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Unpacking teacher decision-making: Connecting complex elements

Alla scoperta del processo decisionale dei docenti: Collegando elementi complessi

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Abstract
Teaching is a complex endeavor requiring countless decisions to be made, sometimes within the blink of an eye. The recent outbreak of emergency remote teaching due to the pandemic emphasized the importance of teachers' expert knowledge in supporting deep learning online. Even though various attempts have been made in the literature, a comprehensive understanding of how knowledge, skills, epistemology, and values affect teacher reasoning and actions remains elusive. While acknowledging the role of single factors, this paper advocates a systemic view of teacher decision-making in technology rich contexts. An Epistemic Frame is suggested as a way of systemically integrate epistemology, skills, values, and knowledge peculiar to the teacher community. Introducing Quantitative Ethnography and Epistemic Network Analysis, this paper argues that the connections among elements of teachers' epistemic frames are pivotal, and thus calls for research methodologies that facilitate the explicit modelling of such connections. To this end, two studies will be introduced as examples.

Keywords: pedagogical reasoning for technology integration; pedagogical orientations; epistemic frame theory; quantitative ethnography; teacher decision making.

Riassunto
Insegnare è un'operazione complessa che richiede innumerevoli decisioni prese, a volte, in un battito di ciglia. La recente esperienza dell'insegnamento d'emergenza a distanza, causato dalla pandemia, ha reso ancora più evidente l'importanza della competenza docente nel sostenere anche online apprendimenti significativi. Nonostante in letteratura ci siano vari tentativi di investigare il fenomeno, rimane sfuggente una comprensione organica di come conoscenze, abilità, epistemologie e valori influenzino il ragionamento e le azioni degli insegnanti. Pur riconoscendo il ruolo dei vari singoli fattori, questo articolo sostiene una visione sistemica del processo decisionale docente in contesti tecnologicamente infusi. Viene suggerito l'Epistemic Frame Theory come un modello per integrare sistematicamente l'epistemologia, le competenze, i valori e le conoscenze proprie della comunità professionale docente. Introducendo poi la Quantitative Ethnography e la Epistemic Network Analysis, questo articolo vuole sostenere che le connessioni tra gli elementi dei quadri epistemici dei docenti sono fondamentali, e richiedono metodologie di ricerca che facilitino la modellazione esplicita di tali connessioni. Infine, si introducono due studi come esempi di tali metodologie.

Parole chiave: ragionamento pedagogico per l'integrazione delle tecnologie; orientamenti pedagogici; Epistemic Frame Theory; etnografia quantitativa; processo decisionale degli insegnanti.

Credit author statement

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Introduction

"Teaching is often cast as something that has been passively observed by students for a long time and therefore appears to many to be relatively straightforward and simple… To the casual observer, teaching looks easy" (Loughran, 2013, p. 119) and yet, the work of educators is an "outrageously complex activity" (Shulman, 1987, p. 11). Researchers have argued over the years that a large part of this complexity is a result of all the pedagogical decisions educators have to make (for example, see Barashay, 2018). Almost 50 years ago, Shavelson (1973) highlighted the importance of decision-making in teachers' work suggesting it is "the basic teaching skill" [emphasis in original] (p. iii), a perspective reflected also in the work of Madeline Hunter (1979) who suggested that "teaching is decision making" (p. 62). Gary Fenstermacher (1986) argued that the role of teacher education is not to program or train teachers to behave in predetermined ways, but to educate them to reason soundly about their teaching (see also Shulman, 1987; Mishra & Koehler, 2006).

The attempts to better understand what underpins effective teacher decision-making are still relevant in the research literature today (see Cox & Laferriere, 2019; Lloyd, 2019; Loughran, 2019), but we have yet to develop a comprehensive method for interrogating pedagogical reasoning. Moreover, the ever-growing influence of educational technologies has seemed to increase "conceptual complexity by at least an order of magnitude" (Graham, 2011, p. 1955). Technologies in education are more regularly acknowledged as real cognitive partners that may amplify learners' capacity to understand, communicate and perceive (Angeli & Valanides, 2009, Ertmer & Ottenbreit-Leftwich, 2010; Trevisan, 2019), and support the activation of higher-order cognitive processes (Kramarski & Michalsky, 2010) when handled by skilled educators. With the recent outbreak of Covid-19, most educators had to switch to digital-based instruction, implemented through *emergency remote teaching* (Hodges et al., 2020). In many cases, this provided merely access to instruction without real consideration of the specificities of online learning (Hodges et al., 2020; Lipscomb & Tate, 2020). A better understanding of teachers' reasoning would help even practitioners in facing new and complex instructional contexts (Boha & Rens, 2018; Crawford et al., 2020).

