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Uniformity, diversity, harmony, and emotional energy in a Chinese STEM classroom

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Abstract

Background: Understanding cultural diversity in STEM education is important for inclusivity and teaching STEM literacy for all. We explore diversity at a micro-cultural classroom level involving students' emotional experiences and interactional practices as they engage with learning, which has received limited attention in naturalistic studies of STEM education, especially in East Asian cultures. In this study, we explore emotional experiences of students during a guided inquiry lesson in a Chinese primary school using an interpretive methodology informed by concepts of emotional energy, uniformity, and harmony. Emotional energy is an individual and collective experience of togetherness and solidarity emerging from successful social interaction. Uniformity and harmony are emotion-related concepts experienced in Confucian heritage cultures. The aims of this study are to explore Chinese students' emotional experiences during a STEM inquiry lesson and to refine the conceptualization of emotional energy from Confucian cultural perspectives.

Results: In a STEM inquiry, context knowledge about micro-cultural diversity and the interplay between Chinese emotional experiences and engagement with ideas are explored. Notions of uniformity and harmony are described through cultural practices as they relate to emotional energy. The study contributes to understanding the diversity of emotional energy as a student experience and social form of engagement, during a STEM inquiry activity in a Confucian heritage context.

Conclusions: This study contributes to understandings of student experiences of uniformity, harmony, and variations to intensity of emotional energy during learning via STEM inquiry. Modifications to the conceptualization of emotional energy in STEM education are indicated. Our findings inform an understanding of student emotive experiences of STEM education in East Asian and multi-cultural education systems internationally.

Keywords: Chinese, Classroom, Emotion, Harmony, Interaction, Science, STEM

Introduction

Studies of emotion in STEM education as a focus for understanding teaching, learning, and engagement are limited in number and scope, with much of the research across the STEM disciplines focusing on cognitive perspectives (cf. Fortus, 2014; Ritchie, 2018). Within STEM education, emotions research is typically classified under cultural, social, and gender issues, representing less than 10% of papers recently reviewed in 36 journals (Li, Wang, Xiao, and Froyd, 2020), and less than 7% in the present publication (Li, Froyd, and Wang, 2019). STEM education papers addressing cultural, social, and gender issues tend to adopt structuralist or factorial perspectives such as cultural factors influencing STEM career choices (Williams and Shipley, 2018), or the interplay between communities of practice and STEM knowledge boundaries (Leung, 2020). Specific studies of emotional experiences within cultural, social, and gender issues are very much under-represented in STEM education research.

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More recent growth in studies of emotion in STEM education has typically focused on psychological perspectives of emotional constructs and experiences. This recent growth is dominated by methods involving qualitative self-report (Rowland, Dounas-Frazer, Rios, Lewandowski, and Corwin, 2019), interviews (Pelch, 2018), and quantitative surveys (Lehtamo, Juuti, Inkinen, and Lavonen, 2018). Such approaches contribute to understanding emotive and cognitive constructs, relationships between constructs, and emotive experiences that are self-evident to participants. One limitation to these forms of emotions research is their inability to capture data as experiences unfold through in-the-moment social interaction. A further limitation involves emotive experiences that are taken-for-granted or unseen by people in the experience. Such taken-for-granted emotive experiences are often embedded in cultural contexts such as the culture of doing a STEM inquiry or the culture of a Chinese STEM classroom in the present study.

A prominent example of the culturally embedded, taken-for-granted quality of emotion in STEM education is a recent study of the emotional experiences involved in the production of objectivity in a school science inquiry (Davis and Bellocchi, 2018). That study explored the interplay between emotive experiences and practices associated with the formation of scientific objectivity. Such perspectives are important in STEM education because they contribute novel understandings about the nature of science or the nature of STEM (cf. Lederman and Lederman, 2014). The perspectives produced through that study would not have been possible from a psychological stance on emotional experience. Much of the experiences being investigated were taken-for-granted by, or invisible to, participants because of the mundane quality of everyday experiences (Liberman, 2013). Despite this taken-for-granted quality, evidence about how experiences unfold are visible through fine-grained analysis of classroom interactions.

A further example of culturally embedded emotions influencing STEM education is evident in a study of social constructivist teaching in a Confucian heritage culture in Vietnam (Hằng, Meijer, Bulte, and Pilot, 2015). Confucian heritage cultures are historically linked with China. In educational settings, they are often characterized by passive learning, a tendency to seek out uniformity in student and teacher behaviors, and a focus on teacher-centered learning. Such characterizations are controversial, and this is evident in the study by Hằng et al. (2015), who identify the Confucian emotion of harmony as associated with the avoidance of argumentation. On this basis, those authors suggest that Confucian harmony and styles of teaching are inconsistent with social constructivist learning in school science, where argumentation is encouraged. Hằng et al. (2015) explored teaching practices and analyzed these in relation to a conceptualization of harmony, but the focus of their study was not on students' emotive experiences. Through our present study, we seek to extend thinking about harmony in STEM education by adopting an interpretive research design to explore taken-for-granted emotive experiences in a contemporary Shanghai STEM classroom. In this way, we seek to improve understandings of culturally embedded emotional experiences that may influence the teaching and learning of STEM education in classroom contexts.

To explore taken-for-granted emotive experiences, we focus on micro-social and micro-cultural practices of teaching and learning during a student-centered STEM inquiry project. By micro-social, we are referring to the moment-to-moment social interactions comprising of individual and collective gestures, facial actions, verbal utterances, conversation, and silences (Ritchie and Tobin, 2018). It is through such interactions that people make sense of the localized social reality in which they are located by co-producing cultural symbols and social structures such as shared ideas in STEM (Roth, Lee, and Hwang, 2008). These forms of localized interaction produce the micro-cultures of particular STEM classrooms. Our research questions are the following:

1. How could Chinese students' learning and emotive experiences of a student-centered STEM project be understood through micro-social and micro-cultural perspectives?
2. How could elements of Confucian heritage cultures be synthesized into our conceptualizations of learning and emotive experiences during student-centered STEM projects?

Literature and conceptual framing

In this section, we review the literature to contextualize key concepts relevant to student experiences in this study, such as harmony, uniformity, diversity, and emotional energy (EE) in STEM education. The micro-social level of analysis we adopt in this study is important to STEM education because this is where students learn and experience STEM knowledge, skills, and ways of thinking. We adopt a sociological and phenomenological perspective (Liberman, 2007, 2013) of STEM learning wherein ideas are performed as social structure within meaning making interactions, and these same performances are experienced emotionally by students. Through the visible performance of shared ideas, actions are regarded as thought itself, which is distinctively different to the representational thinking of psychology where thought is regarded as invisible (Roth, 2008a). These performances and experiences appear in many different ways, and for this reason, we view the appearance of micro-social practices within micro-cultural

contexts as being highly diverse (Liberman, 2007). Diversity in this study does not appear at the level of cultural labels such as gender or ethnicity (cf. Rainey, Dancy, Mickelson, Stearns, and Moller, 2019), but through the particular micro-performances and experiences of students as, and through, everyday classroom interaction (cf. Roth, 2008b). This means that students who perform a science concept such as *circulation*, through particular utterances and gestures, may perform it differently on different occasions of social interaction, while producing a similar meaning. In fact, such student performances *should* change over time as a consequence of learning.

