Exploring the epistemic equity among physics teachers' agency to support inclusivity in learning

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Abstract: This study considers how the learning of physics is powered by culture, language, and subject matter to enable equity to be obtained. We analyse how teachers come to understand the Form 4 physics students' sense making and establish their expectations regarding the learning outcome. This paper draws attention to a discourse analysis of 44 physics lessons from 4 physics teachers at Malaysian Elementary Schools about the epistemic equity of teachers' discourse when assigning value to physics ideas. The data collected for this study is audio video recordings focusing on how well the teachers' agency helps to reposition students as the knowledge producer. This study examines what social conditions constitute teachers' discursive practice during the meaning making process. Three types of social condition, known as elicit, rhetorical, and conclusive, are identified and presented as discourse moves. From our findings, we provide recommendations for policy makers' and teachers' agency to start setting rational goals of inclusivity that could enhance equity in elementary physics education. The recommendations aim at disrupting the historical inequitable structures that exist between the teacher and the students. This study argues for a reconceptualization of pedagogic discourse to accommodate the transformation of social interaction in the physics classroom. The discourse analysis provides teachers with a didactical awareness of how to empower and disempower students.

Keywords: scientific epistemology, classroom interaction, discourse analysis, equity in science education

Introduction

Equity in science education stems from concerns about alienation towards STEM subjects and weak scientific literacy. When Malaysian students managed to score only below average levels for international level tests in 2011 and 2012 (as reported in Malaysia Education Blueprint 2012-2025 (MOE, 2012)), it affected many policy decisions and practices in science education. The Ministry thus became committed to increasing the enrolment in STEM classes and aiming for quality education by leveraging ICT into the teaching and learning process (MOE, 2012). Regarding the education blueprints, ICT is seen as the platform that helps with the transition from a teacher-centred to a student-centred instructional strategy. The initiatives aim to make science content and delivery more attractive to students (MOE, 2012). However, given the continuing problem of decelerating enrolment in STEM classes (Phang et al, 2014), we must explore the need to reframe what equity means and looks like in the physics classroom. This study addresses the issues regarding teachers' agency when teaching physics in Malaysia and how these create epistemic equity for the students during instructional implementation. In an effort to improve critical education outcomes for under-represented groups, especially low-performance students, this study firstly describes how the equality and equity agenda focuses on epistemic equity and how it reflects upon the transformation aiming for a better quality STEM education.

The need for epistemic equity for using ICT in Physics Education

The learning environment in Malaysia is experiencing changes due to the explosion of multimedia into teaching and learning like the 1BestariNet project through the Virtual Learning Environment (VLE) frog. The project was launched by the Ministry of Education in 2011 (MOE, 2012) as one of the initiatives to provide public school students with equal access to learning. Our government has invested millions (MOE, 2010) in teachers and schools through a variety of initiatives, like the Computer in Education Programme and the ICT Literacy Programme for secondary schools (Curriculum Development Centre, 2007) as well as educational and teaching software and training. When the commitment is to greater accessibility, the teachers accommodate new instructional strategies. Their knowledge is required to design a learning environment that allows students to fully participate in the learning and to tailor the learning to their own needs. This allows the implementation to overcome the issues of inequality of access to learning as stated in the education blueprint (MOE, 2012).

However, generally, the instructional strategies remain unchanged because according to Alazam et al (2012) the manner of correctly integrating ICT within classroom is weak among the teachers. The basic assumption of this learning transformation remains a matter of shaping learners' responses through instructional strategy (Palinscar, 2005), thus making it difficult for the transition to a student-centred strategy as intended by the policy makers to reduce issues of equity. Therefore, it invites more criticisms about the investment in ICT when it becomes a mere teaching tool for teachers and students. We believe that the discussion by the policy makers has been useful in moulding the transformational learning, as the equality agenda aims to provide fair learning opportunities. Consequently, only those students who obtain brilliant academic credentials gained the most benefit from this initiative because of the exam-oriented system that requires them to fully utilize the learning resources. Nurul Awanis et al. (2011) criticized how the exam-oriented norm has influenced most of the decision making made during teaching and learning. Looking at this argument, the changes in the policy debates on these issues somehow have not changed the outcomes in educational institution. Even though equity and equality share common concerns and ends, we argue that the equitable issues in science education cannot be solved with equality initiatives alone. Thus, asking teachers to simply incorporate ICT into teaching does not help transform the learning environment. A greater specification on what kind of physics must be part of the learning environment when using ICT in science classroom is needed.

