RESEARCH PAPER

Regarding STEM: Perceptions of Academics Revealed in Their Drawings and Text

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How a sample of university educators described STEM, expected outcomes of STEM, expertise of STEM educators, and STEM learning environments were investigated through drawing- and text- based responses. Data were examined by applying the *Legitimation Code Theory (LCT) Specialisation* plane (Maton, 2014). Participants generally held *knowledge-code* (epistemic relations are foregrounded) or *mixed-code* (sometimes epistemic and sometimes social relations are foregrounded) perceptions. Further analysis showed that participants value both disciplinary knowledge and discipline-related practices such as analysing data and providing evidence-based discussions. The LCT approach has been found powerful in its ability to represent the kind of knowledge that might be valued, and the kind of knowers that might be desired by educators of STEM or individual STEM disciplines including mathematics.

A group of researchers involving the first and third authors of this paper patterned an instrument from the literature entitled, *Draw a STEM Learning Environment* (D-STEM), and implemented it with a sample of national project workshop participants to explore their perceptions of STEM learning environments in 2018 with a selection of school principals and education researchers. Next, the group developed the D-STEM Rubric to analyse the data and reported the participant researchers' (Hatisaru et al., 2019) and principals' (Hatisaru et al., 2020) perceptions of STEM learning environments including the presence of subject integration, the use of realistic problems, and student-centred instruction. The D-STEM instruments have been found to be powerful tools for studying individuals' understanding about STEM and STEM learning environments. Within a follow-up research project funded by the *University of Tasmania* (UTAS) *Research Enhancement Program*, we expanded the D-STEM research to investigate the perceptions of a sample of university academics (n = 15) about teaching and learning of STEM (Hatisaru et al., in press) in that context. In this paper, we use *Legitimation Code Theory (LCT)* (Maton, 2014), a sociology of knowledge approach, to describe the kind of epistemic relations (knowledge practices) and social relations (who enacts them) might be valued and emphasised by participant academics in STEM education. The research question underpinning this analysis is:

> *What perceptions of STEM education are evident in participant academics' drawings and descriptions on STEM?*

The study is significant for three reasons. First, for more than a decade now, there has been increased interest in schools and at universities in STEM education. Less is known, however, about what is valued and put emphasis on in the teaching and learning of STEM. Popular misconceptions about STEM practices reported years ago, such as equating STEM practices to hands-on activities, still exist (Morrison, 2006). For example, some educators view STEM practices as teamwork and communication, while some others think that teachers of STEM do not need to be expert but can be co-learners with the students (Hatisaru et al., 2020). There have been concerns that less attention is given to STEM discipline-specific content knowledge and practices in STEM professional learning activities (e.g., Winberg et al., 2019). The findings

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of this study extend the results of existing studies and contain valuable insights into STEM educators' perceptions of STEM education. Second, past research (e.g., Breiner et al., 2012) indicates that for individuals within an educational institution, a common operational definition of STEM may be helpful for fostering a clearer understanding about how to address issues in STEM to achieve intended learning outcomes. In this study, we explore how a group of academics within a single institution perceive STEM, expected outcomes of STEM, expertise of STEM educators, and STEM learning environments. Finally, the study is methodologically significant, as it presents an innovative conceptual framework (LCT) and a method (visual and textual data) for investigating individuals' perceptions of STEM and STEM education, and that can be used in mathematics education and elsewhere.

Production of the Drawings and Text

Academics from College of Arts, Law and Education 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 understanding and discussing aspects of effective STEM learning environments. Fifteen academics from the disciplines of Architecture and Design, Biology, Education, Information and Communication Technology (ICT), Management, Medicine, Pharmacy, and Physics. Participation in the research was based on interest in being involved, which was indicated by attendance at the workshop. Participation was voluntarily and all workshop attendees gave consent for their responses to be used for research purposes. At the commencement of the workshop, the participants were provided an adaptation of the D-STEM instrument, which was contextualised for higher education, and given 25–30 minutes to complete it. The instrument was comprised of three prompts with space provided for visual (Prompt 1) and written descriptions (Prompt 2; Prompt 3).

