Uncovering patterns and (dis)similarities of pre-service teachers through Epistemic Network Analysis

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Abstract: In an increasingly complex world, initial teacher education is called to enact nuanced pedagogies that are empirically based, practically oriented, and tailored to the specificities of their students. This paper reports on the ways Epistemic Frame Theory (EFT) and Epistemic Network Analysis (ENA), may help teacher educators respond to such challenges. In 2022, secondary school STEM pre-service teachers in Australia and Italy were engaged in virtual school placement programs in which they designed and implemented online lessons, in pairs. Data generated through interviews conducted prior to the beginning of the program highlight these ways pre-service teachers display knowledge, skills, values and overall epistemologies. We use these findings as empirical evidence to tailor their initial education through the virtual school program. Hence, EFT and ENA are used as methods and techniques to visualize and interpret the findings to the service of an empirically-based, practically oriented teacher education.

Keywords: teacher education, virtual schools, epistemic frame theory, epistemic network analysis, physics teachers, technology integration
Introduction

Teacher education is a difficult task (Masterson & Gatti, 2022) that, according to la Velle (2020) is becoming “increasingly complex” (p. 2). In an increasingly complex world, pre-service teachers are entering initial teacher education (ITE) programs with increasingly different beliefs, skills, knowledge, values, identities and epistemologies. In contrast to earlier designs of ITE programs that were “characterised by a strong emphasis on theory that was ‘transferred’ to teachers in the form of lectures on psychology, sociology, and general education” (Korthagen, Loughran & Russell, 2006, p. 1021), today they are challenged to “arrive at a pedagogy of teacher education that is both empirically based and practically oriented” (Korthagen, Loughran & Russell, 2006, p. 1022), tailored to the needs of individual pre-service teachers.

The challenge posed by Korthagen, Loughran & Russell (2006) has been recently exacerbated in a world in which ITE had to face a global pandemic, geo-political instability and socio-cultural challenges to the effectiveness of K-12 teachers. As Juárez & Hayes (2015) claim, “the ‘big house’ of teacher education is on fire and burning brightly” (p. 318). Despite the licking of flames, we have identified a unique opportunity for ITE, “one that arises not in spite of sociopolitical upheaval but precisely because of it” (Masterson & Gatti, 2022, p. 2). The opportunity examined in this paper is one which was initially proposed by an Australian university in an effort to address a lack of possibilities for secondary school pre-service teachers to complete their school placement due to the COVID-19 pandemic restrictions.

In an effort to provide pre-service teachers with chances to practice their teaching with students, faculty established a ‘virtual school’ which offered free online revision classes for students studying Chemistry or Physics in their final year of high school. The design of this virtual school allowed pre-service teachers and faculty staff to address a number of Korthagen, Loughran and Russell’s (2006) principles for ITE: pairs of pre-service teachers, supervised by a faculty member, designed and implemented the lessons online. Lessons were interactive, with students engaging with different and multiple learning opportunities and pre-service teachers actively checking for individual student understanding. Following each virtual teaching session, the assigned faculty member provided the pair of pre-service teachers with an opportunity to reflect on their doing.

The effectiveness of this virtual school program saw it continue in 2021 and expand to offer a full suite of STEM revision opportunities in 2022. Further, a similar virtual school was established at an Italian university and funding provided from each institution allowed one faculty member from Australia to travel to Italy and assist the local faculty establish practices and procedures to enable Physics revision classes to be conducted in the Summer of 2022.

This paper explores data generated by pre-service teachers involved in these two virtual school programs during 2022 through the theoretical lens of epistemic frame theory (EFT) to uncover individual pre-service teacher’s skills, knowledge, identities, values and epistemologies. Epistemic Network Analysis (ENA) will be then introduced as a method to scientifically investigate and visualize pre-service teachers’ characteristics, to the service of ITE programs for the tailoring of instruction. We claim that this data and initial analysis may provide a proof of concept response which illustrates a way in which we might “arrive at a pedagogy of teacher education that is both empirically based and practically oriented” (Korthagen, Loughran & Russell, 2006, p. 1022).

Theoretical foundation

Literature has revealed that effective (online) teachers require a particular combination of skills, knowledge, values, identity and epistemology - collectively these can be understood as elements of an epistemic frame (Shaffer, 2006a). To dive deeper into how people learn to think, Shaffer (2006a) proposed EFT to describe the pattern of associations among skills, knowledge, and other cognitive elements that characterize groups of people who share similar ways of framing, investigating, and solving complex problems. The concept of a frame is from Erving Goffman (1974) who argued that people use a set of organizational principles, i.e. frames, that structure our perception of what is happening and what is important during an activity. Frames are therefore the collections of both individual and social norms, values, and actions that shape how we see the world.