Within the micro-cultural context of the STEM classroom at the focus of our study are interwoven patterns of thought that are enduring across long periods of history. These patterns of thought have existed prior to the participants in our study and will live on within society in various forms. We are referring to ways of thinking that enable us to identify a form of Confucian heritage culture within this classroom. Of particular interest in our study was how Confucian notions of harmony and uniformity are at play within the micro-culture of this particular STEM classroom.

Harmony, uniformity, and everyday culture

Our conceptualization of harmony draws from Confucian perspectives originating in a classical text known as the *Chung Yung* or *Doctrine of the Mean* (Fung, 1976). Harmony is regarded as an emotive experience and may be conceptually described with three key ideas expressed in ancient Chinese language: *Chung* as a process of proportionality, *ho* as harmony achieved through Chung, and a separate idea of *t'ung*, which means uniformity. The distinction between ho and t'ung is important for the present study because the notion of t'ung as *uniformity* or *conformance* in Chinese culture is inconsistent with diversity in the expression of shared ideas. In contrast, the notion of ho or harmony is the achievement of bringing differences and diversity together, as a unity through the shared production of ideas and things that are new. T'ung is like mixing water with water to produce more water. In contrast, ho is like cooking with "water, vinegar, pickles, salt and plums" to produce a new taste that is collectively different from the original, individual ingredients (Fung, 1976, p. 174). The process of achieving harmony defines how all actions and all things must be brought together in a proportionality that is *just right* in order for harmony to be achieved (Fung, 1976).

This concept of harmony through the proportional confluence of diverse ideas is commonly evident in everyday Confucian heritage cultures. For example, in contemporary popular Chinese media, the notion of harmony is often described as *the middle way*, and is commonly referred to in business management contexts as the basis for negotiation (cf. Chenxi, 2018). In the context of a student-centered STEM classroom, harmony may be observed by students performing different ideas through gestures and conversation to achieve a new and collective understanding about a shared STEM phenomenon. In contrast, uniformity could involve one student, or the teacher, putting an idea forward to a group, and everybody in the group accepting the idea without any discussion or debate. Based on this reasoning, in our study, we regard Confucian harmony and uniformity to be two mutually exclusive concepts, consistent with the interpretation by Fung (1976).

Our conceptual stance about harmony and uniformity in the present study contributes to STEM education by challenging previous studies where different interpretations of these concepts were portrayed. For example, Huang and Asghar (2018) explore Chinese teacher perspectives in Taiwan, concerning student-centered pedagogies and the interplay with Confucian values and practices. Their study highlighted government-level educational policies in Taiwan where the Confucian notion of harmony is interpreted as fostering social conformity and uniformity in pedagogical practice and teacher-student relationships. Some teachers in that study express views about notions of Confucian philosophy being used to promote conformity which they conflate with social harmony. Huang and Asghar (2018) suggest that Confucian notions of harmony are in conflict with student-centered pedagogies in science education, where creativity and diversity in ideas are important. The conflation of harmony and uniformity by Huang and Asghar (2018) was driven by everyday teachers' perspectives, which we acknowledge as an example of the plurality of cultural interpretations and transformation.

Other recent studies conducted in Vietnam also interpret the notion of harmony in Confucian philosophy as requiring the achievement of social order through uniformity (Hằng et al. 2015; Thao-do and Yuenyong, 2017). Uniformity is attributed to student obedience and passivity in Confucian heritage science classrooms by Thao-do and Yuenyong (2017). Hằng et al. (2015) also contribute to the conflation of harmony and uniformity by conceptualizing harmony as a cultural preference for stability, which they suggest leads to the avoidance of argumentation and confrontation. In their study, they cite a teaching practice we may associate with an *initiate-response-evaluate* (IRE) style of questioning, which they identify as the achievement of Confucian harmony through conformance with teacher-directed knowledge and teacher-centered practices. Such interpretations of Confucian philosophy, and the notion of harmony in particular, lead to conclusions about Confucian heritage cultures as being *inconsistent* with constructivist learning in science and STEM education (Hằng et al. 2015).

In the present study, we adopt a contrarian stance when defining harmony and uniformity compared with these earlier studies. We appreciate that reconciling interpretations from historically situated Confucian philosophies and everyday experiences of STEM pedagogy is a complicated endeavor. This complexity arises through the character of everyday cultural interpretations, the plurality or diversity of enacted cultures (cf. Roth, 2008b), and the transformation of systems of thought over time. Such complexities lead to calls for more nuanced interpretations of Confucian or other cultural perspectives in contemporary educational contexts (Ho, 2018), and in our present study, we explore some of these nuances.

Emotive experiences and emotional energy

In exploring the nuances of harmony and uniformity, it is important to recognize these notions not just as concepts but as lived phenomena within emotive experiences of everyday micro-cultures. In fact, from a Confucian philosophical stance, harmony is described as a form of emotional experience (Fung, 1976). How harmony may appear in a classroom at the level of student experiences has not been described in STEM education, and we seek to address this throughout the present study. To guide our study of emotive experiences, we adopt in our conceptual framing a novel sociological concept of emotional energy (EE), developed previously in science education contexts (cf. Ritchie and Tobin, 2018). We will apply this sociological approach to explore harmony and uniformity alongside EE.

Conceptually, EE originates in micro-sociology and is described as a sense of solidarity and togetherness achieved through successful social interaction (Collins, 2004). During everyday social interaction, EE may be evident through collective actions involving the formation of shared ideas, the performance of mutually aligned bodily movements, and the fluency of interaction (Collins, 2004). For example, Olitsky (2007) describes an interaction between a teacher and an elementary school student evidencing synchrony in utterances and sounds, and self-coordinating hand actions between the two, as they manipulated a small machine at the focus of an exploratory inquiry. While formal conversation was limited, the back and forth hand actions of teacher and student illustrated strong mutual focus on the shared object and on each other's actions that made coordination possible. That situation is an example of intense experiences of EE. In another study by Roth, Ritchie, Hudson, and Mergard (2011), an event of spontaneous laughter in a science class was analyzed. While laughter is not an emotion, the actions of mutual alignment around shared ideas and the reflexivity of mutual observations between people in-the-moments before and during laughter provide evidence of intense EE as a social phenomenon. It is the intensity of these moments of intersubjective experience and shared attentiveness that make spontaneous laughter a possibility in classroom interactions.

Studies of EE in science education tend to focus on experiences that are described as dramatic, positive, and/or intense. Tobin's (2006) study of a high school chemistry class illustrates dramatic, positive EE, evidenced by high levels of synchrony and mutual entrainment between students, rising pitch in vocalizations, loud, expressive, and rhythmic bodily gestures. Dramatic EE is also described during interactions characterized as situations of conflict that resolve into synchrony and mutual focus as the intensity of EE increases (Roth and Tobin, 2010). Importantly, learning experiences in STEM classrooms involving dramatic EE are often memorable to the students in the experience and can be studied using self-report data. This is not the case for learning experiences in STEM that are undramatic in character, because students are typically unaware of the experience and unable to make a self-report.