Identifying individual factors that shape teachers' reasoning has proved challenging (Cox & Laferriere, 2019; Lloyd, 2019; Loughran, 2019), and developing a comprehensive understanding of the interconnections between those factors, that impact how teachers make pedagogical decisions and implement them in their practice, remains more than ever elusive (Trevisan, 2019; Phillips et al., 2019). Loughran (2019) highlights that many past investigations of teachers' decision-making examine *what* and *how* teachers do what they do. He argues, however, that to understand better teachers' reasoning, understanding the *why* behind the decisions "is crucially important" (Loughran, 2019, p. 526). In support of this argument, this paper explores the multifaceted nature of pedagogical decision-making in technology-rich contexts. First, we will introduce three main lenses so far used to investigate teacher pedagogical decision-making's *what* and *how*: knowledge; skills, practices, and epistemologies; and orientations. Then, we introduce a new way of considering jointly the *what*, *how* and *why* in relation to teachers' pedagogical decision-making: Epistemic Frame Theory. Finally, some evidence from empirical research carried out applying such epistemic framework perspective will be introduced. Overall, the paper aims to contribute to the research community by offering a systemic perspective to the study of teachers' decision-making process, to the use of researchers and policy makers.

1. Past explorations of teachers' pedagogical decision-making

1.1 Cognitive perspective: teacher knowledge for pedagogical reasoning

Research efforts to better understand teacher decision-making date back many decades, building upon Schön's concepts of teacher reflection in- and on- practice (1983) and Gudmundsdöttir's work (1988) connecting pedagogical reasoning to teachers' professional, content and learner knowledge. Many of these past investigations relied on a cognitive perspective connecting decision-making with teachers' knowledge. One influential model was proposed by Shulman in 1987, in the attempt to "unpack the unseen aspects of practice" of teachers (Loughran et al., 2016, p. 368). Shulman's Model of Pedagogical Reasoning and Action (MPR&A) describes a six-step, dynamic, cognitive process performed by teachers in order to teach

(Trevisan, 2019). At its core is the notion that pedagogical reasoning is:

«. . . a starting point for unpacking the unseen aspects of practice and as a way of beginning to make clear that an expert pedagogue (Berliner, 1986) is a skillful and thoughtful practitioner who is informed by a knowledge base and responsive to the diversity of learning needs, demands and expectations inherent in a given teaching-learning experience» (Loughran et al., 2016, p. 388).

While articulating the steps of *comprehension*, *transformation, instruction, evaluation, reflection,* and finally *new comprehension*[1] as illustrated in Table 1, Shulman's MPR&A also posits that the shift from one stage to another is not rigid but dynamic. However, Shulman (1987) considered it vital for teachers to understand, recognize, and work through each part of such cycle. In Shulman's view, while the different steps may be singularly shortened or extended, it is crucial for a teacher to be able to engage in these processes.

Author(s)	Name of the model	Phases/steps	Further researches applying this model
Shulman (1987)	Model of Pedagogical Reasoning and Action (MPR&A)	Comprehension Transformation Instruction Evaluation Reflection New comprehension	Graham (2011) James & Scharmann (2007) Nilsson (2009) Peterson & Treagust (1992) Richardson (2009)
Webb (2002, 2010)	Model of Pedagogical Reasoning	Comprehension Transformation Instruction Evaluation Reflection	
Starkey (2010)	Model of Pedagogical Reasoning and Action for the Digital Age	Comprehension Enabling connections Teaching and learning Reflection New comprehension	Niess & Gillow-Wiles (2017)
Smart (2016)	Technological pedagogical reasoning	Knowledge base Comprehension Transformation Instruction Evaluation (Reflection and New comprehension as transversal processes)	Smart et al. (2015)

Table 1: Theoretical models for teachers' reasoning processes (source: Trevisan, 2019)

Although MPR&A remains highly relevant when talking about teachers' pedagogical reasoning, several aspects of Shulman's model have been questioned over the years (see Trevisan, 2019). Critiques include questions over (a) inconsistencies when defining the overall steps, which moved from seven to six steps (Shulman, 1987; Wilson et al., 1987); (b) differing descriptions of stages (see Smart, 2016); (c) blurry boundaries between stages (see Smart, 2016); and (d) challenges in connecting the different stages (Nilsson, 2009). In addition, increased adoption of digital technologies in educational contexts has led some to question whether Shulman's MPR&A requires a whole new approach (Webb, 2002; Starkey, 2010; Smart, 2016; Niess & Gillow-Wiles, 2017; Harris & Phillips, 2018).