Shaffer (2012, 2017) builds on Goffman’s frame analysis by considering what it means for a person to know something. In this way, epistemic frames consider how certain groups of people think. EFT suggests that in specific
communities there is a systematic pattern of relationships among skills, knowledge, identity, values, and epistemology that form the epistemic frame for that community. Moreover, another critical component is that of epistemology. EFT is grounded in Perkins’ (1992) description of epistemology which he described as “knowledge and know-how concerning justification and explanation” (p. 85). Shaffer (2006) extends this notion claiming 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” (p. 32).

Importantly, Shaffer notes that “epistemology in this sense is domain-specific: Mathematicians make different kinds of arguments than historians do” (2006, p. 32). Pre-service teachers are therefore developing particular, discipline-based ways of justifying their actions and structuring valid claims about content knowledge, while also developing understandings of the “intellectual and historical justification for the traditional disciplines” (Shaffer, 2006, p. 33). Physics education research has highlighted the role of personal epistemologies and epistemic framing for making sense of physics, but also as a resource for teachers to interpret students’ learning (Redish, 2004; Elby & Hammer, 2010). Differences in framing between people with a mathematics or physics background have also been discussed (Redish & Kuo, 2015).

Literature has explored a range of roles and competencies that are advantageous for those working as online educators (for example, see: Boettcher & Conrad, 2021; Cleveland-Innes, 2019; Morris & Finnegan, 2008; O'Brien & Fuller, 2018; Palloff & Pratt, 2003, 2007; Young et al., 2001). Arguably, each of these roles and competencies is underpinned by combinations of the elements of an epistemic frame. When teachers discuss their work in relation to delivering content to students, they are discussing pedagogical skills that reflect values about what is epistemologically important in both teaching and learning that specific content. This provides insights into how teachers understand their identity within a school-based Community of Practice when developing or delivering knowledge about certain epistemologically important content. Similar considerations can be made for each of the nine roles and competencies derived from the literature which are outlined hereafter together with a description of each and examples of supporting literature. The nine (pre-service) teacher roles and competencies are: 1. Teacher as content delivered (Aydin, 2005; Boettcher & Conrad, 2021; Goodyear et al., 2001 and more); 2. Teacher as relationship manager (Bailey & Card, 2009; Bawane & Specter, 2009; Cleveland-Innes, 2019 and more); 3. Teacher as technology user (Álvarez et al. 2009; Bigatel et al. 2012; Farmer and Ramsdale 2016 and more); 4. Teacher as workload manager (Coppola et al., 2002; Goodyear et al., 2001; Varvel, 2007 and more); 5. Teacher as designer (Farmer & Ramsdale, 2016; Goodyear et al., 2001; Morris & Finnegan, 2008 and more); 6. Teacher as critic (Abdous, 2011; Bawane & Specter, 2009; Cleveland-Innes, 2019 and more); 7. Teacher as innovator (Cleveland-Innes, 2019; Goodyear et al., 2001; Williams, 2003 and more); 8. Teacher as leader (O'Brien & Fuller, 2018; Palloff & Pratt, 2003; Young et al., 2001 and more); 9. Teacher as student expert (Boettcher & Conrad, 2021; Cleveland-Innes, 2019; Goodyear et al., 2001 and more).

The study

This paper reports on the initial data and analysis of a wider study on secondary school STEM pre-service teachers’ epistemic frames when engaging in online teaching. That wider study includes a school placement for secondary school STEM pre-service teachers’ within the Virtual School program over the course of eight months throughout 2022. During this time period, the paired pre-service teachers had to plan, deliver and reflect together on online revision classes for high school students who volunteered to participate.

This paper focuses on the participant pre-service teachers’ epistemic frames before the beginning of the Virtual School program, answering the following research question: How might EFT and ENA inform a pedagogy of teacher education that is both empirically based and practically oriented?

Participants

The sampling of the wider study followed a convenience strategy: participants were invited by the researchers of the study at the two leading universities, one in Italy and one in Australia. In Italy, the implementation of secondary school initial teacher education has undergone several rearrangements since the structured, post-degree programme that existed in the 2000s has been discontinued. The current arrangement requires aspiring secondary school teachers to earn a master's degree in the teaching discipline (or a closely related discipline) and additionally acquire 24 credits in the anthropo-psycho-pedagogical area. Hence, Italian participants were recruited among the students enrolled in the
courses in "Teaching and Learning Physics" and "Experiments in Physics for Teaching" (Master's degree courses in Physics and Mathematics, respectively) in 2020-2022. Eight participants (six females and two males, aged between 20 and 30) volunteered and four of them were students in the final year of the Master's degree program. Their major was either Mathematics, Physics, or Astronomy.