Undramatic EE typically involves taken-for-granted experiences that students do not notice themselves (Davis and Bellocchi, 2020, 2019). In a student-centered STEM inquiry, undramatic EE may arise as moments of quietness, such as mutual entrainment by students when making observations and recording data. It may also involve self-coordinating changes in student actions, such as the way in which they stop touching an observed object and start to make observations while physically distancing themselves from their observed object. Such unplanned, self-coordinated restraint evidences mutual alignment both physically and in terms of the idea of self-restraint without the need for any overt conversation to act in this way (cf. Davis and Bellocchi, 2018).

Combining harmony, uniformity, and emotional energy

The above literature provides an overview of two fields of research in STEM education focusing on Confucian heritage cultures and emotive experiences, as ways of understanding student learning in STEM classrooms. Through this study, we seek to understand the various concepts outlined above, and how they may be interpreted during teacher-centered and student-centered learning. We seek to explore further the integration of these ideas both conceptually, and as they are performed and experienced as empirically observable social phenomena during a STEM inquiry project.

Methodology

We adopt an interpretive phenomenological orientation where we perform close observation of students in the naturalistic environment of their everyday STEM class

(Van Manen, 1997). Phenomenological studies in STEM education are adopted for the purposes of exploring experiences of teaching and learning (Dare, Ellis, and Roehrig, 2018). Such approaches enable the exploration of particular occasions of teaching and learning that may inform the historical and contextual features of STEM classrooms (Coles, 2019). For example, in the present study, we are interested in how students experience learning and emotion during a student-centered STEM inquiry lesson, which is a novel way of teaching STEM in Chinese classrooms. As noted in the literature review some aspects of emotive experiences go unnoticed by people in the experience, and our observational and interpretive methodology addresses this issue (cf. Davis, 2017; Liberman, 2007, 2013).

Methods of data production

Study context and data collection

This study was conducted in a voluntary, private, primary school in Shanghai, China, where a new program involving guided inquiry and integrated STEM was being introduced across the school. Most students were from local Shanghai families and spoke some English and Shanghai dialect, as well as Chinese (Mandarin) in which schooling is delivered nationally. The broader study involved 5 classes and 120 students where we video recorded classroom activities during 5 lessons as part of the schools' new STEM program. The program was aimed at teaching integrated STEM with 8–10-year-old children as part of the formal curriculum.

Student-centered STEM inquiry lesson

This is a non-interventionist study where we aimed to explore a student-centered STEM inquiry lesson in a naturalistic setting. We requested to access inquiry lessons as part of the school's STEM program, but the topic and lesson design was decided by the teacher. Our focus in this paper was on a 50-min lesson with a single class, and a particular group within that class, where students were evaluating the properties of different fabric materials as a guided inquiry activity. Properties being explored by students involved the flammability and water resistance of the fabrics that were qualitatively evaluated by students. The students used a teacher-generated worksheet to record their results and conclusions. Students in this study are referred to using the pseudonyms Wang, Sun, Liu, Qiao, Guo, and Chen, and their teacher as Xiao.

Research ethics

As an international collaboration between Queensland University of Technology (QUT) and Shanghai Normal University (SHNU), this study received ethical approval and supervision from the QUT Human Research Ethics Committee and administrative approval from SHNU. Informed consent to conduct the study, and publish images, was obtained in writing, in Chinese (Simplified), from the school principal, teachers, students, and a parent or guardian for each student.

Data selection and transcription

The data in this study focuses on five students completing an inquiry activity. This group was selected initially on a convenience basis given the location of cameras in the classroom. Data were initially selected by authors 1 to 5 individually reviewing the video data, and then sharing moments in the video that may be salient in understanding concepts and phenomena in this study.

Selected episodes were transcribed using techniques adopted in studies of social interaction to provide a fine-grained description of the video data (cf. Bellocchi, 2019). Spoken utterances were transcribed in Chinese simplified characters and in pinyin. Pinyin is the official Anglophonic version of Chinese writing, developed for non-Chinese speakers to understand the sounds of the spoken language. An English translation was also developed, but the analysis was performed in relation to Chinese utterances to ensure particular idioms of everyday language were retained (cf. Roth, 2008b). In alignment with the conversation, bodily actions were also transcribed. These data are presented in the findings as episodes and fragments of interaction with the turn number in the far left column, the speakers' name, and in some cases a letter, such as "A" in the example below to denote a particular topic of interaction. Conversation is presented in Chinese (simplified), English in italics, and pinyin, followed by relevant bodily actions in double brackets.

Episode example

2	A	Xiao	同学们好: *Hello students* tóngxuémen hǎo ((Xiao bows upper body toward class))

Measuring emotional energy

The intensity of EE is modeled by Davis and Bellocchi (2019), which builds on the work of Collins (2004) and emotions research in science education. In that model, intensity is evaluated by studying micro-interactional data as described in the conceptual framing. These data are evaluated in terms of their contribution to the degree of (1) collectivity across bodily gestures and conversation, (2) the generation of shared ideas, and (3) the fluency and cohesion of the interaction. The model is descriptive and enables researchers to describe data across these three dimensions, while making an interpretive, ordinal judgment

about observed EE as being low, mid, or high intensity (cf. Behnagh, 2020).

Data quality evaluation criteria

Our criteria for evaluating data quality in this study is informed by a framework of trustworthiness and authenticity (Lincoln and Guba, 2016) where we consider notions of credibility, theoretical generalizability (Eisenhart, 2009), dependability, confirmability, and authenticity. Credibility of data transcription and interpretive analysis was achieved through collective reading and discussion about methodologies and methods to establish inter-subjectivity across the team. Team members were also involved in collection of field data, thereby gaining an understanding of the class micro-culture. Tests of progressive subjectivity were achieved by individual transcription and data analysis followed by group analysis. Dependability or traceability was also achieved by shared readings of the methodology and methods of this study over a 6-month period, followed by intense study sessions prior to field work and during data analysis phases. This clarity around methodologies, conceptual frameworks, and transcription methods ensure traceability of our collective thinking.

We adopt the notion of theoretical generalizability (Eisenhart, 2009), which may be illustrated in the ways we interpret concrete performances of social interaction. This approach may be described in terms of a dialectic relationship (Roth, 2009) between concrete utterances and gestures, and formal categories as abstract ideas. For example, a person's bodily action of *pouring-water-from-a-beaker* is a concrete action in which the performance is regarded from our methodological perspective as *thought-in-action*. The written phrase pouring-water-from-a-beaker is an abstraction of the concept arising from the concrete bodily performance. This notion of a concrete | abstract dialectical relationship, denoted by the symbol "|", is applied throughout science education research (cf. Davis and Bellocchi, 2018; Roth, 2008b, 2009), and it is this notion that shapes our approach to forming generalizations.

Findings

In the forthcoming findings, we present and analyze four episodes of data with thematic sub-headings introduced here in *italics*. *Uniformity and teacher-centered ideas* addresses episode 1 by exploring how uniformity may be performed in a STEM lesson. *Proportionality, diversity*, and *emotional energy* explores episode 2 through interactions where diverse ideas are evident with low EE, moving toward harmony. *Harmony*, *emotion*, and *intensity* explore episode 3 where student's actions begin to align within the group, as harmony and more intense levels of EE are achieved. Finally, harmony and student-centered ideas explore episode 4 where ideas shared between students are formalized through collective writing on the group worksheet.