Webb (2002) described a modified version of Shulman's MPR&A for technology-related pedagogical reasoning (see Table 1). She suggested that teaching and learning are less separable in the digital age than they might have been before: technology could allow learners to become autonomous and metacognitive, while teaching could become a more collaborative endeavour. Webb (2002) included non-rational elements as ideas, beliefs and values «that teachers use to prioritize and select from their knowledge base to justify their decisions» (p. 241) which Shulman himself recognized as missing in his initial MPR&A (2015). In Webb's Model of Pedagogical Reasoning (2002), *new comprehension* is considered as a data flow from *re-*

1 For a detailed explanation of each of these stages, please see Shulman (1987) pp. 14-19.

flection to *comprehension* (Smart, 2016), and the pupils and their learning processes with technologies are included as further elements (Webb, 2010). The author also suggests that teachers could foster learning by acknowledging, sharing, and enacting the specific technological affordances with their pupils (see Trevisan, 2019).

Louise Starkey also revised MPR&A in 2010. Her Model for Pedagogical Reasoning and Action for the Digital Age (MPR&A-DA, see Table 1) was based on observations and think-alouds of six beginning teachers' pedagogical choices. The findings revealed a general alignment between participants' pedagogical reasoning and Shulman's original interpretation (Starkey, 2010). However, Starkey's investigation also found that participants' instructional decisions were grounded in «learning theories predating the digital era … [and] this was limiting their ability to use pedagogical content knowledge innovatively» (Starkey, 2010, p.243). Consequently, Starkey (2010) embraced a Connectivist approach to learning (Siemens, 2005) in formulating her model, which implies:

1. *Comprehension* of the content: detailed in substantive and syntactic knowledge of the discipline.
2. *Enabling connections* between pupils' prior and new knowledge, and among individuals, with the aim of exploring and probing content knowledge in a personalized learning perspective.
3. *Teaching and learning*, comprising the knowledge of the context, evaluation processes, feedback strategies and on-the-spot modifications of teaching practices when necessary.
4. *Reflection*, as critic analysis and review of teachers' decisions.
5. *New comprehension* about pupils, teaching processes and the content.

Starkey (2010) emphasizes the idea that students build knowledge through "connections in an open and flexible curriculum" (p. 243), while she attributes to MPR&A a more transmissive teaching approach. The author argues that teachers «in a connectivist learning environment would transform existing knowledge as outlined in Shulman's model, but would also encourage students to go beyond the teacher's existing knowledge base by making or enabling connections» (Starkey, 2010, p. 241).

In 2017, Niess and Gillow-Wiles used Starkey's MPR&A-DA for an in-depth study on masters' level mathematic teachers. They observed participants using a systemic combination of multiple technologies (Niess & Gillow-Wiles, 2017), arguing that they must be «holistically integrated to become more than a simple combination of technologies» (p. 82). According to the authors, this would help supporting teachers' professional knowledge, skills, and reasoning for technology integration. In their study, a strong consensus emerged about the value of learner-centered instruction, with the teacher as facilitator or guide, crossing constructivist and connectivist approaches. Finally, the authors suggest that incorporating a system pedagogical approach, especially in teacher education contexts, would involve: (a) integrating instructional strategies and technologies; (b) integrating multiple technologies through active student engagement; and (c) preferring learner-centred instruction approaches (Niess & Gillow-Wiles, 2017).

In an exploration of teachers' pedagogical reasoning, Smart (2016; Smart et al., 2015) observed a shift in Shulman's original steps due to curriculum changes and changes in roles of learners and teachers as a result of the increasing adoption of educational technologies. She found that during *comprehension* teachers would access a variety of materials through technologies arguably unimaginable when Shulman conceptualised his MPR&A. Teachers participating in Smart's research would re-define their content to align curriculum guidelines with their pupils' interests, taking into account also the availability of technologies to best utilize the "technological culture" of their educational context (Smart et al., 2015). During *transformation*, participants would focus on «identifying the value of digital technologies to transform the content» (Smart, 2016, p. 284), and they would perform a transform-during-teaching action when checking for pupils' content (mis)understandings during instruction (see Trevisan, 2019). Smart highlighted how «digital technologies changed the dynamics of the classroom where participating teachers were able to focus on checking for student understanding individually instead of directing from the front of the room» (Smart, 2016, p. 288). Even *evaluation* was deeply modified by technology, especially in terms of instruments used, while *reflection* was observed to happen during all the different stages, especially when participants «had to deviate […] changing their teaching from what they had planned» (Smart, 2016, p. 292). Once again, technologies emerged particularly in *reflection* when teachers reported a major difference in using digital technologies for teaching or for learning. Finally, in *new comprehension,* the author found teachers to share new understandings of content, pupils, and pedagogy, as foreseen by Shulman (1987), but she noticed a strong focus on the use of new digital technologies.