> Prompt 1: A learning environment is the diverse physical location, context and culture in which students learn. Think about STEM classes and the kinds of things that would be done in those classes. Draw a STEM learning environment.
>
> Prompt 2: Look back at the drawing and explain it so that anyone looking at it could understand what it means.

The descriptive narrative requested in Prompt 2 was to clarify and/or expand upon the information contained in the drawings and to assist in subsequent coding using the D-STEM Rubric (Hatisaru et al., 2020). The data from this section would enable the exploration of participant academics' perceptions of teaching and learning of STEM in their context. Also included was Prompt 3 with three prompt stems, which aimed to explore participants' understanding of STEM, STEM teaching and learning, and STEM education expertise:

> Prompt 3: Think about STEM education, learning and teaching. Please complete the sentences below. To me: (1) STEM is ...; (2) The goals and outcomes of STEM education for individuals involves ...; and (3) An educator of STEM knows ...

An Analytical Tool for Analysing the Data: Legitimation Code Theory (LCT)

LCT provides a conceptual tool for analysing knowledge or knowledge practices within academic disciplines, including STEM (e.g., Winberg et al., 2019). We used the *LCT specialisation codes* as an analytical tool to analyse the data generated in this study. As also described in Hatisaru (2021), in LCT, *specialisation* is about what makes someone or something distinct, special, or different (Carvalho et al., 2009). Its premise is that all knowledge, beliefs, or practices are about or oriented towards something, and are practiced by someone. It sets up *epistemic relations* (ER) to an object (e.g., STEM disciplinary knowledge) and *social relations* (SR) to a subject (e.g., STEM dispositions) (Maton, 2014). These relations consider what can be objectively described as knowledge and who can claim to be an ideal knower (e.g., a student or teacher). Epistemic and social relations may be more strongly (+) or weakly (–) emphasised; the strength of the relations originates specialisation codes (ER+/–, SR+/–) (Maton & Chen, 2020). The relative strengths can be placed into four quadrants in the specialisation plane (see Figure 1) at numerous positions (Maton, 2014) and encapsulate the basis of legitimation—or focus or success—in a particular field, event, or practice (Winberg et al., 2019). The *x*-axis represents a continuum of weaker to stronger social relations and the *y*-axis represents weaker to stronger epistemic relations. The relative strength of these relations gives rise to four principal codes: *knowledge code* (ER+, SR–); *élite code* (ER+, SR+); *knower code* (ER–, SR+); and *relativist code* (ER–, SR–).

To operationalise the analysis of the data using the *specialisation plane*, a *translation device* is necessary (Maton, 2014). We used the translation device presented in Figure 1 for data analysis in this study, which was based on Maton (2014), Carvalho et al. (2009), and Ellery (2009).