Uniformity and teacher-centered ideas

Episode 1 illustrates the start of the lesson with the teacher calling the class to attention as shown in turn 1, episode 1 where Xiao, the teacher, stands at the front of the class and utters "起立 qǐlì," meaning *stand to attention*.

Episode 1: Uniformity and teacher-centered ideas

1	Xiao	起立: *Stand to attention* qǐ lì ((class-teacher stand to attention facing each other))
2	Xiao	同学们好: *Hello students* tóngxuémen hǎo ((Xiao bows upper body toward class))
3	All	老师 好: *Hello teacher* lǎo shī hǎo((class bow upper body, class sit, facing the teacher, backs upright, arms folded across bodies))
4	Xiao	上课 前 之前 我们 先 来 看 这个 认不认 识 (0.2) 这些 东西: *Class we will now look at and consider some things,* ((powerpoint shows images of different materials)) *what is this thing?* shàngkè zhī qián wǒmen xiān lái kàn zhège rèn bù rèn Shi (0.2) zhè xiē dōngxī ((Sun raises right hand, Wang/Sun/Liu sitting upright, eyes aligned to teacher))
5	Xiao	你 来 说: *You speak* nǐ lái shuō ((Xiao nominates Chen. Wang/Sun heads face right))
6	Chen	陶 瓷: *Pottery* Táocí ((boy stands to answer, then sits))
7	Xiao	陶 瓷: *Pottery* Táocí ((mimicry of Chen's response))

In response to Xiao in turn 1, the students rise from their seats and stand to attention, followed by teacher Xiao bowing her head and upper body while uttering, "同学们好 tóngxuémen hǎo *hello students*" at turn 2. The class responds by mirroring the bowing motion toward Xiao, concurrent with a loud chorus as students utter, "老师 好 lǎo shī hǎo *hello teacher*." Students then sit quietly, facing the teacher, with their backs upright, forearms folded laterally across their bodies, and resting on the table.

These actions across turns 1 to 3 are part of a routine or ritual that we observed in all classes across the school. The ritual establishes a high level of EE to commence the lesson, where students and teacher rhythmically perform an act of respect toward each other. It is an act that achieves teacher-centeredness, sets aside diversity, and establishes a moment of uniformity in actions, mutual entrainment, and the idea of mutual respect. These actions have implications for the subsequent student-centered STEM inquiry that we discuss later.

At turn 4, Xiao announces that they will be looking at different types of materials during the lesson and completes the turn by referring to an image on the classroom screen with the question "这些 东西 zhè xiē dōngxī *what is this*?" Sun immediately raises his

right forearm to a vertical position, with elbow resting on his left hand close to his body. At turn 5, Xiao points to another student, Chen, who has also raised his hand in the same manner as Sun, and Xiao utters "你 来 说 nǐ lái shuō *you speak*." Following this utterance, Sun returns his right forearm to the lateral position, Chen stands to attention, makes his utterance of "陶 瓷 táocí *pottery*," then sits down immediately into his upright position.

Across turns 4 to 7, we observe a routine of teacher-centered activity where the teacher presents images of different technological objects and materials. This routine continues for several turns in the video. It is clear from these data that the teacher is introducing ideas in the form of images and asking students to confirm what concepts these images represent. Chen achieves this by raising his hand, and when invited to speak by the teacher, he stands, answers, and sits (turn 6). Chen's performance of pottery as an idea is acknowledged as correct by the teacher's mimicry of the utterance "Táocí" (pottery) in turn 7. It is clear that Chen and Xiao achieve uniformity in their ideas because an image of pottery is presented by Xiao and is met with an utterance of *pottery* from Chen. What is less clear are the other ideas being silently recalled by students who did not speak. These students include Sun who also raised his hand, suggesting he had an idea, as well as other students such as Wang and Liu who sat still and silently in an upright, forward facing position.

As this routine continued in the video, after several questions, the teacher invites the class to answer in chorus. As the teacher presents each image, the class responds simultaneously in a melodic chorus. From the perspective of EE, this may be evaluated as mid-level intensity, evident by synchrony of utterances, ongoing bodily alignment toward the teacher, and upright ritualistic sitting. It may be argued that this was a further example of uniformity; however, this was different to the uniformity displayed earlier between Chen and teacher Xiao. In this later situation, there was clearly shared chanting, but how these chants equate to shared ideas is unclear. It may be possible in this choral performance for students to simply chant while thinking about something else.

Proportionality, diversity, and emotional energy

In episode 2, the actions and utterances of Sun, Wang, Liu, Qiao, and Guo provide evidence of several topics or ideas generated by different group members and noted as A, B, C, and D in the transcript. Episode 2, fragment 1, commences with Sun holding a pair of tweezers and uttering, "我 觉得 镊子 不应该 捏在这 Wǒ jué de niè zi bù yīng gāi niē zài zhè er I don't think the tweezers should be pinched at the bottom."

Episode 2, Fragment 1: Diverse actions and diverse ideas

1	A	Sun	**我 觉得 镊子 不应该 捏在这** *I don't think the tweezers should be pinched at the bottom* Wǒ jué de niè zi bù yīng gāi niē zài zhè er ((Sun holds the tweezers, rolls his eyes at Liu and points the tweezers close to his face. Liu pulls his head back and nods up and
	D		down. Rest of the group watch, except Guo who plays with water in a beaker))
2	B	Wang	**对-啊-** *Yeah* duì-ā- ((Liu/Qiao watch Sun as he grasps the blue cloth with tweezers, Wang picks up a magnifying glass, Guo pipettes water from a beaker))
3	A	Sun	**主 要 是 你你 要 是 想** 这 样, **也也:::啊?** *If you think about it*((with uncertainty)) Zhǔ yào shì nǐ nǐ yào shi xiǎng zhè yàng, yěyě:::ā?
4	B	Wang	**你 看 (.) 掉 了** *You see its gone* ((Wang speaks quietly as Sun dropped the cloth from the tweezers, then picked it up quickly)) Nǐ kàn (.) diào le。
5	C	Liu	**如 果**(.) *If(.)* Rú guǒ(.) ((Liu glances at Sun, points at blue cloth and speaks loudly)) **这个:: 在 火 里 不 小 心 掉 下 去了**(.) *this cloth:: was dropped in the fire, what we should do* Zhè ge::zài huǒ lǐ bù xiǎo xīn diào xià qù le (.) ((Liu draws back his left hand, looks at sun then to his own finger actions, imitating tweezer use)) **怎么** *办 how to do* zěnme bàn; ((Sun turns away from group, Wang raiseds hand looking toward Xiao, Qiao looks at the beaker, Guo keeps
	D		focus on the beaker and pipette))

Sun's utterance at turn 1 concerns his inquiry method for how to hold the tweezers, which we have identified as topic A in episode 1, as shown by the notation beside turns 1 and 3. Concurrent with Sun's utterance, we observe in the video Liu, Qiao, and Wang glancing at the tweezers as Sun moves his hand in front of them. We also observe Guo playing with some water in a beaker, which we identify as topic D in episode 2 (turns 1 and 5). During this interaction, there is a moment of disagreement between Sun and Liu (turn 1), evident when Sun holds the tweezers close to Liu and rolls his eyes toward him, as shown in Fig. 1.

