Using Activity Theory to Understand a Mathematics Leader's Motivations and Use of Mathematical Knowledge for Teaching

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Despite the significance of the role, little is known about mathematics leaders in schools. Rachel, a mathematics leader, was observed leading planning meetings with junior primary teachers. Using activity theory, three of Rachel's motivations were identified: influencing teacher affect, developing shared understandings, and avoiding conflict. Observation and interview data analysis revealed the use of pedagogical content knowledge (PCK) as a tool far more than subject matter knowledge. We posit that the dominant use of knowledge types associated with PCK was due mostly to Rachel's object of avoiding conflict.

This paper is about one mathematics leader, Rachel, and her work in leading planning meetings with junior primary teachers at her school in 2015. Mathematics leaders like Rachel are regarded as having significant influence in affecting change in teachers' professional learning and the mathematics practices enacted in schools (Grootenboer, Edwards-Groves & Rönnerman, 2015; Jorgensen, 2015; Millet & Johnson, 2004). Despite the importance of this critical role in schools, little can be found about these middle leaders in the research literature (Sexton & Downton, 2014). With this paper, we aim to contribute new information about mathematics leaders by identifying the motivations of Rachel, and how she used mathematical knowledge for teaching (Ball, Thames, & Phelps, 2008) when leading planning meetings with teachers. We used activity theory (Engeström, 1987) to guide our research work in describing Rachel's motivations, and knowing more about the Ball et al. (2008) knowledge types she used when leading those meetings with her teachers.

Literature Background

Millett and Johnson (2004) claimed that mathematics leaders in schools have opportunities to lead teacher professional learning and mediate change in teachers' practices associated with mathematics teaching. This image of the mathematics leader as a professional learning provider in schools has endured since that time (Grootenboer et al., 2015; Jorgensen, 2015; Sexton & Downton, 2014). Jorgensen (2015) revealed that schools make provisions to develop this leadership role as a form of "coach" who supports teachers' learning about curriculum and planning. Mathematics leaders have identified the facilitation of planning meetings as an important aspect of their work in primary schools (Sexton & Downton, 2014).

Teachers' planning for mathematics teaching has garnered attention from the MERGA community in recent years (e.g., Davidson, 2016; Roche, Clarke, Clarke, & Sullivan, 2014; Sullivan, Clarke, Clarke, Farrell, & Gerrard, 2013). Planning is an important role in primary teachers' work responsibilities (Roche et al., 2014). Sullivan et al. (2013) reported that primary school teachers place a greater emphasis on collaborative planning with peers (compared to secondary school teachers). Many Victorian Catholic school teachers claimed that they do indeed work in teams of two or more when planning for mathematics teaching (Roche et al., 2014). Creating units of work appears to be a goal when primary school teachers meet to collaboratively plan (Davidson, 2016; Roche et al., 2014), but planning can be a complex task for teachers (Davidson, 2016). Teachers' mathematical

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knowledge is a critical issue in mathematics planning processes because that knowledge impacts the decisions that teachers make during planning opportunities (Davidson, 2016). This recognition of the importance of teacher knowledge is not new (e.g., Ball et al., 2008; Shulman, 1986; Sullivan, Clarke, & Clarke, 2009).

Building on Shulman's (1986) seminal yet theoretical work, Ball and colleagues sought to conceptualise, measure, and evaluate the knowledge that is required for mathematics teaching. Ball et al. (2008) gave rise to their framework named mathematical knowledge for teaching (MKT), which they believed captured both the subject matter knowledge (SMK) and pedagogical content knowledge (PCK) needed for the work of teaching mathematics. Ball et al. included three types of SMK and three types of PCK in their knowledge framework.