Smart proposed a Technological Pedagogical Reasoning model (TPR, see Table 1), based also on MPR&A issues about stage boundaries blurring and the redefinition of curriculum material access through technologies. In her TPR model, she comprises the main steps of MPR&A (i.e. *comprehension, transformation, instruction, evaluation*), but deems *reflection* and *new comprehension* as transversal processes, adding a knowledge base modelled after Shulman's description (1987) with the addition of Technological, Pedagogical and Content Knowledge (TPACK - Koehler & Mishra, 2008).

Smart and colleagues (2015) researched TPR and the factors influencing its development among Australian teachers. They observed experienced teachers (digital pedagogy leaders in their schools) and used the a) SMART Classrooms Professional Development Framework (SCPDF – Smart et al., 2015) which provided a self-assessment mechanism for teachers' attitudes and practices with technology; and b) a Digital Pedagogical License (DPL) portfolio. The authors found traces of the different TPR processes, with particular reference to *new comprehension* related to technology use (Smart et al., 2015; Trevisan, 2019).

Models of teacher decision making summarised in Table 1 are almost entirely based on cognitive processes. Webb's (2002) inclusion of ideas, values and beliefs marks a notable addition to conceptualisations of teacher decision-making. Other studies indicate that teachers make pedagogical decisions based on a range of factors, including but not limited to their knowledge, as we will see below.

1.2 The importance of skills and practices

To better understand reasoning, past research has focused also on the skills and practices of educators in different contexts, including effective literacy teachers (Wray et al., 2000), mathematics teachers (McDonough & Clarke, 2003), and science teachers (Bartholomew et al., 2004). While these studies contribute to the understanding of teachers' classroom skills and practices, it quickly becomes clear that what is considered 'effective' is highly contextually dependent. Teachers' underlying epistemologies contribute substantially to the determination of which skills and practices constitute effective teaching. For example, it is reasonable for Chemistry teachers to be interested in the development of skills that allow students to cognitively break down or atomize materials to their constituent components. A Biology teacher, on the other hand, is more likely to be interested in having their students think in 'big picture' ideas or in systems (Bartholomew et al., 2004).

Teachers develop knowledge, reasoning, skills, and practices concurrently, but we do not yet have a comprehensive understanding of the nature of such connections or how they impact pedagogical decisions (see for example Angeli & Valanides, 2018). To understand better both the theory and the practice of teaching, it is necessary to examine how teachers' skills and knowledge, their practices, the perceived educational affordances of technology, as well as their pedagogical reasoning process intertwine (Feng & Hew, 2005; Smart, 2016; Harris & Phillips, 2018).

1.3 Orientations: dispositions that underpin decisions

In addition to knowledge and skills, practices and epistemologies, teachers' attitudes have received much attention in research (Seufert et al., 2021). Empirical investigations illustrate the impact of the role of beliefs on a variety of teacher decisions (Munby, 1982; Rizhaupt et al., 2017; Christensen & Knezek, 2018) including the integration of technology (Ertmer, 2005; Ottenbreit-Leftwich et al., 2018).

Teaching and learning beliefs have been widely recognized to function as filters or enablers of behaviour, particularly with regard to teachers' technology integration (Ertmer, 2005; Crompton, 2015; Niess & Gillow-Wiles, 2017). Pedagogical beliefs, or «teachers' educational beliefs about teaching and learning» (Ertmer, 2005, p. 28), are usually observed in a spectrum from teacher-centred, traditional beliefs, to student-centred, constructivist ones (Ertmer & Ottenbreit-Leftwich, 2010; Kim, 2016; Knezek & Christensen, 2018). Several studies found correlations between the beliefs' orientation and the educational practices enacted, especially regarding technology integration (see for example, Christensen & Knezek, 2018; Ottenbreit-Leftwich et al., 2018; Trevisan, 2019).

