The views of STEM specialisation among academics

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In this paper, an analysis of responses to the D-STEM task (Draw a STEM Learning Environment), provided by fifteen university educators at an Australian university, was used to illustrate the views of STEM specialisation among STEM educators. Participants relatively exhibited either *knower-code* view (foregrounding dispositions of STEM knowers) or *knowledge-code* view (foregrounding STEM disciplinary knowledge), while *élite-code* view (foregrounding both) was observed less. The LCT approach (Legitimation Code Theory) has been found promising in developing a language by which what counts as STEM specialisation can be explicitly communicated.

Keywords: Draw a STEM Learning Environment; Legitimation Code Theory; STEM specialisation

Introduction

The acronym STEM is sometimes used to refer to each of the four component disciplines (Science, Technology, Engineering and Mathematics) separately, and sometimes to the integrated teaching of two or more of them (e.g., science and mathematics). There has been an increased focus on the teaching and learning of STEM both in schools and at universities. Yet, there is widespread confusion about how STEM is implemented in the classroom. Much of the research in STEM education in the last decade, thus, has focussed on the teaching and learning practices required, and the learning outcomes that are possible through implementing STEM in the classroom (e.g., Hobbs et al., 2018). The literature on the impact of STEM education on student learning outcomes, however, presents mixed results, and what kind of STEM specialisation is valued and emphasised within STEM education is less known. Useful theoretical perspectives and analysis approaches are needed to initiate effective interventions that can result in improvements in student learning outcomes.

In a previous research project, we investigated the perceptions of a sample of university academics (*n*=15) about teaching and learning of STEM (Hatisaru et al., accepted). As part of the project, in this paper, I present a sociology of knowledge approach, *Legitimation Code Theory*, to describe what kind of epistemic (knowledge practices) and social relations (who enacts them) might be valued and emphasised by participant academics in STEM education. The research question was: *What views of STEM specialisation are evident in participants' D-STEM responses?*

Legitimation Code Theory (LCT)

LCT provides a conceptual tool for analysing the nature of knowledge and its practices within intellectual fields, including STEM. One of the dimensions of LCT is *specialisation*, i.e. what makes someone or something distinct, special, or different (Carvalho et al., 2009). Its premise is that all knowledge, beliefs or practice claims are about or oriented towards something, and by someone, and it sets up *epistemic relations* to an object and *social relations* to a subject (Maton, 2014). These relations consider what can be objectively described as knowledge *(epistemic relations – ER)* and who can claim to be an ideal knower *(social relations – SR)*. Epistemic and social relations may be more strongly (+) or weakly (–) emphasized, and the strength of the relations originates *specialisation codes (ER+/–, SR+/–)* (Maton & Chen, 2020). Maton (2014) suggests a *specialisation plane* where these strengths can be placed with infinite positions but in four key modalities are:

> *knowledge codes* (ER+, SR–), where possession of specialized knowledge, principals or procedures concerning specific objects of study is emphasized as the basis of achievement, and the attributes of actors are downplayed;
>
> *knower codes* (ER–, SR+), where specialized knowledge and objects are downplayed and the attributes of actors are emphasized as measures of achievement;
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> *élite codes* (ER+, SR+), where legitimacy is based on both possessing specialist knowledge and being the right kind of knower; and
>
> *relativist codes* (ER–, SR–), where legitimacy is determined by neither specialist knowledge nor knower attributes – 'anything goes' (Maton & Chen, 2020, p.38).

Any claim to the basis of achievement, success and legitimacy can be considered as specialised by its *epistemic relations*, by its *social relations*, by both, or by neither of them (Carvalho et al., 2009). According to these four modalities then "what matter is: 'what you know' (knowledge codes), 'the kind of knower you are' (knowledge codes), both (élite codes), or neither (relativist codes)" (Maton & Chen, 2020, p.39). As I understand STEM education as an opportunity to build both discipline specific knowledges and ideal knowers, I used LCT in conceptually framing the study.

