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Understanding the secondary-tertiary transition in mathematics education: contribution of theories to interpreting empirical data

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The paper reports a review of studies on the secondary-tertiary transition in mathematics. With an interest in the contribution of theories, it intends to explore what insights empirical studies using new theoretical lenses have added. While there is a move towards socio-cultural theorizing, some dimensions pertaining to issues of social (re)production still appear under-researched.

Keywords: university mathematics, sector transition, theories, socio-cultural studies.

Introduction

In mathematics education, the expression ‘transition problem’ commonly refers to difficulties when students enter a new school sector, or begin a new more ‘advanced’ course. While the notion has been used also for passages between other contexts, this contribution focuses on the transition from school to university, which has long been described as particularly problematic (e.g., De Guzman, Hodgson, Robert, & Villani, 1998), *inter alia* alerting to high dropout rates. Nevertheless, a difficult transition may not only be seen as a *problem* for the students, but also “as something potentially positive for their development and future opportunities” (Jablonka, Ashjari, & Bergsten, 2017, p. 76). ‘Smoothing’ the transition may not necessarily be desirable. Conceived as problematic, the transition has attracted much attention in mathematics education over the years, and the analytical lenses employed for its study have been diverse. However, a comparison of the overviews in De Guzman et al. (1998) and Gueudet (2008) shows that new theories might contribute to deepening the understanding of the secondary-tertiary transition. While De Guzman et al. categorized ‘types’ of problems in ‘theoretical’ categories (*epistemological/cognitive; sociological/cultural; didactical*), their discussion also included under-theorized notions (e.g., type of mathematics, contact to teachers, ways of studying). Gueudet (2008) used similar categories (*thinking modes, mathematical language and communication, and didactical transposition and contract*) but in contrast to De Guzman et al. (1998) explicitly contained the discussion within a range of theoretical frameworks with reference to empirical research drawing on these frameworks. In a later “survey of the state of the art” regarding transitions in mathematics education, Gueudet, Bosch, DiSessa, Kwon and Verschaffel (2016) pointed to the diversity of theoretical orientations, but also to the importance of complementarity.

In this paper studies from the last ten years on the secondary-tertiary transition in mathematics education will be reviewed with the aim to trace the development in terms of the theoretical approaches taken and how these have contributed to new insights regarding the transition.

Method

For an initial literature search, articles published during the last ten years in major (mathematics) education research journals and conference proceedings as well as articles listed in the MathEduc

database that explicitly addressed the secondary-tertiary transition were identified. From these, only articles reporting empirical studies with an explicit theoretical approach were included in a first step of the analysis. From these around 100 articles, a final sample of around 50 articles drawing on theories *not already discussed* in Gueudet (2008) was selected for a second step; weakly theorized quantitative studies were not included. The main stated results of the studies were used to identify how theoretical approaches contribute to insights regarding the transition. For the notion of theory, the selection was guided by the discussions in Radford (2008) and Jablonka and Bergsten (2010). Certainly, some of the theoretical orientations discussed in Gueudet (2008) continued to be used and developed during the period studied; for example, in the first step of the analysis around ten articles drawing on ATD and/or TDS and five using a cognitive approach were found. These represent an important part of the theoretical development of the area but will not be included here due to space limitations. As the literature review was not based on a fully comprehensive search, some recent theoretical developments might have been omitted. The categorization made from the analysis of the sample, however, has a strong base in the articles found.

In the next section, the dominating theoretical approaches identified will be presented. These were found in 37 (of the 50) papers; single studies employing *Horizon content knowledge* (MKT) and *Three worlds* (Tall), *use-and-exchange-value*, *communities of practice*, a framework for textbook comparison, as well as a few studies using theoretically less specified notions such as *competences*, *interest*, *expectations*, *transmissionist pedagogies*, and *perspective*, will not be discussed here.

Contributions of different theoretical approaches

In the selected articles, five theoretical approaches not discussed in the review by Gueudet (2008) were identified, which unavoidably only adumbrate distinct categories: *Bourdieuian sociology*, *Bernsteinian sociology of education*, *Cultural anthropology*, *Cultural Historical Activity Theory* and *Commognition*. How these contribute to the understanding of the transition will be illustrated by way of examples of specific studies.