According to Ball et al. (2008), the three types of knowledge that comprise SMK are common content knowledge (CCK), specialised content knowledge (SCK), and horizon content knowledge (HCK). CCK is considered the knowledge of mathematics that is commonly used by adults in settings outside of teaching (Ball et al., 2008). It is knowledge that is required to solve mathematical tasks encountered in everyday life (Sullivan et al., 2009). Examples of CCK include recognising when answers are incorrect, calculating answers correctly, and using mathematical terms and definitions appropriately (Ball et al., 2008; Hurrell, 2013). SCK relates to mathematical knowledge that is unique to the teaching of mathematics. This knowledge is generally not required for purposes outside of the teaching profession (Ball et al., 2008). In a sense, this type of knowledge goes beyond what most adults require for doing and using mathematics. Examples of SCK include knowing if a student-invented algorithm or strategy could be generalised, finding examples and non-examples to make a mathematical point, and understanding the different interpretations of the operations (Ball et al., 2008; Hurrell, 2013; Sullivan et al., 2009). HCK is understood as the knowledge of how mathematical topics are connected with other topics, and knowledge of those mathematical ideas that students encounter in the later years of schooling (Hurrell, 2013; Sullivan et al., 2009). Examples of this knowledge type include the teacher's ability to articulate how a mathematical idea develops through curriculum documentation (Hurrell, 2013).

Pedagogical content knowledge within the Ball et al. (2008) framework includes knowledge of content and teaching (KCT), knowledge of content and students (KCS), and knowledge of content and curriculum (KCC). KCT concerns knowledge of mathematics content and knowledge of teaching. A teacher who enacts KCT can discern the advantages and disadvantages of particular representations for ideas, identify appropriate tasks to use in lessons, and sequence them in ways that support learning and teaching (Ball et al., 2008; Sullivan et al., 2009). KCS is teaching knowledge that combines mathematical content and ways that students come to understand (or misunderstand) mathematical ideas and content (Ball et al., 2008). Examples of KCS include knowing common misconceptions often developed about mathematical topics, anticipating likely student responses to tasks, and knowing which aspects of mathematical tasks students will find easy or challenging (Ball et al., 2008; Hurrell, 2013; Sullivan et al., 2009). The final knowledge type, KCC, is knowledge of mathematical content and curriculum. With this knowledge, teachers understand how concepts are represented within the curriculum and when they are expected to be taught. KCC is also knowledge of teaching materials and resources that support the teaching of ideas in the curriculum (Hurrell, 2013).

With planning meetings acting as an important aspect of mathematics leaders' work (Sexton & Downton, 2014) and knowing that mathematical knowledge plays a critical role

in those meetings (Davidson, 2016), we wanted to contribute to the literature about mathematics leaders. We wanted to gain insights into Rachel's motivations when leading planning meetings with her teachers. We also wanted to highlight the types of mathematical knowledge for teaching (Ball et al., 2008) that she used when leading those meetings. With a need to know more about Rachel's motivations and use of the Ball et al. knowledge types, activity theory was chosen as the theoretical perspective for the study.

Theoretical Perspective

The theoretical perspective for the doctoral study on which this paper is based uses an activity theory framework influenced mostly by the work of Engeström (1987). A number of important concepts are engaged when using activity theory. The first idea is the activity system (Engeström, 1987), which forms the main unit of analysis. The activity system is comprised and organised by a number of nodes (italicised in this paragraph). The activity system is concerned with the subject (which can be an individual or collective) who is working towards an object whilst enacting activity within a social context that includes the community. Within activity theory, the activity system is viewed as dynamic and ever-changing, where rules, division of labour, and mediating artefacts act as mediators of the activity under investigation (Engeström, 1987). Acting as mediators, these nodes have the potential to support or constrain the achievement of the object. Due to the confines of this paper, only the object and mediating artefacts will be discussed briefly.

Within activity theory, the object of activity has two different meanings. In one sense, the object may be a physical and/or mental product (Engeström, 1987), or the object can also be the motivation or goal held or pursued by the subject (Leontyev, 1978). The object provides reasons for the subject's behaviour(s) within the activity system. Mediating artefacts, or tools as used by Vygotsky (1978) and thus used as a term by us in the remainder of this paper, are an important feature of activity theory. The subject uses tools to mediate activity so that the object can be achieved. Vygotsky (1978) claimed that tools can be both physical and psychological in nature. Examples of physical tools include computers and pens, and psychological tools include language and signs. Psychological tools are used by humans to influence themselves or other human beings. The subject of any activity system uses a combination of both types of tool (Engeström, 1987).