Epistemic and Social Relations in STEM Education

In STEM practices (e.g., an engineering design), knowledge from different disciplines (e.g., mathematics) are used, and STEM problems are solved through a combination of practices from two or more STEM disciplines (e.g., scientific experimentation and engineering design). Although students draw upon subject knowledge of individual STEM disciplines, STEM problems are interdisciplinary. To facilitate concept development, concepts are presented in multiple modes of representations (e.g., symbols, visuals, real life situations) with the problems structured to require translations between them (Glancy & Moore, 2014). A common set of STEM practices underpin planning and pedagogy includes inquiry through representations, problem-solving, design-based approaches and incorporating digital technologies. Curriculum is developed drawing upon multiple models of discipline integration (e.g., multidisciplinary, interdisciplinary). By doing so, learning experiences are created that are engaging for students and that maximise student learning through linking with relevant concepts and processes from the individual STEM disciplines (Hobbs et al., 2018). A set of practices that are inherent in the individual disciplines such as developing and using models, planning and carrying out investigations, analysing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, evaluating and communicating evidence-based information support and strengthen each other in STEM learning. These practices represent the capabilities that students are expected to gain in their years of schooling, and that they are essential in today's knowledge-based society (Vasquez et al., 2013).

To enable those capabilities, teachers of STEM set goals, lead instruction, facilitate student learning within each or across STEM disciplines, and invite students to shape the learning experiences. Students draw upon and develop their skills as they collaboratively engage in the STEM problems or projects (Glancy & Moore, 2014).

In this study, epistemic and social relations in STEM education are underpinned by the literature cited above. The strength of these relations could be identified along a continuum of subject specific knowledge and a continuum of holding appropriate attributes or dispositions to STEM as in Table 1:

Table 1: Epistemic and Social Relations in STEM Education (adapted from Winberg et al., 2017).

Epistemic relations (ER)	Stronger (ER+) ↕ Weaker (ER−)	Knowledge of component disciplines	Knowledge of or learning about component disciplines of STEM. Knowledge practices include integration, scientific inquiry, reasoning and problem solving. Having little or no knowledge of STEM component disciplines.
Social relations (SR)	Stronger (SR+) ↕ Weaker (SR−)	Attributes or dispositions of 'knowers'	Quality, characteristics or abilities of STEM knowers including collaboration, communication and teamwork. Viewing STEM education for purposes other than building productive attributes, or misunderstanding what STEM education does offer.

The Study

This study has grown out of a previous research project funded by the University of Tasmania College of Arts, Law and Education (CALE) Hothouse Research Enhancement Program and implemented by a team of researchers led by the author. The project aimed to explore the perceptions of educators about STEM, STEM learning environments, and necessary capabilities for the educators of STEM at an Australian, research focussed university (Hatisaru et al., accepted). Academic staff from CALE and the College of Sciences and Engineering were invited to participate in the research, through their attendance at a workshop (2–3 hours in duration) run by the research team. The workshop focussed on unearthing and considering aspects of effective STEM learning environments. Fifteen academics from across the two Colleges voluntarily participated in the study.

At the commencement of the workshop, the participants were provided the D-STEM instrument (Hatisaru & Fraser, 2021) and 25–30 minutes to complete it. The instrument comprised both drawing and written descriptions and was constructed as a double-sided sheet. On the first page, participants were asked to draw a picture of a STEM learning environment. On the reverse side, participants were asked to provide a brief explanation of their drawing and were also given the opportunity to complete three prompts: *(1) STEM is …*; *(2) The goals and outcomes of STEM education for individuals involves …*; and *(3) An educator of STEM knows …* Once completed, all participants attached their drawings to a wall in the room and were given time to peruse each other's drawings. This session was intended to provide the participants with an opportunity to reflect, both on the variation in understanding of STEM learning environments within the workshop participants, and upon themselves as educators of STEM (Hatisaru et al., accepted).