Bourdieuian sociology

A group of studies drew on Bourdieu's notions of *habitus* and *capital* to analyse students' struggles during the transition. Kleanthous and Williams (2013) employed the notion of habitus to develop a framework for measuring parental influence on students' inclination to pursue mathematics studies in higher education. They interpreted their findings to be consistent with a Bourdieusian view in that "family influences might inculcate a mathematical habitus that encourages choosing mathematically-advanced courses at school, which thus enhance mathematical confidence and inclination, and shapes positive dispositions to study mathematically-demanding courses in the future." (p. 64).

That also those students who find the transition hard may hang on to successfully complete the transition was illustrated in Hernandez-Martinez and Williams (2013), where these students were labelled as *resilient*, defined as a socio-cultural term. For the analysis the authors employed Bourdieu's notions of cultural and social capital, adding that "students can *develop* capital through reflection" (p. 49), a capital allowing agency for example during transition to align "their habituses with the conditions of the new field" (p. 49). Based on a narrative analysis of data from two student

interviews, the authors identified biographical “narratives of resilience” (p. 50) that showed how reflexivity led to the development of a capital during schooling that eventually became valuable during the transition, for example when experiencing risks to progression. For education practice the authors therefore suggested that “processes that encourage reflexivity in students should be incorporated in pedagogical practices at all levels” (p. 57).

Bergsten and Jablonka (2013) interviewed students at the beginning, middle and end of their first year of study in a five years engineering programme at two Swedish universities, and interpreted their data in terms of Bourdieu’s notions of *field* as well as *cultural*, *economic* and *symbolic capital*. Regarding the choice of programme at university, the outcomes corroborated those of Kleanthous and Williams (2013), showing how “the cultural capital possessed by the families influence the choice to enrol at a university” (Bergsten & Jablonka, 2013, p. 2293). Students also appeared to have acquired a cultural capital in their science- and technology programmes at secondary school that has developed into a disposition towards academic studies (many talking about “a natural continuation”). While expectations about future professions differentiated between students from different study programmes in terms of the importance of cultural and economic capital as well as the symbolic capital that multiplies their impact, the views of the role of mathematics in this context were more coherent, with a focus “less on particular mathematical skills as a form of cultural capital”, but more on “a general habituation to solve problems in a rational way” (p. 2294).

Bernsteinian sociology of education

To identify issues and operationalize notions seen as critical for the transition, some studies employed key concepts from Bernstein’s theory of pedagogic discourse, in some instances combined with other theoretical constructs. Kouvela, Hernandez-Martinez and Croft (2018) focused on the discourses that frame the changes in teaching and learning practices during the transition from school to university, and how these discourses transmit *messages* to the students that affect how they experience and handle the transition. Drawing on Bernstein the authors distinguished *strongly classified* and *strongly framed* messages. The empirical study involved first-year mathematics students and two lecturers, and included lecture observations, student questionnaires and interviews; a grounded theory approach amounted to categories of messages (what students should do during and after lectures, assessment, general study habits). These messages, transmitted by the lecturers to their students, were analysed in terms of classification and framing helping to decompose each message and “identify, through the underlying structures of power and control, in what ways the message can be influential on students’ transition” (p. 173). The general conclusion was that messages common between school and university ease the transition, while differences can “prompt action to be taken by students and can change their thinking” (p. 181).

Jablonka, Ashjari and Bergsten (2017) investigated how first year students interpreted the type of mathematics they encountered at university. To explicate the expression ‘type of mathematics’ and create a language of description for the reading of the empirical data, an analytical framework drawing on Bernstein’s notions *knowledge classification* and *recognition rules*, elements of *social semiotics* by Halliday and Hasan, Eco’s conception of a *model reader*, and Sierpinska’s idea of mathematical and didactical discourses as *mathematical* and *didactical layers* in textbooks was

developed. In individual interviews, textbook excerpts were shown to 60 first year engineering students at two Swedish universities, asking them to rank the texts according to which they saw as “more mathematical”. The framework allowed a description of students’ articulation of their recognition rules, and the authors concluded that “recognition of differences in strength of classification of different mathematical discourses emulated in a range of pedagogic practices relates to success in the examinations” (p. 87). The study thus illustrates how academic success relates to a recognition of the university mathematical discourse.