Looking at this issue, Rodriguez et al. (2012, pp 1) claimed that equity in physics education focuses on how '*different learning environments impact diverse learners*' as a method of supporting high academic goals. The learning environment referred to in the Realist Theory of Reality by Bhaskar (2008) is represented by the stratification of real, actual and empirical domains. The current movements and debates for change in equity focus on the education institution, which is the actual domain. The actual domain is represented by the initiatives that require more enrolment in STEM classes and improvements in students' achievement despite their differences. However, according to Bhaskar (2008), the real domain is the reality that is capable of producing change. 'Real domain' is just using a more academic terminology to refer to the condition created by the learning environment, which is mostly characterized by the teachers' agency. Knowledge about the condition that permits the changes to happen reflects upon the scientific epistemology of the teacher, which can be observed through their discussions. Scientific epistemology investigates the origin, scope, nature, and limitation of knowledge during knowledge construction (Boyd et al., 1991). Therefore, to bring about a transformation in education requires findings ways of organizing knowledge to support the instructional strategy.

The manner in which physics teaching is treated in the context of Malaysia differs from in developed countries. The norms of physics teaching involve following a standard curriculum structure, and new instructional strategies are decided by the Ministry of Education. The physics subject is generally known for being difficult due it being conceptually abstract (Erisnosho, 2013), which means it can be challenging for teachers to deliver the content. Therefore, it is not surprising that Pandian and Balraj (2010) reported that teachers are employing multiple instructional strategies to make learning more engaging. Their finding showed that Malaysian teachers understand the need to engage students during knowledge construction. However, engaging students and empowering participation are two different issues. Engaging students, from a philosophical perspective, requires a curriculum design that enables students to achieve an improvement in their scientific epistemology. This means that being engaged in learning requires a consensus-building dynamic (Duschl, 2008) to be present in knowledge building communities, such as those formed by teachers and students. Teachers must be able to design a learning environment that empowers students to exercise their epistemic agency. Nonetheless, current studies about the liabilities and powers on teachers discourse have discussed them only as equality issues when Malaysia is changing the mode of language of instruction between the Malaysian language and English language. Duschl (2008) further explained that this dynamic can only be examined through the argumentation which is the discourse between teachers and students. The communicative setting developed in the learning environment helps students to choose what counts as knowledge (Kelly, McDonald and Wickman, 2012) and this setting helps with personalizing learning. Hence, personalizing learning requires an understanding about different discourse contexts and in what way this affords students different ways of understanding the same topic. Following this, equity in science education demands a consideration of the epistemic equity issues. Referring back to Rodriguez et al. (2012), the epistemic equity goals can be translated as promoting accessibility when deciding what and whose knowledge counts. For the penetration of ICT to be meaningful, epistemic equity must not be studied in isolation from the design process for the new learning environment.

The Epistemological Foundation for ICT in Science Education

We also argued that the previous finding is insufficient to account for how individuals function as a classroom community. Our work is in the line of social constructivism theory in which learning occurs as a result of socialization (Vygostsky, 1978). Vygotsky (1978) understood that learning occurs when students socialise among themselves to scaffold new learning. The Malaysian science curriculum shares a similar view with Vygotsky where the teaching of physics requires active participation from students. An ideal science education, according to Erduran (2013), requires teachers to create an environment where students can participate in socially valuable discourse involving argumentation. The learning experience is viewed as the students being scientists themselves rather than simply doing science; thus, accelerating thinking activities becomes the main agenda.

Two pedagogical practices inherent to the approach of teaching physics as science practice are dialogic and argumentation (Erduran, 2013).