Another important concept of activity theory is contradictions. Contradictions are inherent and ever-present in activity systems (Engeström, 1987). Due to the dynamism of the activity system, interrelationships exist between the different nodes of the system (Engeström, 1987). By examining these interrelationships, contradictions can be identified within the system. Contradictions are viewed as catalysts in transforming the activity system, bringing about potential change if addressed by the subject (Engeström, 1987).

In using this theoretical perspective, we mobilised activity theory concepts associated with the activity system – namely subject, object, tools, and contradictions – to know more about Rachel's leadership work. We positioned Rachel as the subject within the activity system, and then situated the Ball et al. (2008) knowledge types as the psychological tool that Rachel used to mediate the objects of her leadership when facilitating planning meetings with her teachers. We then wanted to identify the objects (motivations) of Rachel's activity system, and know which knowledge types she used to mediate those objects that she pursued in planning meetings.

Method

Participant

Rachel, the mathematics leader, works in a Victorian Catholic primary school that participated in the Contemporary Teaching and Learning of Mathematics (CTLM) project (Sexton & Downton, 2014) in 2011 and 2012. Rachel leads planning meetings with teachers who are released from teaching duties once a fortnight to attend the meetings.

Data Generation

Rachel was observed on three occasions during 2015 (from April to November) at times that she nominated. Rachel worked with her Grade 1/2 teachers during each meeting. One meeting was focused on planning a unit of work on time measurement (which included a focus on a unit of work on addition and subtraction), and two other meetings focused on 2D transformation, symmetry, and visualisation. The total amount of observation time was 165 minutes. Rachel was interviewed on five occasions during the time of the observations: once after the first observed planning meeting, and then before and after the remaining meetings. The data generated through observations and interviews were recorded and transcribed. In line with ethics protocols, only Rachel's activity (speech, actions, etc.) was recorded and analysed.

Data Analysis

Analysis of data was approached using a deductive method where *a priori* concepts, derived from theory and literature – namely object, tools, and the Ball et al. (2008) knowledge types – were used to analyse data. Specific examples of the knowledge types were retrieved from literature to support the coding of data (e.g., Ball et al., 2008; Hurrell, 2013; Sullivan et al., 2009). Interview transcriptions and observation notes were coded for Rachel's use of particular knowledge types using those examples. To illustrate our coding, we provide some examples of our work. In one planning meeting, Rachel referred to tessellation and provided a definition for this mathematical idea. We coded this as knowledge associated with common content knowledge (CCK). Another time, Rachel warned her teachers that understanding angle as rotation is challenging for younger students to understand. This was coded as a form of knowledge of content and students (KCS). We read and coded interview transcriptions and observation notes for specific examples of the MKT knowledge types as well as the concepts from activity theory. Parts of observation notes and transcriptions were then independently coded by a colleague to check coding consistency.

Results and Discussion

The findings that we share are tentative ones that have been highlighted so far in the doctoral study. Rachel's leadership of planning meetings is indeed dynamic, as she was charged with leading up to at least five teachers in each meeting. Rachel said that she saw leadership of planning meetings as part of her role (Sexton & Downton, 2014), and confirmed that planning was a critical part of teachers' work (Roche et al., 2014).

Motivations of Rachel's Work

We identified three of Rachel's motivations (objects) when coding the data: influencing teacher affect, developing shared understandings, and avoiding conflict. The first two motivations were explicitly discussed and enacted by Rachel. Therefore, we have deemed these to be conscious objects. The third object, avoiding conflict, is one that we believe is unconscious to Rachel, yet it was one that was pursued by her in her work.

Influencing teacher affect. Rachel identified developing teachers' confidence about mathematics topics as one of her motives when planning with her junior primary teachers. When asked about what she wanted the teachers to learn, Rachel would often refer to the teachers' confidence. An example of this was when Rachel spoke about the purpose of her work: "I want them [the teachers] to have more confidence in the language of the unit…I really want them to be confident in the unit". This behaviour of instilling confidence has been described by Edwards-Groves, Grootenboer, and Rönnerman (2016) as a dimension of trust which they have termed "interpersonal trust" (p. 378). This is an important aspect of the work of middle leaders in primary schools (Edwards-Groves et al., 2016). Rachel also made references to teachers feeling comfortable with what to do, say, and use during lessons that formed the units of work. In terms of activity theory, this object would be considered a motive (Leontyev, 1978) as well as a mental product (Engeström, 1987).