Cultural anthropology

A couple of studies used theories that can be located in the rather broad field of cultural anthropology. Four research groups referred to the idea of a phased *rite of passage*, coined by Arnold van Gennep at the beginning of the 1900s. Clark and Lovric (2008) first suggested that this is a useful model for the study of the transition to university (mathematics). The transition period is characterised through a *separation* phase (end of school, anticipating university life), *liminal* phase (from finishing school to beginning university), and *incorporation* phase (first year at university). It thus constitutes first of all a formal grid for framing the transition but does not specify what or how to approach the particular issues related to the phases.

One attempt to apply the model is found in a pilot study by Bampili, Zachariades and Sakonidis (2017), which presents data from interviews involving 12 students during their transition to mathematics studies at a Greek university. At the three phases of Clark and Lovric’s model questions were asked regarding the dynamics of the social-personal life, academic life and mathematical content dimensions to investigate how “the academic and social dimensions interact to shape the passage from the liminal to the incorporation phase regarding mathematical content” (p. 1987). In the paper, data from one student were discussed “because her responses during data collection strongly indicated that she was undergoing a rite of passage regarding mathematics” (p. 1987). Based on their findings the authors considered the study as “a good starting point for exploring specific issues considering transition more extensively” (p. 1991).

Wade, Sonnert, Sadler, Hazari and Watson (2016) conducted an online qualitative survey involving secondary and tertiary level mathematics teachers in the USA about what they conceived as good high school preparation for students for the college calculus courses. As a framework for interpreting their data they used the *rite of passage*. In particular, the separation and incorporation phases were investigated through thematic analyses that revealed five categories in which secondary and tertiary teachers “differed significantly in the relative frequency of addressing them” (p. 7). While teachers at university pointed at preparation of specific areas within algebra and precalculus as vital, teachers at secondary level highlighted “classroom environment realities of teaching in the separation phase.” (p. 7). The authors concluded that a better understanding of the “gap between the teachers’ and the professors’ outlooks” is needed and that these two groups need to “realize more clearly that they are part of one and the same rite of passage process” (p. 13).

Corriveau and Bednarz (2017) drew on *cultural theory* (referring to the work of Edward T. Hall), in particular the distinction between *formal*, *informal*, and *technical* modes of culture and on *ethnomethodology*. They sought to understand how differences in secondary and post-secondary

teachers' "ways of doing mathematics" rather than differences in formal or technical aspects of mathematics present difficulties for students. More specifically, the secondary teachers aimed at "giving form" to symbols that "speaks" to the student, representing particular generalisations, while the post-secondary teachers worked to "give voice" to the pre-existing general symbols. The authors concluded that "the 'informal' mode of mathematical culture specific to each teaching level plays a key role in attempts to better grasp transition issues" (Corriveau & Bednarz, 2017, p. 1).

Cultural Historical Activity Theory

Several transition studies used Cultural Historical Activity Theory (CHAT) to frame their research. In a project in the UK on student participation in post-compulsory mathematics education, Black et al. (2010) interviewed 40 students at three occasions during the transition period. In doing so, they used a notion of *identity*, which in their reading of CHAT is "historical in origin and emerges from the subjectivities (how one views oneself) we experience in the process of doing activities" (Black, Williams, Hernandez-Martinez, Davis, & Wake, 2010, p. 58). The authors argued that what they termed *leading identity* (based on Leont'ev's concept *leading activity*) defines a student's motive for study and also influences the relation to mathematics. A narrative analysis of interviews with two students with different experiences and showing "contrasting aspirations in their interviews" (Black et al., 2010, p. 59) was conducted. For the analysis an operationalization of the constructs leading activity, leading identity, cultural models (such as 'math is hard') and troubles/obstacles used to read the data was developed. The two students were both drawing on "cultural models regarding learning mathematics and studying in general" (p. 68) which framed their leading identities; in one case to become an engineer, in the other to obtain a university degree. The authors suggested that a leading identity implying the use value of mathematics as a motive for its study has a stronger potential to "bring about a commitment to persisting with mathematics, particularly for at-risk students who may face more difficulties or challenges than others" (p. 71).

Within the same project, investigating the transition from school to college mathematics in the UK through student pre- and post-transition interviews, Hernandez-Martinez et al. (2011) categorised the transition 'problems' in *social dimension*, *continuity of curriculum/pedagogy*, and *individual-progression/differences*. Rather than only a discourse focusing on problems, the authors also identified "a more positive discourse on challenge, growth and achievement" (p. 119). They focused on the notion of *identity*, relying mainly on CHAT, in particular the ideas of *self in practice* and *consequential transitions*. As a result, the authors suggested it to be viable to "re-think transition as a question of identity in which persons see themselves developing due to the distinct social and academic demands that the new institution poses" (Hernandez-Martinez et al., 2011, p. 119).