In Australia, participants were enrolled in a Physics method unit in an ITE program. Three of these participants were males and were all enrolled in a Master of Teaching (postgraduate) program while one was a female enrolled in a Bachelor of Education (undergraduate) program. All participants were aged between 20 and 44 years of age.

**Data collection and analysis strategies**

Following IRB approval, all the pre-service teachers involved participated in a 30-45 minute, semi-structured online interview in the participants’ native language - prior to the start of the digitally-based Virtual School program. Interview questions were designed to explore pre-service teachers’ perceptions of the different roles and competencies of online teachers. Due to the limited word count, hereafter are the key characteristics of the interview protocol. Questions were formulated considering five main epistemic elements: 1. Skills (e.g. *Have you had any professional development to enhance your virtual teaching skills?*); 2. Knowledge (e.g. *Do you look for different types of software applications to change the way you represent content or to have students work with content if different ways?*); 3. Values (e.g. *How important is it for you to have flexibility in the way you structure your lessons?*); 4. Identity (e.g. *If a colleague was asked about something you do really well as a virtual teacher, what would they say?*); and 5. Epistemology (e.g. *What subject areas are you focusing on as part of your teacher training?*).

All interviews were conducted by one or two member(s) of the research team using the Zoom web conferencing system and were both audio and video recorded using the inbuilt recording tools in Zoom. The audio recordings were uploaded to an online artificial intelligence transcription service (https://otter.ai). Interviews were coded for the roles and competencies in Appendix A by two members of the research team per context, separately. Interrater reliability was calculated using Cohen's kappa coefficient which returned substantial results $k = 0.73$ in Australia and $k = 0.55$ in Italy (McHugh, 2012). Where differences in either researcher team were noted, discussions between members of the research teams were undertaken until consensus was reached.

The totality of the data was then visualised using a psychometric tool known as Epistemic Network Analysis (ENA) (Shaffer et al., 2009). ENA assumes: (1) that it is possible to systematically identify a set of meaningful features in the data (Codes); (2) that the data has local structure (segments or conversations); and (3) that an important feature of the data is the way that Codes are connected to one another within conversations (Shaffer, 2017; Shaffer, Collier & Ruis, 2016; Shaffer & Ruis, 2017). ENA models the connections between Codes by quantifying their co-occurrence within conversations, producing a weighted network of co-occurrences, along with associated visualizations for each unit of analysis in the data. Critically, ENA analyses all of the networks simultaneously, resulting in a set of networks that can be compared both visually and statistically. The key assumption of the method is that the structure of connections in the data is the most important in the analysis. In other words, ENA poses to be an appropriate technique for any context in which the structure of connections is meaningful. We claim that ENA might be a useful technique for modelling the epistemic frames of virtual (pre-service) teachers offering as evidence its models of the relationships among the roles and competencies in Appendix A as they occurred within our interview data.

We applied ENA (Shaffer, 2017; Shaffer, Collier, & Ruis, 2016; Shaffer & Ruis, 2017) to our data using the ENA1.7.0 Web Tool (Marquart, et al., 2018). We defined the units of analysis as all lines of data associated with a single value of Country (i.e. Italy and Australia) subsetted by the interview speaker (i.e. the pre-service teachers). The ENA algorithm uses a moving window to construct a network model for each line in the data, showing how codes in the current line are connected to codes that occur within the recent temporal context (Siebert-Evestone et al., 2017), defined as 4 lines (each line plus the 3 previous lines) within a given conversation. The resulting networks are aggregated for all lines for each unit of analysis in the model. In this model, we aggregated networks using a binary summation in which the networks for a given line reflect the presence or absence of the co-occurrence of each pair of codes.

The ENA model normalized the networks for all units of analysis before they were subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data. For the dimensional reduction, we used a singular value decomposition, which produces orthogonal dimensions that maximize the variance explained by each dimension (See Shaffer et al., 2016 for a more detailed explanation of
the mathematics; see Arastoopour, et al., 2015 and Sullivan et al., 2017 for examples of this kind of analysis). Networks were visualized using network graphs where nodes correspond to the codes, and edges reflect the relative frequency of co-occurrence, or connection, between two codes. The result is two coordinated representations for each unit of analysis: (1) a plotted point, which represents the location of that unit’s network in the low-dimensional projected space, and (2) a weighted network graph. The positions of the network graph nodes are fixed, and those positions are determined by an optimization routine that minimizes the difference between the plotted points and their corresponding network centroids. Because of this co-registration of network graphs and projected space, the positions of the network graph nodes—and the connections they define—can be used to interpret the dimensions of the projected space and explain the positions of plotted points in the space. Our model had co-registration correlations of 0.95 (Pearson) and 0.9 (Spearman) for the first dimension and co-registration correlations of 0.99 (Pearson) and 0.95 (Spearman) for the second.