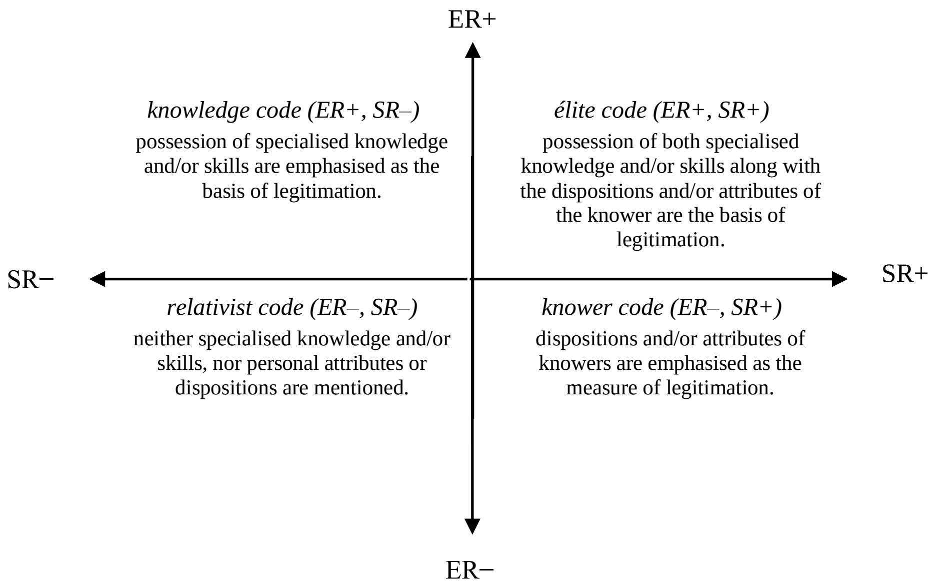

Figure 1. The translation device used in this study.

According to this device, the participant responses located in the *knowledge quadrant* may focus on discipline specific knowledge relating to STEM. In STEM education, however, the *knowledge code* not only incorporates the content knowledge of the associated disciplines (e.g., science and mathematics), but it also extends to the skills and practices that are associated with them such as scientific inquiry, investigations, analysing and interpreting data, and designing solutions (Ellery, 2019). Responses in the *knower quadrant* may focus on dispositions and/or attributes of the knowers (e.g., students) including being self-directed and confident, willingness to explore, share experiences, consider multiple views, and be reflective (an ideal knower) (Maton & Chen, 2020). Responses in the *élite quadrant* may emphasise both possessing specialist knowledge and being the right kind of knower as the measure of achievement, and these responses therefore may highlight the necessity of possessing both legitimate knowledge and legitimate attributes or dispositions. Finally, responses in the relativist quadrant would have no or little STEM content and no or little STEM dispositions or attributes. By examining these codes, the underlying perceptions in participant responses could be made explicit.

An Overview of Data Analysis

We implemented a content analysis of the statements or words that the participants used to respond to three prompts given, and their D-STEM depictions and descriptions. We were interested in the way participants described STEM, expected outcomes of STEM for individuals, expertise of STEM educators, and a STEM learning environment. A code book, mapping specialisation codes to data, using *specialisation codes* as presented in Figure 1, was utilised in the analysis of data. Participants were assigned identifiers (P1, P2, P3, etc.) to maintain their anonymity. The data were analysed by the first two authors manually using excel spreadsheets. By way of illustration of the coding process, examples of each of the specialisation codes identified in the participants' responses are provided in Table 1.

The same specialisation codes were used in the analysis of the participants' STEM drawings and associated descriptions. Adapted from Maton and Chen (2020), when a STEM drawing or description included more indicators of specialist knowledge and/or skills, 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. In Figure 2, two responses are presented representing the *knowledge-code* (P6) and *knower-code* (P3) drawings.

Table 1
LCT Specialisation Codes Enacted in the Participants' Responses (emphasis added)

Codes	(1) STEM is ...	(2) Outcomes of STEM includes ...	(3) A teacher of STEM knows ...
Knowledge (ER+, SR–)	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+)	*Thinking about our world, our place in it*, understanding and developing ways to further *think about it and interact differently*. (P4)	Enabling the student to *think outside the box* about a problem. (P15)	That *we don't know everything, but we know* how to try to know everything. (P3)
Élite (ER+, SR+)	*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–)	A *learning platform*. (P13)	-	*To give* immediate *feedback*. (P13)