A research study in the southern region of Malaysia confirmed that teachers' epistemic understanding is the predictive variable for students' epistemological development (Abd Rahman & Phang, 2017; Abd Rahman, 2013). Epistemology is an essential debate when it comes to understanding the norm of scientific practice in the classroom. However, to begin a debate about the epistemological norm in the context of Malaysian science education, a deeper understanding is needed to appreciate the social system which supports the norm. From the literature, discursive practice is considered one of the most influential pedagogies in teaching. The interest in teacher-students interaction has inspired many scholars to understand the discourse for their development, role, and function during teaching and learning. Turning to the Malaysian context of education, this stance toward exploring discursive practice had previously been discussed regarding students' cognitive attainment at an individual level. Research by Tan and Arshad (2014) examined the cognitive level of questions ranging from low order to higher order questions. In the study, teachers and students applied a problem-based learning (PBL) approach and showed an improvement based on an increased number of questions posed by students. However, the actual concern arose when only a small percentage of the questions were categorized as belonging to the higher order level. The interest in cognitive accomplishment in this study, however, is limited to explaining the actual contexts that prevent the transition from low order to high order questions. Ahmad et al. (2012) argued in their study that the teacher-centred approach remains prevalent among Malaysian teachers. They concluded that teachers' pedagogical practice is unproductive because of the teachers' authoritative position. The study implied that teaching in Malaysia is very traditional, as it is far from being an ideal place to cultivate critical and creative thinking. Following this, the social system is recognized as the governance to cultivate the thinking process among students. However, while the study provided few details about the form of social system, Ahmad et al. (2012) stated that the intention is to create an active learning environment that will allow students to not only engage actively but also to think actively in the classroom. Such a view is coherent with the outcome of epistemic equity. Achieving epistemic equity requires teachers to provide an environment that enables the practice of thinking to be visible.

To view meaning-making as a social system, a cultural turn is necessary to understand what governs the learning process. Moving to a sociocultural perspective, Vygotsky (1978) suggested focusing on discourse and practices at a social level. This interpretation is supported by Bybee (2012), who emphasized the significance of social discourse to the expansion of inquiry. Teaching 'physics as practice' is a common term used by many scholars who work within the argumentation or nature of science areas to describe the enculturance practices of science in the classroom. Here, physics is treated as a scientific practice rather than a mere subject. In this study, we approach the issue from a sociocultural perspective to explore how discursive practices are staged in a physics lesson. The social turn provided by the science discourse has a great influence on a variety of cognitive functions which has been previously explained in studies by Yunus et al. (2004), Ahmad et al. (2012), and Tan and Arshad (2014). In this article, we are interested in the social system created by teachers' discursive practices. The dialogue is examined to understand

(a) the discourse moves that prevail during teacher-students interaction
(b) the social role carried by a discourse move to privilege certain types of knowledge as important while others are excluded.

Methodology

Our study took place at four secondary public schools in Johor, Malaysia. Four physics teachers volunteered to participate in this study, and they were observed for four months. During teaching, they cooperated by using PowerPoint slides and short videos as part of the research process. The entire lessons were video recorded using an audio video recorder resulting in a total of 44 audio video recordings. As observers, we acknowledged that our presence might alter the norm of physics teaching, though the observation process was done in an overt way. This is titled the Hawthorne effect (Cook, 1967), which occurs during observation when teachers show an alteration to their teaching behaviour. To mitigate this issue, prolonged observations were done during data collection. The data analysis began with 44 transcripts of teacher-students interactions with a total duration of 3,080 hours of observations (from 60 to 80 minutes for each lesson equivalent for one period of lesson).

All samples showed a similar and consistent discursive practice despite their different teaching methods. We found similarities between teachers because their discursive practice was very limited regarding orientation with the students' discourse. During the discourse, the teachers demonstrated to the students their own system of values, known as epistemology, toward physics knowledge. A critical discourse analysis was employed using the analytical framework from Fairclough (2003), which emphasizes particular social problems within the utterances analysis. During analysis, each line of the utterances is repeatedly interpreted to identify the agency within the discourse. Line-by-line analysis was done in two phases to identify (i) the social problem later known as the agency and (ii) the social condition produced by the agency. The coding is done by taking into account the following sequences of a teacher's discourse that showed a similar social context.