Moreover, openness or resistance to change, self-efficacy and teachers' attitudes are found to play an important role in determining teachers' (technology integrated) actions (Ottenbreit-Leftwich et al., 2018). Openness to change refers to the «willingness to try new instructional innovations and take risks in teaching» (Baylor & Ritchie, 2002, p. 399), committing time and effort in a risk-taking attitude to the task (Vannatta & Fordham, 2004). Researches have proven that openness to change has important relations, e.g., with ICT frequency of use in teaching practices (Ottenbreit-Leftwich et al., 2018), and with teachers' abilities to integrate ICT (Knezek & Christensen, 2018; Trevisan, 2019). The contrary is also true, as studies have found that teachers' resistance to change may be based on pedagogical beliefs and manifest in their reluctance to use technological tools (Kimmons & Hall, 2016). Bandura's Social Development Theory (1986) explains self-efficacy as a belief in one's ability to perform a particular task (Gencturk et al., 2010, p. 286). As they engage preferably in activities in which they feel more prone to success (Pajares & Schunk, 2002), teachers' self-efficacy proves to be a strong predictor of both intentions and realization of technology integration (Abbitt, 2011), as well as its efficacy (Ertmer, 2005; Hew & Brush, 2007; Koh & Frick, 2009). Finally, person's attitude is interpreted as an affective evaluation of a behaviour, based on the beliefs that they hold (Fishbein & Ajzen, 1975). This is also referred to as a *value belief* (Ertmer & Ottenbreit-Leftwich, 2010) or a subject(ive) norm belief (Hazzan, 2003). Teachers' attitudes are important predictors of behaviours and intentions, influencing self-efficacy as well as adoption of technology (Knezek & Christensen, 2018; Ottenbreit-Leftwich et al., 2018).

When observing teachers' beliefs, attitudes and practices together, research findings are twofold: some suggest close alignment among them (Ertmer et al., 2012; Kim et al., 2013; Phillips et al., 2017), others notice a gap between beliefs and practices (Chai, 2010; Heitink et al., 2016; Niederhauser & Lindstrom, 2018). This mismatch could be referred back to the filter / barrier action of beliefs and attitudes: for example, Kim and colleagues (2013) indicated how teachers' beliefs can predict, reflect, but also hinder and interfere with technology integration. In addition, this belief-action gap might be explained in part by the intrinsic structure of belief systems described in many theories. Thagard's (2000) *Coherence Theory of Justifications* states that beliefs emerge and develop in a logic of coherence and support with pre-existent beliefs (see also Kim, 2016). Here, when a contradiction is noticed, individuals will adjust their system of beliefs to avoid overt contradictions (Leatham, 2006). This perspective could well explain how general beliefs (e.g. pedagogical ones) could be reflected in specific technology integration beliefs, and thus in practices (Ertmer, 2005; Kim et al., 2013). On the other hand, Green (1971) suggested that beliefs develop in relatively autonomous clusters that allow conflicting beliefs, if in different clusters (e.g. beliefs about teaching and learning could not be related, in an individual's system of beliefs, with technological ones). This could account for technology integration practices that do not seem to reflect teachers' declared beliefs (Heitink et al., 2016; Niederhauser & Lindstrom, 2018). When it comes specifically to the use of technology in education, other models examine the issue differently. *Technology Acceptance Model* (TAM - Davis et al., 1989) was among the first attempts to examine technology acceptance behaviours with respect to beliefs about perceived ease of use, usefulness, attitudes, and intention to use it. More recently, the *Will Skill Tool Pedagogy* (WSTP) model indicates how teachers' knowledge (in *Skill* and *Pedagogy*), along with non-cognitive aspects (e.g. motivation and attitudes in *Will*), may account for up to 90% of teachers' technology integration practices (Knezek & Christensen, 2016; see also Niederhauser & Lindstrom, 2018).

Niederhauser and Perkmen (2008) grouped belief-related terms under the umbrella of *dispositions*, as an array of personal characteristics contributing to decision-making and behaviour. In a more recent study, Allen and colleagues (2014) see dispositions as «a person's core attitudes, values and beliefs demonstrated through both verbal and non-verbal behaviours as one interacts with oneself, others, one's purpose, and frames of reference»(p. 2). Schoenfeld (2011) recognizes that each of these terms offers insights into what teachers do, and he uses the term *orientations* to encompass all of these often-overlapping constructs.

There is difficulty in determining how single dispositions or orientations influence teachers' actions and their use of technology (Ottenbreit-Leftwich et al., 2018). The focus of most research has been on the separate influences of these constructs on teacher decision-making, to reveal its *what* and *how*. However, we contend that by studying the interconnections of the factors that underlie pedagogical practices, we can better understand the complex reasons *why* teachers make their decisions. To understand better teachers' decision-making, we argue that rather than quantifying individual factors we should consider teachers' epistemology, skills, values, and knowledge – taken as a collective in an *epistemic frame* (Shaffer, 2006).