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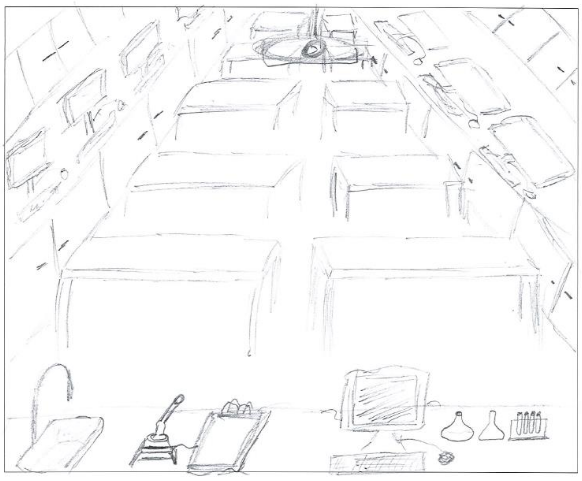
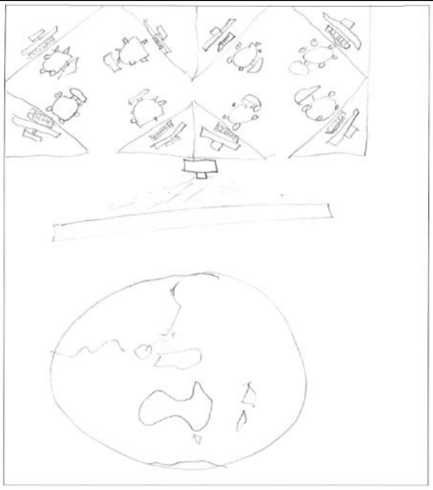
Further elaboration of the *knowledge code* was warranted because, in STEM, the *knowledge code* not only incorporates content knowledge of the associated disciplines, but it also extends to the skills and practices that we associate with these disciplines. When referring to Maton's (2014) model of specialisation, Maton and Howard (2016) noted that "the model distinguishes epistemic relations into ontic relations that specialize the known and discursive relations that specialize the discursive practices whereby it is known" (p. 64), but that these two relations are collapsed into a single *knowledge and skills* scale within the LCT framework. They suggested the creation of "two scales that addressed knowledge and skills separately" (p. 64), and after further consideration, they expanded the *knowledge and skills* labels to the *Knowledge*, *Theory and Concepts (KTC)* and *Skills and Practices (SP)*, respectively, to increase the clarity and understanding of these two labels.



Lab partner tables (standing, no seats) to encourage movement. Side walls have cabinet space full of lab equipment, and networked computers for inquiry.

Teacher desk in front with relevant equipment (e.g., microscope) linked to digital outputs to share with students through the projector. (P6)



Computers set up so that students can work independently on computer-based individual tasks. Students can turn around and work in small groups to achieve things together and discuss their problems. A big ocean so that all students can learn together and share what they know. Easy access outside to the rest of the world. (P3)

Figure 2. Examples of responses representing the *knowledge-code* (P6) and *knower-code* (P3) drawings.

In STEM, KTC is the disciplinary content knowledge or the theory underpinning the relevant discipline(s), what we might call the 'facts and figures', whereas SP includes the skills, practices and methodological approaches that we consider as part of the training within each STEM discipline. Skills and practices cover those used in scientific inquiry (e.g., analysing data and providing evidence-based discussions) along with the disciplinary skills that students of STEM are trained in (e.g., making observations in the field, designing new technology). Assignment of each of the relevant measures to KTC+/– and SP+/– considered the context of the response and the participant's disciplinary focus (or otherwise):

(KTC+, SP–): Related areas of knowledge (P9, Prompt 3)

(KTC–, SP+): Teaching students to apply real scientific approach where science, mathematics are instruments. (P11, Prompt 1)

(KTC+, SP+): Beginning with a problem or question and then using appropriate disciplines to answer/address the problem. (P5, Prompt 2)

Findings: Perceptions of STEM Education in Participant Academics

With fifteen participants and four measures per participant, there were a total of 60 responses (*f*: frequency) to analyse. Participants' responses to three prompts and their STEM drawings grounded on *specialisation codes* are presented in Table 2. In general, the participants described STEM through using *knowledge code* ($f = 26$) or *knower code* ($f = 18$), and to a lesser extent *élite code* ($f = 12$). Two participants (P12 and P13) had responses assigned as *relativist code* ($f = 4$) with P13 the only participant showing consistent responses assigned as *relativist code* ($f = 3$).

