, according to Leron (1983), the common practice of presenting proofs linearly in undergraduate lessons is unsuccessful in its support of student learning, as it lacks the dimension of communicating how such proofs are generated and thought of. Rather, Leron's notion of a "structural proof" suggests to first supply students with the general structure of a proof, and only then start filling in the missing details.

Continuing the analogy, while this paper focuses on *key events* as experienced by many students, in the literature we may find research focusing on *key mathematical ideas* (e.g., Gowers, 2007; Hanna & Mason, 2014; Raman, 2003). Raman (2003) states that: "For mathematicians, proof is essentially about *key ideas*; for many students it is not" (p. 324). Gowers (2007) emphasizes the relevance of key ideas to mathematical activity, by claiming that a focus on the key ideas of a proof may increase its memorability and promote its mathematical understanding. This naturally comes with the pedagogical implications of how to reveal to students what these key ideas are, and how these may serve their learning. In relation to lesson design, I suggest that the notion of KMEs may be considered in combination with key mathematical ideas that could be learned in context of the problem (as in Example 1, a KME around a non-routine solution method for a challenging mathematical problem).

An additional use of KMEs for lesson design relates to the affective domain, and more specifically to negative student emotions. As we know, negative emotions are a natural part of mathematical learning, and as Goldin (2014) suggests, may even lead to greater satisfaction and pleasure when "overcoming" challenging problems. However, it is our responsibility as educators and researchers to support students' meta-affect in relation to such experienced emotions. As claimed by Goldin (2000, p. 218):

> "The challenge to the educator is to interrupt the incessant negative feelings, a first and necessary step in the needed cognitive and affective reconstruction. The challenge to the researcher is to find ways to do this."

I suggest that the concept of KMEs may be utilized in lesson design as a tool to "steer" student emotions towards specific segments of a lesson, and thus be able to reduce the overall experienced negative emotions. This is illustrated in Lesson-P (see Example 2), in which the creation of a very positive event at the beginning of the lesson (on how to approach the problem), managed to neutralize possible negative student emotions stemming from not understanding the subsequent solution. Such a case demonstrates that, even though we may not be able to stop students feeling frustrated when dealing with challenging mathematics, we may utilize the idea of KMEs in order to design lessons that could shape what would ultimately be perceived as a more positive memorable learning-experience.

KMEs and Theoretical Considerations on Learning

> "The line, even in science, between serious theory and metaphor, is a thin one—if it can be drawn at all. [...] There is no obvious point at which we may say, 'Here the metaphors stop and the theories begin.' " (Scheffler, 1991, p. 35)

In regard to existing literature and theory, I suggest that the KME concept may provide a theoretical contribution to our views on learning, as well as on the evolvement of student affect during the process of learning. Sfard (2015) argues that we conceptualize and examine human learning by utilizing metaphors, and that "what often appears as but an innocent figure of speech may in fact inform how we think about the topic, what we are able to notice, and what pedagogical decisions we are likely to make" (p. 635). Furthermore, Sfard (1998) emphasizes

that in order to produce a critical theory on learning, we must be willing to lean on more than one "metaphorical leg" (p. 11), even if the different metaphors induce some level of contradiction.

Though learning is not a linear process, I argue that some of the very useful learning metaphors we find in the literature at least hint towards some level of linearity. Conceptualizing student learning over the course of a lesson in metaphors such as "paths", "pathways", "trajectories", or "tracks", indeed has great pedagogical value in terms of lesson design. As suggested by Simon's (1995) notion of *learning trajectories*, a teacher may hypothesize on learning paths of students, whilst aiming to "match" these with preconceived teaching goals. However, at least on a theoretical level, this metaphor may imply an unrealistic linearity in the process of learning, where students have to go through a series of consecutive steps, each one supporting the following. It is interesting to note that even when discussing emotions, which are clearly nonlinear, in context of learning, we find it convenient to conceptualize these into *affective pathways* (Goldin, 2000) that progress from one emotional state to the next.

I suggest that the concept of KMEs may supply a "horizontal" approach to learning (see also Figure 1: Key Memorable Events), enriching the more dominant "vertical" view on learning as pathways. The KME notion suggests a hierarchy between different events and their contribution to learning, whilst putting emphasis on what we may regard as "*snapshots*" or *highlight moments* in a lesson as identified by many. I do not wish to imply that other moments in a lesson are insignificant for the learning, or even that they do not play a contributing role in the creation of a KME. However, I suggest such a hierarchal approach is not only a useful tool for lesson design, but also examines learning in closer relation to what we may refer to as our "human experience". If for example we imagine a musical piece, it is reasonable to assume we will not remember all individual notes. Rather, our overall experience is shaped by certain highlight moments during its course (Huron, 2006). Bringing the analogy back to KMEs, the findings presented in Example 1 and 2 suggest that a student's overall learning-experience in a lesson is shaped by several key moments during its course.

Lastly, I suggest that the KME concept may supply an added layer to Goldin's (2000, 2014) theory on local and global affect. While the KME construct addresses emotion experienced during a lesson, the dimension of strong memorability points towards a possible affective phase situated in an "intermediate zone" between local emotional states and longer-term attitudes and beliefs. Though there seems to be a consensus in the literature, that the more stable attitudes and beliefs are a result of a lengthy and slow process of experiencing repeated emotional states (e.g., Goldin, 2000; Zan, Brown, Evans, & Hannula, 2006), not all these experienced states are of equal importance. Focusing on those experienced emotions during what is here referred to as KMEs, may supply us with a more accurate indication of how this transitional process possibly takes place.

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