At turn 2, Wang utters "对-啊- duì-ā- *yeah*," as his attention turns away from the tweezers and toward a magnifying glass which he picks up from the table. Based on the actions that follow, Wang's response of "yeah," suggests the utterance was made to allow Sun to continue, but also to allow Wang to find his own focus on the magnifying glass, which we identify as topic B. Finally, Liu re-commences talking about topic C at turn 5 with, "如果(.)这个:: 在火里不小心掉下去了(.)怎么办 Rú guǒ (.) Zhè ge::zài huǒ lǐ bù xiǎo xīn diào xià qù le (.) zěn me bàn *If this cloth was dropped in the fire, what we should do*." At the same time, Guo is still playing with the water and beaker (i.e., topic D).

Through the transcript data, it is evident that the interaction within this group is not about a single idea. There are multiple ideas evident through the discontinuity between interactional turns, and even within turns such as turns 1 and 5, where Guo is simply doing his own exploration with some water at the side of the group. This is a situation involving diverse ideas, as each student performs an idea which is not immediately accepted or acted upon by others in the group. These data

Panel A Panel B

Fig. 1 a Sun (left) rolls his eyes at Liu (right). **b** Sun points tweezers at Liu

also evidence mid- to low-intensity EE because there is limited synchrony between actions or agreement on ideas, as evident in Fig. 1 (turn 1) as Sun rolls his eyes during a disagreement with Liu. These aspects of the interaction limit its fluency as each student shifts from one idea to the next.

As the interaction unfolds beyond fragment 1, the diversity of ideas continues and is further evident with the physical dispersion of the group. In episode 2, fragment 2, Wang and Qiao turn toward teacher Xiao and raise their hands. At this moment, Wang loudly exclaims "teacher we want fire."

Episode 2, Fragment 2: Dispersion and diverse ideas

6	E	Wang	老师(.) 我们 要 火? *Teacher we want fire* Lǎo shī(.) wǒmen yào huǒ? ((Wang's turns toward Xiao and raises his right hand. Qiao faces toward Xiao, raising his left hand. Guo plays with the water))
7	C	Liu	我们 还 有 一个 方 法 *We have another way* wǒmen hái yǒu yīgè fang fǎ ((Liu glances at Sun)) 是 把 这个 *Yes this* Shì bǎ zhè ge ((Liu points to cup and Sun glances at cup)) 打 开: *turn on* Dǎ kāi 如果 这个 *If this* Rú guǒ zhè ge ((Liu pointed at the tray and looked at sun. Sun glanced at the tray. Wang turned to look for xiao)) 一 不 小心, 镊 子 掉 的 话, 我们 马 上 浇灭它 浇灭它 *No be careful, if we drop the cloth we must extinguish it.* Yí bù xiǎo xīn, niè zi diào de huà , wǒ men mǎ shàng jiāo miè tā jiāo miè tā
8	F	Sun	现在 干 嘛呢, (0.2s) *What are you doing now* ((Liu looks at Sun)) Xiàn zài gàn ma ne, (0.2s) 每种 两 块 肯 定 试两 次 *Will test two pieces of each twice* měi zhǒng liǎng kuài kěn dìng shì liǎng cì。((Wang raises his hand and turns his body. Sun touches the cloth, Liu watches Sun, Qiao/Guo play with water))
9	E	Wang	肖 老师::: *Teacher Xiao* xiāo lǎoshī ::: ((Wang/Liu raise a hand and turn, with Sun, toward Xiao))
10	E D	All	((Sun turns and walks away with Wang. Liu put down his hands and rubbed them in front of his chest. Qiao/Guo still play with water))

The actions by Wang and Qiao to attract Xiao's attention at turn 6 evidences a shared idea around their desire to have their group's candle ignited by the teacher, notated as topic E. However, Liu remains concerned about his safety question in turn 5 from fragment 1, which re-appears in fragment 2, turn 7, where Liu glances at Sun, makes reference to the beaker, and indicates how the water may be used to extinguish the fire if required, notated as topic C. At the end of turn 8, Sun begins to talk to himself with the utterance "现在 干 嘛 呢 Xiàn zài gàn ma ne *What should we do now now*," which is followed by a pause. Sun then continues at turn 8 with his idea about how many tests they should perform on each piece of cloth with, "每种 两 块 肯 定 试 两 次 měi zhǒng liǎng kuài kěn ding shì liǎng cì *will test two pieces of each twice*." This new idea is shown as topic F in episode 2, fragment 2. Meanwhile, Wang still has his hand raised at turn 9, Qiao has lowered his hand and gone back to playing with the water (i.e., topic D), and Liu now has his hand raised to also attract Xiao's attention (i.e., topic E). At turn 9, Wang loudly calls "肖 老师::: xiāo lǎoshī ::: *Teacher Xiao*" with an elongation of "shi:::" in an effort to attract the teacher's attention within a loud classroom. Finally, at turn 10, following teacher Xiao's non-response to their calls, Wang and Sun both walk away from the group to speak to Xiao face-to-face.

Throughout episode 2, fragment 2, we observe further diversity in topics as noted with E, C, F, and D in the transcript. These topics relate to different aspects of the methods for the inquiry activity, which the students are developing as they proceed in an uncoordinated and disjointed effort. Physical dispersion of the group is evident in the actions described at turn 9.

Harmony, emotion, and intensity

In this next episode, the students have regrouped. In episode 3, turn 1, Sun performs a fire test on the blue cloth, with Wang, Qiao, and Guo watching closely, and Liu watching while he also plays with a pipette, in the video.

Fig. 2 Turn 2, Wang (left) laughs, Sun holds the burning cloth, and others look attentively

Episode 3: Blue and Red cloth are not fireproof

1	All	((Sun took the blue cloth with tweezers and burned it on the candle flame. Wang, qiao and guo are all focusing on the fire test of blue cloth))
2	Wang	啊：：：?吓 死了 *<<surprise-fear>>* ā：：：? xià sǐ le ((Wang's upper body rose from the table to the whole body. Sun put the burning blue cloth into the beaker; Qiao's eyes fix on the blue fabric; Guo watched silently)) 哇：：： 不 是 防 火 的 *wow::: it is not fire proof* wā：：： bú shì fang huǒ de ((Liu's eyes moved from the pipette to the blue cloth, but continued to move his hands, took a small step back))
3	Liu	
4	All	((All watched Sun conduct a fire test with tweezers and a red cloth, drops fire into water; Liu kept fiddling with the pipette))
5	Wang	不 是 防 火 的，红 色 也 不 是 防 火 的 *It is not fireproof, red cloth is not fireproof* bú shì fang huǒ de, hóng sè yě bú shì fang huǒ de

At turn 2, Wang responds loudly to the blue cloth burning with, "啊:::?吓 死了ā::: ? xià sǐ le *I was scared*," where the elongated utterance of "ā" is a common expression of surprise in Chinese language (Zheng, 2017), and the phrase "xià sǐ le" expresses a feeling of fearful surprise. Wang's utterance was quite loud and accompanied by him pulling his head and upper body back away from the cloth that was burning vigorously. This response evidences his high-intensity physical focus on the cloth and Sun's actions. Wang's surprise was shared by Liu evident with his loud expression of "哇::: 不 是 防 火 的 wā::: bú shì fang huǒ de *wow::: it is not fire proof*." Liu's response mirrored Wang's response and also stated an inference about the burning cloth in that it is highly flammable. This moment was shared by all group members with their actions evidencing a high level of intensity in EE, shown in Fig. 2.