Developing shared understandings. The second object of Rachel's activity concerns the development of shared understandings between teachers. During interviews, Rachel often commented that she wanted consistency in teachers' understanding of teaching approaches, tasks, and language and terms that were to be used when the teachers taught. Rachel once commented, "We want to make sure there is consistency and the teachers are aware of the important steps and processes to teach it [the unit of work]". Rachel also said it was important that she supports the teachers in consistent understanding of the important mathematical ideas that were to be taught.

Rachel's focus on developing shared understandings of mathematical ideas during planning meetings is important because Sullivan et al. (2013) found that teachers often experience difficulty in articulating important ideas during planning meetings. It was observed, however, that during the meetings, Rachel rarely engaged teachers in discussions about those mathematical ideas. Instead, Rachel would often tell teachers the mathematical ideas that the topic focused on, and she would tell them statements about those ideas that she called "key understandings". These key understandings have been described by Roche et al. (2014) as a feature of planning documents used in many Victorian Catholic schools. Mathematics leaders have reported using such understandings in planning meetings during the CTLM project (Sexton & Downton, 2014).

Even though it is important that Rachel is focusing on these aspects of planning, her practice of telling teachers and not engaging in mathematical discussions about mathematical ideas could be viewed as a contradiction with her activity system (Engeström, 1987). We believe this because Rachel said that she viewed facilitated planning meetings as opportunities for collegial discussion; however, there were very few opportunities for teachers to engage in discussions where they were required to question, explain, and elaborate upon their own understanding of mathematical content that they were expected to highlight when teaching. Addressing that contradiction by including more discussions about important mathematical ideas between the teachers could be one way that Rachel uses that contradiction to develop her activity system (Engeström, 1987). By attending to this, Rachel has an opportunity to align her activity more closely with her

espoused object. Rachel could enact the practice of inviting her teachers more often to discuss ideas in planning meetings.

During the second planning meeting, Rachel did do this by organising one of the teachers to bring work samples associated with one of her suggested tasks. This task was related to the conservation of volume where the students had to use 24 cubes to construct different containers that held the 24 cubes exactly. It was noted that during that experience, there were in-depth discussions among the teachers about important measurement ideas, ways of supporting students to notice the differences and similarities of the containers, and ways that teachers might use iPad photos as assessment opportunities.

Avoiding conflict. The third object identified in Rachel's activity relates to the relational dimension of her work. Rachel often discussed a sense of empathy for her teachers and their work demands. Rachel mentioned that, as a school leader, she needed to be aware of how busy teachers were in her school. She often said that she had to be conscious of the teachers' work responsibilities. Rachel acknowledged this by stating: "they are so busy especially because they're all writing reports at the moment... I've got to be very mindful of that". This empathy for teachers is another description of interpersonal trust reported by Edwards-Groves et al. (2016). Rachel's response, generated by her empathy, was to offer and seek ways to reduce teacher workload.

During each of the meetings, Rachel said that she would create particular resources (e.g., laminated flashcards), collect materials for classroom use, prepare and photocopy templates for teachers to use, or complete the planning of the units of work for the teachers when time ran out for the scheduled meetings. Rachel explained the reason for completing the units of work during an interview: "If I didn't do that, they would then have to get together tonight… That takes another whole night of planning for them. And that's a lot". In each meeting, Rachel would offer ideas about tasks that formed the basis of lessons. When asked about reasons for this, Rachel said, "They've been teaching all day and suddenly they've got to focus in on something and that's why I think, sometimes they're happy if I've got an idea." We elaborate on this further in the next section.

We have coded this as an unconscious object of Rachel using the code "avoiding conflict". We do not mean any negative connotations by this label. We use this term because the empathy that Rachel feels for her teachers provides reasons for her behaviours. This object of avoiding conflict would also be deemed a motive or goal (Leontyev, 1978) that is driven by Rachel's concern for her teachers. We are questioning, however, if this object of avoiding conflict is in fact actually contributing to Rachel's own workload as the mathematics leader, and thus another contradiction has surfaced in her activity system.