Table 2

Participants' Responses Grounded on the Specialisation Codes (f = 60)

	Knowledge (ER+, SR−)	Knower (ER−, SR+)	Élite (ER+, SR+)	Relativist (ER−, SR−)
Drawing and its description	P2, P6, P7, P9	P1, P3, P10, P11, P14	P4, P5, P8, P12, P15	P13
(1) STEM is...	P1, P2, P3, P5, P6, P9, P10, P11, P12, P14	P4, P7, P8	P15	P13
(2) Outcomes of STEM includes ...	P1, P2, P5, P6, P8, P9, P11	P3, P4, P7, P10, P13, P15	P12, P14	-
(3) A teacher of STEM knows ...	P2, P6, P9, P10, P11	P3, P4, P8, P15	P1, P5, P7, P14	P12, P13

We next located participants' responses in the *specialisation plane* based on the frequency of responses in each quadrant (see Figure 3). When the frequency of responses of a participant in a particular quadrant was three or more than three ($f \geq 3$), we assumed that the participant held the relevant quadrant perception. When their responses spread across two quadrants, we considered that these participants show *mixed-code* perceptions, and when responses were spread around more than two quadrants, we decided not to group these participants as their dominant views were indeterminant (* in Figure 3).

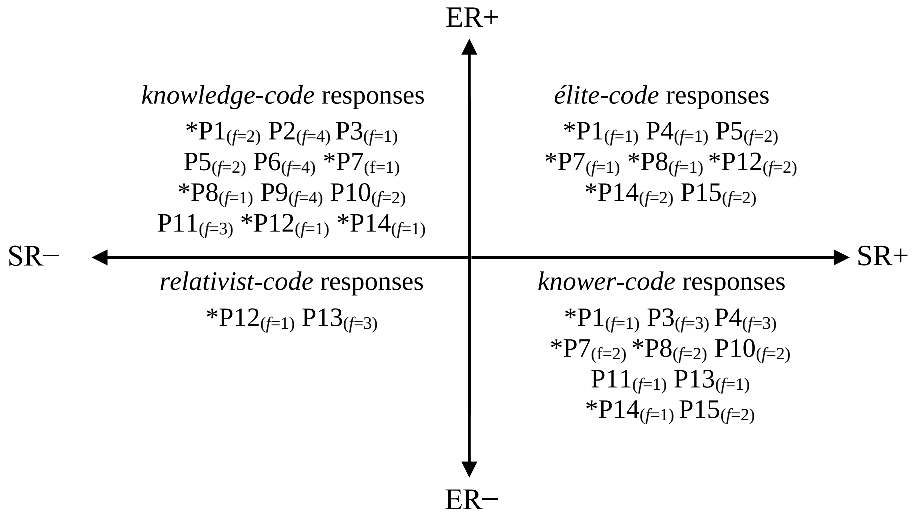


Figure 3. Participants' responses located into the specialisation plane.

Based on these judgements, none of the participants showed consistent *élite-code* perceptions. P2, P6, P9, and P11 displayed *knowledge-code* perceptions as they chiefly emphasised possession of knowledge and/or skills of STEM, while the dispositions or attributes of the knower were less evident or completely absent in their responses. Both P3 and P4 showed *knower-code* perceptions as they mostly downplayed specialist STEM knowledge and/or skills and emphasised social relations. Some of the participants (P5, P10, and P15) reflected *mixed-code* perceptions—sometimes emphasising STEM disciplinary knowledge and/or skills, and other times dispositions and/or attributes of students or educators; and sometimes both. Within this group, P10 displayed *knowledge-knower* code, P5 showed *knowledge-élite* and P15 showed *knower-élite* code perceptions.

The distribution of participants across the various *specialisation codes*, with only two participants holding *knower-code* perceptions, is not surprising considering that the participants were academics from various STEM-related disciplines. It might be expected that they would value or promote an understanding of disciplinary knowledge and/or skills in their teaching and student learning. Having three participants in the *mixed-code* perceptions group suggests that both the attributes of STEM knowers and STEM knowledge and/or skills are valued by some participant academics. For example, as described by participants when responding to the D-STEM prompts, STEM includes "related areas of knowledge" (P9) and "the scientific method" (P6). It is "about incorporating science, technology, engineering and mathematics—two or more of these disciplines" (P5). STEM-educated persons are "curious" (P8), "interested in science and mathematics" (P10), and show "proactive attitude" (P13) and "empathy, awareness and openness to the unexpected" (P4). They find STEM as "an important part of understanding the world and making it better" (P3), "[work] on important issues relevant to the community" (P7) and think "outside the box about a problem" (P15).