High-intensity EE is evident in Fig. 2 as all five students have moved closer to the burning fabric, with a shared focal point for their facial and eye alignment. This physical alignment is one aspect of intense EE that is supported further by the increased collectivity around ideas in episode 3 as shown in the transcript.

Harmony and student-centered ideas

In episode 4, we illustrate the achievement of harmony around student-centered ideas. The basis for our interpretations is evident across two fragments in episode 4 that we have labelled as (1) creating space for collective writing, and (2) new shared ideas. Episode 4, fragment 1 commences at turn 1 with Wang asking "抹布?抹布要了干嘛? mā bù ?mā bù yào le gàn ma ?*A rag? Why would you want a rag?*"

Episode 4, Fragment 1: Creating space for collective writing

1	Wang	抹布？抹布要了干嘛？*A rag? Why would you want a rag?* mā bù ？mā bù yào le gàn ma ？ ((Wang took a look at the rag on the right, put down the pen that filled in the worksheet, and picked up the rag and put it on the left))
2	Sun	°擦°(.)°擦° ° *wipe °(.)° wipe °* °cā °(.)°cā ° ((Sun takes the rag to wipe the table))
3	Wang	哦。*Oh* Ó ((Wang nods and continues to fill out the learning form))
4	Qiao	还有蜡烛，和那个油*the candles, and the oil* hái yǒu là zhú, hé nà gè yóu((Qiao pointed to the learning form))

Wang's utterance is in response to Sun's request for the rag on the opposite side of the table, and this interrupts Wang who is starting to complete the worksheet on behalf of the group. At turn 2, Sun explains that he wants to wipe the water from the workspace and Wang passes the rag across to Sun. This is an important action because cleaning the workspace creates a usable space for Sun to become involved in writing, which we observe in a subsequent turn. At the moment of turn 3, however, Wang returns to writing and Qiao contributes an idea to Wang's writing with the suggestion at turn 4 about "还有蜡烛，和那个油hái yǒu là zhú, hé nà gè yóu *the candles, and the oil*." Fragment 1 is important as it is the beginning of practices we may identify as collective writing involving entrainment of the

group toward mutually constructed ideas as indicated in the actions of Wang and Sun in Fig. 3: Wang is writing and Sun is cleaning the space for the group to participate in writing.

In Fig. 3, Wang is completing the upper half of the worksheet comprising a table for making notes about the three types of cloth (red, blue, and purple). Once the workspace is clean, Wang looks at Sun and asks "蓝色布料是什么来着? lán sè bù liào shì shenme lái zhe? *What is the function of blue cloth?*" in episode 4, fragment 2, turn 1.

Episode 4, Fragment 2: New shared ideas

1	Wang	蓝色布料是什么来着？*What is the function of blue cloth?* lán sè bù liào shì shenme lái zhe ？ ((Wang writes and looks at sun))
2	Sun	蓝色布料，蓝色布料的是:::= *The blue cloth, The blue cloth is:::=* lán sè bù liào , lán sè bù liào de shì :::= ((Wang holds his chin and watches Sun fill out the learning form))
3	Wang	=先填紫色布料，防火 *Write purple cloth first Fireproof* =xiān tián zǐ sè bù liào , fáng huǒ ((Wang looks at Sun and the worksheet))
4	Sun	对，紫色布料防火*Yes, purple cloth is fireproof* duì , zǐ sè bù liào fáng huǒ. ((Sun pointed his finger at the worksheet, remainder of group watch Sun and Wang))
5	Wang	((After getting Sun's affirmative answer, Wang marked the "fire prevention" function of purple cloth))

In episode 4, fragment 2, turn 2, Sun attempts to make a comment about the blue cloth but is unable to make a clear statement. Wang responds at turn 3 with "=先填紫色布料, 防火 =xiān tián zǐ sè bù liào, fáng huǒ *Write purple cloth first Fireproof*" and confirms Wang's utterance at turn 4 whereupon Wang marks the worksheet at turn 5. This ongoing sharing of ideas in response to the worksheet and stepwise completion of the worksheet as a group activity is observed by Liu, Qiao, and Guo who are standing around the workspace and watching the writing activity. This process unfolds fluently suggesting there is no disagreement from group members. In this way, the worksheet begins to be filled in with ideas that are uttered and confirmed within the group. In the video, once the table part of the worksheet is completed, Sun takes the worksheet and pen from Wang, who does not oppose this action, and Sun fills words into blank spaces in some sentences at the lower part of the worksheet. As he completes these responses Wang and Liu look closely at the worksheet, before it is left by Sun on the workspace. No further contributions are made by other group members, suggesting they are satisfied with the recorded ideas.

Discussion

Our study extends previous research by refining Confucian conceptualizations of harmony and uniformity, and illustrating possible ways in which these concepts may appear as social phenomena through interactions in a STEM classroom. We have specifically considered teacher-centered and student-centered phases of a STEM inquiry lesson in a Chinese classroom. We have also considered the interplay between uniformity, harmony, proportionality, and EE, during student experiences of classroom interactions, to synthesize conceptual links that may be useful in advancing knowledge in this novel area of STEM education research.

Student experiences of uniformity

Previous studies suggest uniformity as a feature of Confucian heritage classrooms is inconsistent with learning through student-centered STEM projects (H ng et al. 2015; Huang and Asghar, 2018; Thao-Do and Yuenyong, 2017). As noted earlier, these studies tend to conflate harmony and uniformity as simultaneous experiences evident through passive learning and avoidance of argumentation. However, in the present study, we interpret the practices in episode 1 as an example of *uniformity* of ideas through the Confucian notion of *t'ung* (Fung, 1976), which is the social achievement of conformance

Fig. 3 At turn 2, Wang (left) is writing, and Sun (2nd left) is wiping the table

with uniform ideas. In episode 1, the ideas presented are teacher generated and reproduced by students through a highly disciplined and practiced, ritual, without any scope for divergent thinking, such as students introducing new ideas.

Practices of uniformity were at the initial phase of the lesson we explored, and within several minutes the lesson transformed into being student-centered. In this situation, uniformity may have been useful because it focused the students on the topic of fabrication and materials, which was relevant for the project that followed where the qualities of materials were tested through guided inquiry. In this way, the practices achieving an experience of uniformity may provide an opportunity to revise familiar ideas with students, and to achieve a mutual focus across the class, as a lead into the ensuing lesson.