The key aspect of the investigation was the qualitative analysis of the statements or words that the participants used to respond the prompts given, and that in their D-STEM depiction and description. Data analysis searched for patterns within the participants' accounts, on the way they describe STEM, expected outcomes of STEM, expertise of STEM educators, and a STEM learning environment (Table 2). A code book mapping *specialisation codes* to data, and vice versa, was used in the analysis of data. Participants were assigned a code (P1, P2) to protect their anonymity.

In the analysis of the participants' D-STEM depictions and descriptions, additionally, the *knowledge* and *knower codes* developed by Maton and Chen (2020), were used to support the data analysis. When a D-STEM drawing and/or description included more indicators of specialist knowledge and less or no indication of personal beliefs, personal dimensions of learning, collaborative learning or of personal skills (e.g., teamwork, collaboration), they were assigned the *knowledge code* (ER+, SR–), while they were assigned the *knower code* (ER–, SR+) when the emphasis was vice versa. When the drawing or associated description included emphases to both, it was coded as *élite* (ER+, SR+). Some responses were coded as *relativist* (ER–, SR–) as neither epistemic nor social relations were mentioned.

Table 2: *Specialisation Codes* Enacted in the Participants' Responses (Italics added).

Codes	Data source: The description of D-STEM drawing	1. STEM is ...	2. Outcomes of STEM includes ...	3. A teacher of STEM knows ...
Knowledge (ER+, SR–)	This is the fisheries training vessel (FTV) BLUEFIN. With capacity to hold 18 students, 2 Academics and 6 crew at sea for 5 days, *to teach fisheries management concepts and environmental issues*. In the diagram there are multiple fish cohorts, with variable abundance. Small fish escaping the gear. Cameras to film fish behaviour. 3 escape. When hauled data is collected on wildlife interactions and the biological measurements of the catch, this is an *experiential learning environment that imparts deep learning* (P2).	Cross curricular *understanding of all related science* to help detailed meaning of topic being investigated (P9).	Offering opportunities to explore real world *based upon existing knowledge, models and techniques*. Enhance *scientific knowledge, skills and logical thinking* (P1).	Two skills: - Subtle level - Gross level – *topics specific to subject being taught* (P11).
Knower (ER–, SR+)	Primarily Maths education. Comfortable, homely, light and airy environment. Food/drinks available to aid with *building co-operative group which is supportive of all and making mistakes OK*. Interactive materials to demonstrate concepts in hands on activities – both teacher and students to use. Use of colour and sound to supplement presentations. Plenty of boards to present material in written form/access by teachers and students. Copies available at end of session. Time out *to reflect, interact and question prior to regroup* (P1).	*Thinking about our world, our place in it*, understanding and developing ways to further *think about it and interact differently* (P4).	Is to *encourage young individuals to develop interest in* science and mathematics-based courses (P10).	That *we don't know everything, but we know* how to try to know everything (P3).
Élite (ER+, SR+)	Collaborations across generations – where everyone is *sharing, proposing, testing, discussing* from drawings, prototypes and real 1:1 objects. Can review visit/photograph (the real 1:1 objects). Many sites, many voices. Children, university students, Phd students, ecologists, scientists, artists, designers (P8).	*Science, engineering, technology and maths*. Forms the basis of most learnings. *Allows a broader view* (P15).	*Literacy acquisition* to be able to judge information sceptically, requiring evidence, *being open and transparent* (P14).	Each of *the big ideas in each discipline*; knows how to make experiences authentic; *make the learning meaningful*; what evidence constitutes learning in each of the disciplines (P5).
Relativist (ER–, SR–)	Dynamic teaching space – mobile chairs – open space *[Physical environment]* (P13).	A *learning platform* (P13).	-	*To give* immediate *feedback* (P13).

Results

The results of the participants' responses to three prompts and their D-STEM depictions and descriptions grounded on *specialisation codes* are presented in Table 3.