We undertook further analysis of the *stronger-epistemic-relations* assignments (i.e., ER+, SR–; ER+, SR+) for each of four measures to explore these participants' perceptions in more depth. As shown in Table 3, of these twenty-five assignments, twelve were coded as (KTC+, SP–) and nine (KTC–, SP+), with four responses judged as (KTC+, SP+). The split between (KTC+, SP–) and (KTC–, SP+) responses indicate a focus on either KTC or SP in these participants, indicating that while some may give importance to facts and figures, others may value the skills and practical aspects of the relevant disciplines.

Table 3
Stronger-epistemic-relations Assignments (f = 25) Differentiated as KTC (+/–) or SP (+/–)

	Knowledge (ER+, SR–)		Élite (ER+, SR+)
Drawing and its description	P2 (KTC–, SP+) P6 (KTC–, SP+) P9 (KTC+, SP+)		P4 (KTC–, SP+) P5 (KTC–, SP+) P15 (KTC+, SP+)
(1) STEM is ...	P2 (KTC+, SP–) P3 (KTC+, SP–) P5 (KTC+, SP+) P6 (KTC–, SP+)	P9 (KTC+, SP–) P10 (KTC+, SP–) P11 (KTC–, SP+)	P15 (KTC+, SP–)
(2) Outcomes of STEM includes ...	P2 (KTC+, SP–) P5 (KTC+, SP+) P6 (KTC–, SP+)	P9 (KTC+, SP–) P11 (KTC–, SP+)	
(3) A teacher of STEM knows ...	P2 (KTC+, SP–) P6 (KTC–, SP+) P9 (KTC+, SP–)	P10 (KTC+, SP–) P11 (KTC+, SP–)	P5 (KTC+, SP–)

Across the *knowledge-code* (P2, P6, P9, and P11) and *mixed-code* (P5, P10, and P15) perceptions participants, the split between KTC (+/–) and/or SP (+/–) was also interesting. That is, within the *knowledge-code* perceptions group (*f* = 15), seven (KTC+, SP–) and seven (KTC–, SP+) were observed, and within the *mixed-code* perceptions group (*f* = 8), four (KTC+, SP–) and three (KTC+, SP+) were recorded. The *mixed-code* perceptions participants provided a greater proportion of *élite-code* responses than the *knowledge-code* perceptions participants. This difference most likely reflects the different foci the two groups have with regards to the *knower code*, with the *mixed-code* perceptions participants more likely to focus on both content knowledge and skills and practical aspects of the relevant disciplines when providing a response consistent with stronger *epistemic relations* coding.

Concluding Remarks

In answer to the research question, what perceptions of STEM education are evident in participant academics' drawings and descriptions on STEM, we have been able to apply the LCT framework to identify a diversity of *knowledge-code* and *knower-code* perceptions of STEM amongst academic participants. *Knowledge-code perceptions*—or the valuing of disciplinary knowledge and skills—dominated, while the relative value or importance of knowledge versus skills in STEM education was mixed. Understandings of STEM and the ideal knower, as requiring or encompassing both specialised knowledge and skills as well as dispositions and/or attributes (*élite code*) were not common. These data highlight two things; firstly, perceptions of STEM varied across the group of academics and secondly, individuals within the group did not hold coherent perceptions across each response type (i.e., drawings; and three prompts). Both findings indicate the need for further investigation of the perceptions of STEM within academic contexts, with larger sample size and which consider individuals' discipline background, research and teaching focus and experience, with a particular focus on the relevance and/or importance of interdisciplinarity. Most importantly, the methodological significance of the LCT when used in the analysis of diagrams and text, has been highlighted. It is powerful in its ability to represent the kind of knowledge that might be valued, and the kind of knowers that might be desired by educators of STEM or of individual STEM disciplines including mathematics.

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