Commognition

A number of studies drew on the theory of *commognition* (Sfard, 2008) to analyse the transition to university mathematics education as a *discursive shift* that may involve a *commognitive conflict*, that is "the encounter[s] between interlocutors who use the same mathematical signifiers (words or written symbols) in different ways or perform the same mathematical tasks according to differing rules" (Sfard, 2008, p. 161). This approach provides a language for describing mathematical work as discursive practices, characterized by their shared *word use*, *visual mediators*, *endorsed*

narratives and *routines*. In a UK context, Thoma and Nardi (2018) investigated how a group of first year mathematics students solved closed book exam tasks, and also interviewed the two lecturers involved in the courses. In the students' scripts four manifestations of (unresolved) commognitive conflict were observed, two of which (the numerical domains involved, and visual mediators and rules of school algebra and set theory) seen as "stemming from the use of visual mediators and rules from the school mathematics discourse" (Thoma & Nardi, 2018, p. 165). A challenge for beginning students at university is then to recognise the switch and adapt to different discursive contexts, which was not required in the arithmetic and algebra dominated school mathematics. Some further examples are found in Nardi, Ryve, Stadler and Viirman (2014) who discuss empirical studies highlighting "*commognitive conflicts* that characterise the transition to *literate* mathematics" (p. 194).

Discussion

The studies reviewed above illustrate how the framing of the secondary-tertiary transition in mathematics education has widened in scope during the last decade. With the exception of *commognition*, the theoretical approaches identified as "new" have been developed outside mathematics education; however, most of them have been imported first into other research areas in mathematics education. Many of the studies recruit a combination of different theoretical resources in order to achieve their research aims. Overall, the transition as a process has come more into focus, which is also reflected in the methodologies (e.g., interviewing students at different points in time). Referring to recent work, Gueudet et al. (2016) made a similar observation in noticing a trend towards approaches that intend to grasp transition as a process in its complexity.

Notably, all approaches discussed might be subsumed under "socio-cultural" theorizing. This is a move away from views that essentialize students' mathematical and cognitive dispositions that may (or may not) make them successful in crossing the boundary between school and university mathematics education. The new approaches illustrated above certainly have enriched the field, as transition is not only pictured as problematic but as necessarily involving discontinuities. By drawing on theoretical tools developed within coherent frameworks in the analyses of mathematics-specific practices, critical experiences of the transition as well as social and cultural (dis)continuities have been identified that otherwise would have remained hidden; some questions would not have been asked without turning to theories developed outside mathematics education. This applies not only to such issues as implicit rules for the use of mathematical symbols or modes of argumentation, but also to the organization of the content of mathematical courses, their modes of study and resources used. This development is also in alignment with the general trend in mathematics education research, including university level (cf. Inglis & Foster, 2018). However, the dominant focus here is on the "cultural" to the detriment of the "social" in "socio-cultural" theorizing. How social orders or hierarchies are (re)produced in the transition remains under-researched, despite numerous statistical reports on underrepresentation or dropout in higher (STEM) education of particular social groups. While, for example, ATD offers a precise language of description for conceptualising differences between mathematical cultures, sociological approaches, in particular if they allow a description of mathematical practices, discourse and knowledge structures in relation to mechanisms of inclusion and exclusion, are important to understand how

particular social hierarchies are (re-)produced *within* particular mathematical cultures (see e.g., Bergsten, Jablonka, & Klisinska, 2010; Bergsten & Jablonka, 2013; and the review of sociological theories in mathematics education in Jablonka, Wagner, & Walshaw, 2013).

As to the cultures of doing mathematics, similarly as noted by Gueudet (2008), technology as one area relevant for the transition appears under-researched in our sample of papers. While as long as 30 years ago technology (in particular CAS) was seen as a key resource for ‘reshaping calculus’ in the USA, “the potential of technology in helping students in the ‘rite of passage’ to tertiary education has not yet been researched” (Bardelle & Di Martino, 2012, p. 787). There are however recent attempts in theorizing technology use in the transition (Gueudet & Pepin, 2018). Still, even after suspending traditional ways of doing university mathematics (e.g., through technology), going through a status of liminality will be necessary in the process of enculturation.

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