2. Epistemic frame theory: a new perspective on teachers' decision-making

Shaffer (2006) proposed the notion of *Epistemic Frame Theory* to highlight the associations between skills, knowledge, and other (non)cognitive attributes that are shared by individuals with similar understandings, approaches to learning, and solving problems. The notion of *frame* is based on Goffman's work (1974), indicating that people use a set of organization principles (i.e. *frames*) that structure their perception of both what is happening and what is important to pay attention to during a specific activity. Throughout everyday experiences, Goffman argues, people filter information and build frames that organize an understanding of the most important details about the current situation to plan future actions. The way information is structured depends on a variety of factors, including the person and the activity, as well as broader contextual factors and interactions with other people. Thus, frames can be seen as the collection of both individual and social norms, values, and actions that shape how we see the world (Goffman, 1974). Shaffer (2012; 2017) developed Goffman's concept of frames by exploring the process of how individuals gain knowledge. In this perspective, *epistemic frames* reveal how certain groups of people think, considering that epistemology «is a particular way of thinking about or justifying actions, of structuring valid claims. Epistemology tells you the rules you are supposed to use in deciding whether something is true» (Shaffer, 2006, p. 32).

According to *Epistemic Frame Theory*, certain groups (such as teachers) share a systematic relationship between skills, knowledge, identity, and values that shapes their practices. Moreover, Shaffer (2006) highlights that epistemology is domain-specific, challenging the "straightforward and simple" perception of teaching (Loughran, 2013). To be an effective teacher, one must not only develop particular, discipline-specific ways to justify actions and structure valid claims about content knowledge, but also understand the «intellectual and historical justification for the traditional disciplines» (Shaffer, 2006, p. 33). Teachers have to think in a particular way to make decisions, and this way is determined partly by the discipline they are teaching as this discipline has its own set of rules for structuring valid claims, justifying actions, and establishing truth. Nevertheless, considering only the epistemological underpinnings of the content being taught will only enable a partial understanding of why teachers make certain decisions. In agreement with Shaffer, we argue that it is essential to examine a teacher's skills, knowledge, and dispositions or orientations alongside their epistemologies. However, it is a challenge for researchers to connect these cognitive and non-cognitive elements in a coordinated manner.

2.1 The multifaceted nature of teacher decision-making

Teachers' decision-making can be understood by looking at what makes them unique as a group and it is therefore important to see the *culture* shared by that specific community of practitioners. Gee (2001) describes learning a practice as understanding the «talking, listening, writing, reading, acting, interacting, believing, valuing, and feeling (and using various objects, symbols, images, tools, and technologies)» (p. 719) of a particular community. He labelled this learning of a practice as learning the *discourse* of that practice, seeing learning as a form of enculturation (Oshima & Shaffer, 2021). As Shaffer (2017) points out, learning the *discourse* of teachers' practice occurs by developing and transforming one's identity as teachers with the help of others: learning a discourse means becoming part of a *community of practice*, a group of people who think and solve problems in the same way (i.e. who share the same culture, and hence frames and epistemologies – see Oshima & Shaffer, 2021; Phillips, 2016). Nevertheless, while knowing the lexicon of a community (the *codes* to the discourse) is crucial, it is not enough. The process of enculturation in a community of practice «entails understanding *how codes are systematically related to one another within some cultural context*» (emphasis in original – Oshima & Shaffer, 2021, p. 5). Understanding teachers' unique discourse codes and the connections among them would shed light on the epistemic frames of that community.

As we argue that links among the components of teachers' epistemic frames are critical, we advocate for research methodologies that can explicitly model such connections. Two studies will now be introduced, as examples of a systemic approach to the investigation of teachers' decision-making. The first considers specific disciplinary knowledge (epistemics) as the base of teachers' frames of action, employing Quantitative Ethnography to understand teachers' *discourse.* The second explores the connections among the different factors shaping teachers' pedagogical reasoning for technology integration through Epistemic Network Analysis (ENA). ENA is a «method for analysing epistemic frames by creating a network mode that quantifies how codes are connected one another in discourse» (Oshima & Shaffer, 2021, p. 5).