In general, the participants described the STEM specialisation through using *knowledge* (P2, P6, P9, P11) or *knower codes* (P3, P4, P7, P8, P10, P15). In their responses, P2, P6, P9 and P11 emphasised possession of knowledge, skills or procedures of STEM, while the dispositions or attributes of the knower was less evident or completely absent. This demonstrates that these participants downplayed attributes of STEM knowers over specialist knowledge: *the knowledge-code view which refers to strong epistemic and relatively weak social relations (ER+, SR–)*. In contrast, P3, P4, P7, P8, P10 and P15 downplayed attributes or dispositions of STEM knowers over disciplinary STEM knowledge: *the knower-code view which refers to strong social and relatively weak epistemic relations (ER–, SR+)*. Whilst the responses of P13 addressed *relativist codes* (see Table 2), the responses of P12 and P14 largely involved *élite codes*. That is, P12 and P14 emphasised both STEM disciplinary knowledge and dispositions of the knower or learner: *the élite-code view that indicates strong epistemic and social relations (ER+, SR+)*. The remaining two participants' responses (P1 and P5) included mixed views – *knowledge codes* were evident in their responses to the first and second prompts, but they used *élite codes* when responding to the third prompt, and *knower codes* to their D-STEM depictions and descriptions.

Table 3: Participants' Descriptions Grounded on the *Specialisation Codes*.

	Knowledge (ER+, SR–)	Knower (ER–, SR+)	Élite (ER+, SR+)	Relativist (ER–, SR–)
D-STEM depiction and description	P2, P6, P9	P1, P3, P5, P7, P10, P11, P14, P15	P4, P8, P12	P13
Prompt 1	P1, P2, P5, P6, P9, P10, P11, P12, P14	P3, P4, P7, P8	P15	P13
Prompt 2	P1, P2, P5, P6, P9, P11	P3, P4, P7, P8, P10, P13, P15	P12, P14	-
Prompt 3	P2, P6, P9, P11	P3, P4, P8, P10, P12, P15	P1, P5, P7, P14	P13

There might be many kinds of *knowledge* and *knower codes* based on the form taken by the STEM disciplinary knowledge and the ideal knower of STEM. In this study, to the participants, STEM knowledge is "about incorporating science, technology, engineering and mathematics – two or more of these disciplines; inquiry based" (P5). It entails "related areas of knowledge" (P9) and "the scientific method" (P6). The ideal knower sees STEM as "an important part of understanding the world and making it better" (P3) and "[works] on important issues relevant to the community" (P7). The ideal knower is "interested in science and mathematics" (P10) and "curious" (P8). They show "proactive attitude" (P13), "empathy, awareness and openness to the unexpected" (P4) and think "outside the box about a problem" (P15).

Concluding Remarks

This study investigated the views of STEM specialisation among a sample of university educators revealed in their responses to the D-STEM task. The languages of description in the responses of the participants were examined by applying the LCT *specialisation plane*. The study has revealed that participants hold relatively the *knower-code* or the *knowledge-code* views, while the *élite-code* view was less common. In other words, according to many participants, the dominant measures of success in STEM education seemed to be either having specialist knowledge or being the right kind of knower, rather than both.

The findings are limited to the responses of a small sample of voluntary educators, teaching at an Australian university, to a drawing task and three prompts about STEM education. They may not be generalised to the entire university, to Australia or other contexts. The findings, however, contain several implications and point out new research avenues. Firstly, the value of the study is addressed from the perspective of the productivity of the conceptual and methodological approaches to the issue of STEM specialisation. The languages of description analysed in the study showed that the LCT has power for representing something about how educators of STEM perceive knowledge, what kind of knowledges they value, and what kind of knowers they desire in their field. The descriptions used by most of the participants contained main and recurring codes that were used to describe specialisation within a field. Consistent with Maton and Chen's (2020) finding which showed the dominance of the *knower-code* practices of university educators in Australian online teaching context, many of the participants referred to STEM education as if it is about personal experiences, the quality or characteristics that an individual has, or a way of acting, being or thinking (e.g., P3 in Table 2). Further, the study raises questions about the role of the *élite-code* view in STEM education and draws attention to the importance of this view. What is not known and requires interviews or classroom observations to discover is the specialisation views enacted in practice.

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