Use of Mathematical Knowledge for Teaching by Rachel

Rachel used both subject matter knowledge (SMK) and pedagogical content knowledge (PCK) when leading the three planning meetings. The most used knowledge type of SMK as a tool was common content knowledge (CCK). There were 22 observed uses of this knowledge type during the meetings. Examples of CCK used by Rachel in the meetings included rotation as a transformation type, common language used to describe rotations (e.g., quarter turn, clockwise rotation), and representing, reading, and matching times on analogue and digital clocks.

Rachel also used knowledge associated with the specialised content knowledge (SCK) during the meetings. There were 14 uses of SCK as a tool to mediate the objects of her

activity. Examples of SCK used by Rachel included subitising (as means of quantifying small collections) and recognising and naming time and volume as measurement attributes.

The least used knowledge type associated with SMK was horizon content knowledge (HCK). There were only four coded uses of this knowledge type as a tool during the 165 minutes of planning meeting time. This suggests that little attention was given to how mathematical topics are connected to other topics, which could result in a fragmented picture of the mathematics curriculum and how it develops into the secondary curriculum.

The pedagogical content knowledge (PCK) category of Ball et al.'s (2008) framework and its knowledge types were used far more dominantly by Rachel. Rachel used PCK types nearly three times more often (110 uses) than the combined use of knowledge types associated with SMK. Knowledge of content and teaching (KCT) was the most used knowledge type by Rachel with it being used 57 times during the three planning meetings. This is more than the combined uses of knowledge of content and students (20 uses) and knowledge of content and curriculum (32 uses).

Knowledge of particular tasks/activities for teaching content (which is categorised as KCT) was used 18 times, and knowledge of concrete materials for teaching content (KCC, also 18 times) featured mostly as tools that mediated the objects of Rachel's activity. Rachel provided insights into reasons why she uses these particular knowledge types:

> Yeah, I found that in general, and the reason I keep doing it is because they go, "Yeah! I really like that." So, it makes me think, "Oh well, maybe the activity is a good one." But then I also think I've got more time to think about maths and be looking, be on the lookout for activities and… that I've got some of them in my head… So, part of me thinks yes, that's what I should do, but then the other part thinks, I hope I'm not taking over too much.

Rachel identified the reason why she tends to focus on the use of KCT and KCC. Rachel was very aware of teachers' work pressures, so we believe that in order to avoid conflict, Rachel used knowledge of tasks (KCT) and materials (KCC) as a psychological tool to minimise teacher workload, and thus achieve that unconscious object. The avoiding conflict object of Rachel's leadership in planning meetings influenced the knowledge types she used as a tool, which then in turn, mediated the object of her activity system. This is where we see the dynamism of Rachel's activity system at work (Engeström, 1987).

The quotation from Rachel above also suggests the presence of another object that relates to responding to teacher affirmation. The teachers make up the community node of Rachel's activity system, and this node is interacting with this new object. We will need to generate and analyse further data to substantiate this claim. Rachel did appear to question the support she provided during planning times, thus diagnosing her own contradiction.

Conclusion and Implications

We have highlighted conscious and unconscious objects of Rachel's activity system when leading three planning meetings with her teachers. These motivations are influencing teacher affect, developing shared understandings, and avoiding conflict. Without being explicitly aware of the Ball et al. (2008) framework, Rachel did indeed use all knowledge types captured in that framework. She did, however, use knowledge types associated with PCK far more than those categorised as SMK.

The knowledge types of knowledge of content and teaching (KCT), in particular knowledge of tasks/activities, and knowledge of content and curriculum (KCC), as knowledge of concrete materials and resources, were prevalently used by Rachel. We conclude that her use of these knowledge types was influenced by the motivations of her work, namely the object of avoiding conflict.

We suggest there is potential for mathematics leaders to become more familiar with knowledge types, like those of the Ball et al. (2008) framework to support their work. Mathematics leaders could use the framework as a tool to achieve, and possibly transform, objects of their leadership activities. In this way, leaders have the opportunity to plan, facilitate, and evaluate opportunities that influence teacher learning. Leaders will need specific examples of the knowledge types if this was to happen.

By using activity theory, we were afforded new ways to view the knowledge types of Ball et al. (2008). We now see the knowledge types as psychological tools that mathematics leaders might use to mediate objects of their leadership work in schools. We believe that this new view of the knowledge types has potential for further research.

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