Teaching practices leading to uniformity of ideas may therefore have an emotive purpose to focus collective attentiveness, rather than an immediate learning purpose. This would be important before releasing a group of 10-year-olds into a student-centered inquiry, and indicates the relevance of some uniformity in this form of STEM teaching. In our study of episode 1, the achievement of uniformity could also be interpreted contemporaneously with EE. Emotional energy is evident as the level of mutual attentiveness and self-awareness of bodily practices throughout episode 1. For example, on the teacher's command of "qǐ lì," the class stood to attention, greeted the teacher in unison, and then sat in a ritualized bodily position common across the class. Bodily entrainment was also evident in speech acts such as Xiao's mimicry of Chen at turns 6–7, which also evidences the alignment of ideas and a level of fluency indicative of shared feelings and mutual attentiveness (cf. Davis and Bellocchi, 2018). Although it may be argued that there was limited evidence that all students shared the same STEM-related ideas, the coordinated, rhythmic actions of students illustrated a high degree of self- and other-awareness as each student played their part in the performance of this classroom ritual. On this basis, teaching practices that achieve uniformity at the start of a lesson may offer value in terms of emotive outcomes such as high-intensity shared attentiveness and achieving a sense of togetherness or EE. This emotional achievement sets the tone of the lesson before the class launches into student-centered learning. For this reason, the experiences of uniformity and EE at the start of a STEM inquiry may contribute to the remainder of the lesson.

Experiences of proportionality and diversity

As noted in our conceptual framing to this study, our Confucian notion of harmony is achieved through a process of proportionality (i.e., Chung) involving the mixing of diverse ideas (Fung, 1976). Previous studies of harmony in STEM education have not explored this notion of proportionality in terms of what it may mean or what it may look like in practice. We have described this process throughout episode 2 showing how different ideas and different foci for individual attentiveness are being established. Each student is exploring possible methods for the inquiry activity, but in an individualized and uncoordinated manner. These different actions provide evidence of different practices and different ideas which we interpret as a high level of *diversity* in ideas and attentiveness. In practice, some teachers may regard these moments of interaction as disorderly. For example, actions by the student Guo, who is playing with the water on his own, may be considered by teachers as being off-task. Similarly the robust discussion in episode 2 between Sun and Liu about how to hold the tweezers may also be considered minor and irrelevant to learning STEM. Our counter-argument to these views is that episode 2 shows the messiness of doing a STEM inquiry (McLaughlin and MacFadden, 2014), where students are exploring real STEM phenomena and their own methods for exploration through inquiry. The particularities of student-centered learning are also non-linear in that the topics of interaction across episode 2 appear to jump from idea to idea, often with more than one idea being discussed at the same time. Importantly, some ideas disappear, while some endure across the interaction, and it is the enduring ideas that shape later episodes. For example, Liu's persistence with the idea on how to control the fire by using the water starts at episode 2, turn 5, is ignored at turn 6 and Liu mentions it further at turn 7. This idea is then dropped as an interactional topic and is performed later through Sun's actions at episode 3, turn 4, when he drops the fire into the beaker of water. By following this idea initiated earlier by Liu and acted upon later by Sun, we are able to show how shared ideas may unfold over time through social interaction in a student-centered context. The complexity of non-linear and sometimes playful practices for forming shared ideas needs to be appreciated when seeking to understand learning through doing STEM projects (cf. Tobin, 2006).

To understand the emotive processes of these practices, we interpret episode 2 as low-intensity EE because of the lack of mutual bodily entrainment toward any particular shared object. Also there was much diversity of ideas as shown by the different foci by Sun, Wang, and Guo throughout episode 2, fragment 1. A final indicator of low-intensity EE is the lack of fluency in the interaction, which is most evident in Fig. 1 where Sun and Liu have a disagreement about their inquiry methods. This disagreement evidences a lack of fluency or low collectivity in feelings toward one another's ideas and actions, and on this basis, it provides evidence of low-intensity EE.

In the present study, we propose that episode 2 illustrates students experiencing the Confucian notion of proportionality through the introduction of different ideas as contributions to the overall endeavor of their STEM project. Not all ideas are accepted within the group, but each contributes to the mix and is considered part of the interactional processes. In the context of science inquiry projects in non-Chinese schools, similar episodes involving diverse ideas are described. For example, Roth and Tobin (2010) describe student disagreement about science inquiry ideas as form of conflict, and Menekse, Purzer, and Heo (2019) describe similar processes of conflict as part of the learning practices in an engineering context. In a further study, Davis and Bellocchi (2020) describe a science inquiry project where the topic changes several times, evidencing conflict that rapidly resolves into quieter moments of shared scientific observation.

In studies of non-Confucian heritage classrooms, student discussions of diverse ideas are described as conflict, consistent with argumentation and confrontation (cf. Davis and Bellocchi, 2018; Roth and Tobin, 2010). In the Chinese context, similar actions also appear in student-centered situations, but as we have shown, these may be interpreted as a process of proportionality for working with diversity when moving toward harmony. It is not so much student-actions that are different, but the ways we might interpret these actions and experiences from differing cultural perspectives. With harmony and proportionality being such deeply embedded features of Confucian cultures, we adopt the view that addressing diversity and difference in everyday social interactions is regarded to be non-confrontational. Yet, this does not mean harmony equates to uniformity. It may be more reasonable to interpret proportionality during moments of diversity and difference as a culturally specific form of argumentation that is not regarded as conflict within Confucian cultures. This reframing of diversity, difference, proportionality, and conflict has implications for STEM education across international and inter-cultural contexts. It means that we should view social constructivist, student-centered STEM inquiry as form of teaching to be consistent with Confucian cultures, where learning and emotions are experienced and interpreted differently, compared with non-Confucian cultures.

Student experiences of harmony

As the students in this study progress through their project, the diversity of ideas tends to diminish. This does not occur through any overtly planned actions to achieve harmony. Instead, we simply see a change in the way the group interactions take shape. An example of these changes is evident in episode 3 where the students have acquired a flame on their candle as a source of fire to test the fabric materials for flammability. This unifies the group so that they experience high levels of mutual attentiveness around the fire and in relation to their mutual responses. For instance, when the flame erupts suddenly, the whole group move back from the flame, two of the students make utterances indicating experiences of fear and surprise. What makes episode 3 an example of harmony, which is different to uniformity in episode 1, is that harmony was achieved through a naturalistic, self-organizing quality of social interaction. There was no teacher or dominant student to impose consensus or uniformity in the ideas being performed. Students' mutual attentiveness, shared focus, and shared ideas were achieved through a natural confluence of all the previous ideas and interactions the students had experienced during the lesson.

A further interpretation of episode 3 relates to its qualities of intense dramatic EE that involves intense focus, sudden movements, and loud utterances. Although showing evidence of loudness and surprise we interpreted this episode as an illustration of harmony because of the focus on similar ideas such as the flammable materials and the sharing of similar emotional experiences. These moments in episode 3 are clearly different, more focused than episode 2, showing greater evidence of shared emotionality.

The self-coordinating character of harmony that is clearly different to the imposed character of uniformity continues to be evident in episode 4. However, in episode 4, harmony is contemporaneous with a shift in EE that remains intense, but becomes more subdued and less dramatic than it appeared in episode 3. In episode 4, we observe a shift in practices away from collective observation in the inquiry and toward the practice of collective writing as the students complete their lesson worksheet (cf. Davis, 2017). As we saw in episode 4, there was no announcement about collective writing. One student started to read the worksheet, others started to make space so that the worksheet could be shared, and then students contributed ideas that were recorded by two self-appointed scribes. In this way, the worksheet became a focus for the harmonization of ideas that was performed by students efficiently and quietly. Given the common place of worksheets in STEM projects (cf. Davis and Bellocchi, 2018), we argue that such moments of harmony are ritualistic, but this remains different from the ritual of uniformity described in the early part of the lesson. The difference being that harmony involves a self-organizing social order leading to the synthesis of shared ideas out of diversity and difference.