2.2 Two studies: opportunities offered through ENA and Quantitative Ethnography

Phillips and colleagues (2019) used a Quantitative Ethnography approach to investigate the relationship between disciplinary knowledge and various forms of teacher decision making. This pilot study analysed the lesson plans of six teachers who worked in a specialist Mathematics, Science and Technology secondary school in Melbourne, Australia. This school only enrols students in their final three years of secondary schooling. A pair of teachers from each of the specialist areas within the school volunteered to participate in the study, and each of these pairs co-taught classes with approximately 50 students typically aged around 16-years. The six participants provided the data for this investigation in the form of 45 lesson plans for the first unit to be taught in the academic year 2018-19. This data was coded using the NVivo12 software for evidence of teacher knowledge (based on Shulman's knowledge base for teaching -1987) and Shulman's teacher decision-making framework (MPR&A - Shulman, 1987, Table 1). Then, the researchers examined the relationship among the coded forms of knowledge and MPR&A through a Quantitative Ethnography approach (Shaffer, 2017). Quantitative ethnography aims to use «Big Data to help us transform it into Big Understanding» (Shaffer, 2017, p. 398). An inherent part of this process is taking etic representations (namely, researchers' understanding of the phenomenon through codes), and generate emic understandings through close collaboration with the participants (namely, sharing the codes with the participants to allow for a reinterpretation of the phenomenon). Thus, the researchers used Epistemic Network Analysis (ENA) (Shaffer et al., 2009; Oshima & Shaffer, 2021), as a tool which allows for Quantitative Ethnographic explorations and enables the visualization of the discourse of a community of practice.

The results from ENA analysis of teachers' lesson plans revealed substantially different connections among knowledge forms and components of the MPR&A for teachers with differing epistemological backgrounds. For example, the Mathematics teachers showed greater co-occurrences of reflection, evaluation, and transformation of content knowledge, than the Science teachers – whose lesson plans did not show any evidence of such co-occurrences. The nature of the disciplinary domain, on the other hand, appears regularly in Science teachers' lesson plans (co-occurring with four other MPR&A stages and knowledge forms), but not so in Mathematics teachers' lesson plans. Most strikingly, the IT teachers' lesson plans showed comparatively fewer co-occurrences between disciplinary domain, knowledge forms and stages of MPR&A, and yet had the most codes represented of all three domains. Through ENA, these co-occurrences were examined further, resulting in three-dimensional representations of teachers' epistemic frames' components and their relationships.

Following the Quantitative Ethnographic approach, Phillips and colleagues (2021) shared the intermediate results (i.e. etic representations) with each of the teaching teams, who confirmed that many of the ENA representations reflected their tacit understandings of their practices (i.e. emic representations). Examining the representation of their lesson plans, one of the science teachers commented that «content is kind of in a way the driving force, as a central part of what we have to do, so it makes sense that content would be such a central part of what's in there». The discussion between the Mathematics teachers also confirmed that some of the ENA representations reflected conceptions of their shared practice:

> Mathematics teacher 1: The other thing with maths is because [pupils] all come in from different schools. At least the first half of the year is really trying to get everyone at the same level, so bringing up the students who might have lower skills up to that. So, I guess, the less connection between the PCK [pedagogical content knowledge] and the learners can be explained that we want to get everyone

> to the same point so that they're then ready to move into VCE [the Victorian Certificate of Education which is completed in the final two years of secondary schooling] which I guess makes sense.
> Mathematics teacher 2: Which is probably why the faint [connections] are to the learners because we don't know enough about them, we haven't taught them before, particularly Year-10 it's our first year.

These examples illustrate deep emic understandings of the context in which the lesson plans have been developed. The comments of the two mathematics teachers reveal that the need to ensure that all students (Year 10) have comparable content knowledge trumps the desire to develop particular approaches to address particular students at particular times and for particular purposes (that is, the essence of PCK). The two IT teachers were initially surprised by the ENA representation of their lesson plans, commenting on the lack of connections between knowledge forms and decision-making processes (MPR&A). When unpacking the representation, they highlighted once more the influence of the context in framing experiences and conceptualizations. In the particular school where the study took place, the several Mathematics and Science teachers employed interact daily with one another and other teaching partners. As a result of such continuous dialogue with people holding different dispositions and teaching approaches, these teachers produced more detailed lesson plans. In contrast, only two IT teachers are employed in said school, and as they dialogue mainly and only with each other, they came to share the same understandings and dispositions, thus producing lower-detailed lesson plans.