**Results**

We used ENA to visualize participants’ epistemic frames and model similarities and differences in their characteristics. Figure 1 shows three elements: 1. the positions of individual pre-service teacher centroids (red circles representing Australian participants and blue circles representing Italian participants); 2. with the aggregated means or group centroid (a red square for Australian participants and a blue square for Italian participants); and 3. the confidence intervals for each country-based data.

![Figure 1: Visualization showing mean and individual differences based on geographic location](image)

As illustrated in Figure 1, distinct differences can be seen between each group of participants suggesting, in line with the literature, that quality ITE may not follow a “one-size-fit-all” logic. These participants were showcasing epistemic frames that have been shaped by their previous experiences – both academic and personal (see ABTI model on teacher cognition – Forkosh-Baruch, Smits & Phillips, 2021). At the same time, these peculiar epistemic frames suggest that an homogenous approach to ITE program design may have less than optimal results. The differences among the two groups may be related to several issues: culture, school context, academic/teaching experiences, gender, age, personality and so forth. To better understand where the similarities and differences are wider, and hence hypothesize the reasons behind them, we need to take a closer look at the epistemic networks for the two geographic-based groups of participants.

Figure 2 provides specific detail in the differences between the two cohorts by showing a subtraction network where particularly strong connections made by Australian pre-service teachers during their interviews are shown in red, while those made by Italian pre-service teachers are shown in blue.
Figure 2: Subtraction network showing differences based on geographic location (Australia: red; Italy: blue)

Figure 2 reveals more specific detail that could guide further development of the Virtual School program in each country by addressing themes that were less obvious in a particular geographic context. Indeed, we might hypothesize that a successful online teacher might want to be proficient on all nine roles and competencies. Operating specifically to support the weaker connections within each participant’s epistemic network might yield to better results in that sense.

The use of EFT and ENA also allows for examinations of differences between individuals within a cohort. For example, Figure 3 shows differences between two Italian pre-service teachers (whose centroids are in the blue circles), while the differences between two Australian teachers are illustrated in Figure 4 (participants’ centroids are in the red circles).

Figure 3: Differences in network visualizations for two Italian pre-service teachers. Participant A’s epistemic network in orange; participant B’s epistemic network in blue.
Figure 3 highlights how pre-service teacher A might be more proficient on the interconnected roles of critic, designer and technology user in their work. Hence, they might be more focused in identifying issues in their teaching and/or their student learning; in designing tasks and materials that cater to the emerging needs; and finally in using technologies and the online environment with a critical approach to its pros and cons for student learning. Participant B’s network, on the other hand, is more on the side of teacher as relationship manager, connected with being a leader and a designer. Their focus hence might be on promoting student engagement and building educational relationships by designing ad hoc lesson plans and striving for teacher change in their work context.

![Diagram of Figure 3 network visualization for pre-service teacher A and participant B's network with roles such as critic, designer, and technology user highlighted.]

Figure 4: Differences in network visualizations for two Australian pre-service teachers. Participant C’s epistemic network in red; participant D’s epistemic network in green.

Figure 4 highlights how pre-service teacher C might be more proficient on the interconnected roles of critic and technology user, which also show the highest frequency (in the size of the nodes). They are also interested in the role of student expert, possibly showcasing competence in understanding how different students might react to different technology uses, approaches to teaching and learning, or types of tasks and contents. Participant D’s network, on the other hand, is more on the side of teacher as a designer and content deliverer, along with technology user. Their focus hence might be on designing ad hoc lessons and tasks, also with the use of technologies, in relation to the best approach to the disciplinary content at stake.

The visualisation of individual differences in Figures 3 and 4 allow faculty in each geographical context to consider new ways in which pairs of pre-service teachers may be selected for team teaching within the Virtual School program. One could choose to pair pre-service teachers who have similar epistemic networks to reinforce particular elements of their epistemic frames; alternatively, one could choose to pair pre-service teachers with markedly different networks to challenge their pre-existing frames.

**Conclusion**

The preliminary data reported here represent a subset of the teachers who took part in the wider study, yet they suggest that ENA is capable of highlighting both individual and context differences. This seems to us a promising, evidence-based strategy to tackle the needs of aspiring teachers and build on their resources to design better quality ITE and identify individual development paths.

Data on the wider sample are currently being studied and will add to our understanding of how ENA visualizations can help tailor ITE to the specific needs/characteristics of our pre-service teachers. Post results will help us understand if and in which ways the Virtual School experience can impact on teachers’ epistemic frames, allowing for a better integration of this experience in ITE. However, the results of this initial investigation already provide insights into the
ways in which ENA and EFT may help inform a pedagogy of teacher education that is both empirically based and practically oriented.

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References