Synthesis of concepts

This study contributes to our understanding of student experiences in Confucian heritage classrooms where

student-centered STEM projects may be used as a teaching strategy. We suggest that uniformity and harmony are two different concepts that should not be conflated and may be identified through different interactional practices in STEM classrooms. We have also established a practice-based example of proportionality in the mixing of diverse ideas as a prelude to achieving new shared ideas as a form of harmony. Practices of proportionality may appear similar to practices of conflict described in non-Confucian settings. We suggest that the difference between conflict, or argumentation, in non-Confucian classrooms, compared with proportionality in Confucian classrooms may be the way these experiences are culturally interpreted. This interpretation is consistent with other studies of emotional experience, where similar events may be interpreted and experienced differently by different people (Collins, 2004).

A further advancement of knowledge in this study is the interpretation of EE contemporaneously with interpretations of uniformity, proportionality, diversity, and harmony. These Confucian conceptualizations of students' experiences are useful in refining the description of EE as a social phenomenon in STEM classrooms. We have described how uniformity and harmony may be both associated with intense EE, and how uniformity may be productive of ongoing EE to support a subsequent student-centered STEM inquiry. Further, we have shown in this study how intensity of EE may diminish during experiences of proportionality. This is an important observation requiring further research, because periods of low EE are often avoided by people (Collins, 2004) and may lead to student disengagement. Understanding how students can maintain engagement across these low-intensity EE durations of a STEM inquiry are therefore important for STEM educators. Finally, in the achievement of harmony, we illustrate the possibility for both dramatic and undramatic forms of EE. These different forms of EE are important to acknowledge because they are observable in different ways, and the least noticeable undramatic form is often the most important in everyday situations (Collins, 2004), as well as in STEM inquiry contexts (Davis and Bellocchi, 2018).

Conclusions

This paper makes important contributions to studies of emotion in STEM education. Firstly, our study extends the field of emotions in STEM education research beyond self-report forms of research design to explore different conceptualizations and understandings of emotive experiences as observable social phenomena in STEM classrooms (Ritchie and Tobin, 2018). This was achieved with a social, phenomenological orientation to explore emotive experiences that may not be noticed by people in the experience (Davis, 2017). On this basis, our study extends previous research from science education into the broader field of STEM education. Secondly, we have explored the nuances of emotive experiences and social actions in Confucian heritage STEM classrooms by refining conceptualizations of harmony and uniformity (cf. Hằng et al. 2015; Huang and Asghar, 2018; Thao-do and Yuenyong, 2017). We propose that harmony and uniformity are two mutually exclusive concepts arising out of different forms of empirically observable micro-social interaction. To illustrate this in relation to previous science education research, we focused our analysis on teacher-centered and student-centered practices of interaction in a STEM classroom. Thirdly, the notion that Confucian heritage STEM classrooms are inconsistent with argumentation, difference, diversity, and social constructivist learning is strongly challenged by our study (cf. Hằng et al. 2015). We have explored the diversity of ideas in this study as they unfold in a student-centered STEM inquiry project. This exploration shows student engagement with diverse ideas that we explain through a process of proportionality, commonly described as *the middle way* in China (Chenxi, 2018), as being important for the achievement of harmony. We claim that argumentation, difference, and diversity *is consistent* with Confucian cultures, and we suggest social constructivist approaches to STEM education could be re-interpreted and re-framed through Confucian cultural perspectives. Finally, this study integrates Confucian emotive perspectives with emotional energy illustrating both conceptual connectivity and practical examples that will support future research into emotions in STEM in different cultural contexts.

Limitations

In STEM education research, this is a novel investigation into emotional experiences of students in a naturalistic inquiry context using a social, phenomenological (Davis, 2017; Liberman 2013) approach to explore emotional energy (Roth and Tobin, 2010; Tobin, 2006) in a Confucian heritage culture (H ng et al. 2015; Huang and Asghar, 2018). Until further studies of STEM education are conducted using similar methodological approaches across similar contexts, the transferability of this study will be limited. This study also developed a novel conceptual framing (Fung, 1976) to explore Confucian heritage STEM classrooms that challenges previous conceptions drawn from teachers' everyday understandings (H ng et al. 2015; Huang and Asghar, 2018). This exposes a theoretical limitation of this study as we establish novel ideas at conceptual and practical levels of analysis requiring further exploration in future studies. Further emotive concepts also need exploration including the notion of passivity in STEM classrooms (Thao-do and Yuenyong, 2017). Finally, all studies of emotion are limited because their research instruments always shape the emotive phenomena to be

explored and understood. This limitation extends from quantitative self-report studies (cf. Lehtamo et al. 2018) to the present phenomenological study. As interpretive researchers, we recognized ourselves as the primary analytical instrument in this study. We have mitigated the limitations of our study by being explicit in our philosophical or methodological stance, by defining our conceptual framing, and by detailing our data quality criteria.

Future research

The novelty of this paper in integrating Confucian heritage studies and studies of emotion in STEM education opens many possibilities for future research. The nuances we have identified in conceptualizing notions such as harmony and uniformity, and operationalizing these in the practice contexts of student-centered STEM inquiry projects presents opportunities for future investigation. For example, exploring relationships between low-intensity EE as an impediment to engagement during processes of proportionality in student-centered STEM inquiry is an issue we noted in this study. That issue may be related to intercultural interpretations of conflict and proportionality when addressing diverse ideas and argumentation in STEM classrooms. Reconciling argumentation and proportionality may also improve teachers' everyday understandings about possible cohesion and consistency between social constructivist teaching in STEM and Confucian heritage classroom cultures. A further possibility is to apply the methodology and emotive conceptualizations of our study to explore the nuances of STEM education in other cultural contexts such as indigenous cultures or school sub-cultures where students are disengaged. Finally, there is the possibility for the cultural adaptation of EE in the way we understand the concept and lived experiences of EE as a social phenomenon in different school and classroom cultures. This is particularly important if EE is to be understood in non-Western cultures, because the philosophical foundations of EE are Anglo-Euro-American centric. Extending such understanding was our motivation for this study.

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Authors' contributions

JPD led the project and was a major contributor in methodology development, analyses, and writing. JPD, JD, JHT, LQ, and YQL collected, transcribed, and analyzed data, and contributed to writing of the "Findings" and "Discussion" sections. FKC reviewed the data analysis and wrote at various stages of the project. JD coordinated field work and obtained informed consents. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. Due to ethical restrictions video and audio data are not available.

Ethics approval and consent to participate

This study was approved by the Queensland University of Technology Human Research Ethics Committee in accordance with Australian and international standards. The participating school principal, teachers, students, and parent/guardian for each student, provided written informed consent to participate in this study and to publish images, in QUT approved formats, written in Chinese (simplified). All participants provided consent before fieldwork commenced.

Consent for publication

The authors confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

Competing interests

The authors declare that they have no competing interests.

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