The importance of presenting etic ENA representations to the teachers to develop deeper emic understandings proved to be a vital part of this quantitative ethnographic exploration of teachers' knowledge and decision-making. Despite the small sample size of teachers involved in this project (n=6), this study provides what we believe is one of the first Quantitative Ethnographic accounts of the co-occurrence of teachers' knowledge forms and MPR&A stages. With the ENA representations introduced in this paper, researchers may develop new insights into teacher knowledge and decision making that challenge the homogenous nature of these two frameworks evoked by many of Shulman's publications.

ENA and pedagogical reasoning for technological integration

The second study we report engaged 288 student-teachers across three European countries, to investigate their decision-making processes during technology-integrated lesson planning tasks (Trevisan, 2019). Factors considered in the study were student-teachers' knowledge (TPCK – Angeli & Valanides, 2009); dispositions (Niederhauser & Lindstrom, 2018); perceived technological affordances (practices); and pedagogical reasoning (MPR&A and its modification MPR&A-DA by Starkey, 2010). These factors were investigated through multiple means for data collection: observation, pre-/post-questionnaires, documentation, and two rounds of focused interviews (Trevisan, 2019). Student-teachers from three European countries (N=288) were engaged in the study when ideating technology-enhanced lesson plans, during their initial education. The semi-structured interviews (n=36) focused on the realization of said task proved particularly effective to access student-teachers' decision-making processes, offering rich *discourse* information. Data was processed through ATLAS.TI for coding and co-occurrences, and consequentially run through ENA for further analyses on the systemic organization of the different factors considered.

Once again, ENA posed as valuable instrument to visualize and measure both the components of participants' decision-making processes, and their connections. Results suggested the complexity of the reasoning underpinning the ideation of a lesson plan (see also Trevisan & De Rossi, 2020). They agreed with Stefaniak and colleagues' (et al., 2021) work, highlighting how (future) teachers employ dynamic decision-making processes balancing "environmental conditions impacting the learning environment with their learners' needs and predispositions that they bring to the learning experience" (p.4). Technological-pedagogical dispositions were found to align with elicited reasoning steps as per MPR&A(-DA), with subsequent perception of specific technological affordances in practice (as suggested by Chai, 2010; Ertmer et al., 2012; Kim et al, 2013; Dennen et al., 2018; Stefaniak et al., 2021). Similarly, participants' consideration of work contexts was strongly related to their identification of appropriate learning goals and methods, which in turn altered their teacher identities. Participants' discourse frameworks, as displayed by ENA, showed country-specific differences, with varying focuses on pupils' needs, teacher knowledge, or the different roles subjects play in educational relationships (Trevisan, 2019). The research findings would confirm Shulman's MPR&A (1987) relevance still today, as the inclusion of its technological declination through Starkey's MPR&A-DA (2010) did not prove any technology-specific pedagogical paradigm (see also Harris & Phillips, 2018). Moreover, the emerging framework of discourse displays once again the multifaceted complexity of (student-)teachers' decision-making process, both shaping and being moulded by professional knowledge, dispositions, skills, contextual practices and technological tools.

3. Conclusions

Contrasting the perception of the casual observer (Loughran, 2013), teaching is far from straightforward. It implies complex, multifaceted professional knowledge (Koehler & Mishra, 2005), realized in dynamic ill-defined contexts (Harris & Hofer, 2011) in which different social subsystems concur to shape a peculiar wisdom of practice (Shulman, 1986, p. 11). In the present paper, we first present various models for teachers' decision-making processes (i.e. pedagogical reasoning) that are closely connected to the definition of teachers' professional knowledge (Shulman, 1987). Later, issues of practices, contexts, and non-cognitive components (i.e. dispositions and orientations) were introduced to better approach the implicit decisional phenomenon underpinning teaching practices.

We argue that to understand fully the multifaceted nature of teaching, especially in the complex digital age, a more systemic perspective is needed. We thus introduced epistemic frame theory as a lens to examine associations between teachers' knowledge and skills, (non)cognitive components, and reasoning within their communities of practice. Also presented were two studies that examined teacher decision-making processes as complex systems. We argue that Epistemic Network Analysis (ENA) helps make visible and measurable both the different components of teachers' decision-making process, as well as how they are interconnected (see also Oshima & Shaffer, 2021). ENA seems to hold the potential to provide greater insights into the multifaceted nature of teaching, rather than focusing exclusively on single elements at a time.

The authors recommend that teacher education researchers explore the possibilities enabled by Epistemic Frame Theory and Quantitative Ethnography for exploring teachers' practices and decision-making processes using a systemic approach to the matter. The implications could also extend to teacher training programs, as they could take a multifaceted approach to developing teacher competence.

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