Findings

This study aims to describe the social condition patterns that served as the mechanism for producing the learning environment. Prior to interpretation, we realized that despite the existence of teacher-students interaction, teachers' agency is arbitrary, and their utterance is considered as the absolute truth despite the inquiry process. In the analysis, teachers' agency is represented by their discourse moves. 'Discourse moves' is defined as any utterance that connects the communication with the ideas in physics. The discourse moves demonstrate agency presence when teachers begin to sculpture the explanations. Within the discourse, we successfully identified three norms of teacher's discourse, namely, elicit, rhetorical, and conclusive. These norms described how on a daily basis, these are the learning environment norms created by the teacher's discourse when teaching physics. The analysis is further done to identify which discourse move has a high potential for creating inequitable access to knowledge construction. The findings and analysis are summarized in Table 1.

Table 1: Learning environment produced by Teachers' Discourse Moves

Norms of utterance	Discourse moves	Descriptions
Elicit	Prompting	Instructions and demonstrations that increase the likelihood of obtaining correct responses or desired outcomes
	Seeking for info	simple bits of information
Rhetoric	Emphasis	stating the important fact explicitly or implicitly
Conclusive	Extends	extends current sequence by exploring
	Further details	contribution on same topic; adds to current sequence
	Consolidate	making a conclusion after discussion

During the interaction, three parties are involved in the sequences, namely, teacher (T), student (S), and classroom community (Ss). The physics teachers in this study used guided inquiry, confirmatory inquiry, and open inquiry as part of their instructional design.

<u>Elicit: When only questioning involved without prior references</u>

Two types of discourse moves emerge in this episode: 'prompting' and 'seeking for info'. 'Seeking for info' is more open-ended in nature where the purpose is not to undermine the student's answer. The nature of questions varies as the sequences move on whereas prompting usually showed a teacher's effort to induce students to give the correct answers. At this stage, the teachers did not make any claim or give any explanation prior to questioning. In Excerpt 1 below, the teacher made a move to explore students' prior knowledge about elasticity. The discourse move is coded as 'seeking for info' since it is only used to encourage students to think through and communicate their ideas.

Excerpt 1: Describing elasticity

Line	Utterances
1.	*T: This is last sub topic before we enter new chapter. Here, The last sub topic is about elasticity. Ok, what about elasticity that you know?* **(seek info)**
2.	*S: [female] Rubber.*
3.	*T: Rubber, anyone?* **(seek info)**
4.	*Ss: Spring.*
5.	*T: Hah, spring, anyone?* **(seek info)**
6.	*Ss: [male] Rubber gum.*
26.	*T: Spring is made from what?* **(prompting)**
27.	*Ss: Steel.*
28.	*T: Aah...metal, not steel. If that metal, we use it as it is, will it have elasticity?* **(prompting)**
29.	*Ss: No*

In a second episode, she made a move to prompt for a specific answer in line 26. In line 28, the teacher did not assert whether the answer is correct or wrong. In these excerpts, without confirming nor rejecting, the discourse moves are said to reorienting students' attention from focusing at teachers' answer scheme.

Rhetoric: When teachers gave a rhetorical explanation or asked a rhetorical question. This involved positioning teachers' values toward their ideas or the students' ideas

For this episode, the teachers' discourse moves appear to be rhetorical. Rhetorical discourse holds the greatest influence in the sequences in which it is re-orienteering students to view teachers as the final arbiter of knowledge. A series of prompts show the presence of the emphasize move to ensure the students are acknowledging the teacher's idea. For instance, in line 45, the teacher asked about the phenomenon when a rubber band is pulled. The question is specific because she used "what" instead of "how" to obtain a desired answer. Since students seem confused on what the teacher requires from them, majority of the them answered rubber. Later, the teacher prompted again in line 47, which emphasized students' unawareness about the particles' existence. The following moves were meant to persuade students to accept the idea about particles and elasticity. During this episode, her discourse moves are coded as emphasizing with an intention to leave an impact on students.

Excerpt 2: Describing activities of particles in elasticity

Line	Utterances
45.	*T: Stretch, not stiffen. what is actually expanding here (in rubber band) when it is being pulled?* ***(seek for info)***
46.	*S: Rubber*
47.	*T: Inside it, the rubber contains…? Particles?* ***(prompting)***
51.	*T: So, this one (rubber) will expand. It has particles inside it. So, since it is a rubber band, if you exert more force, the particles will meet closely just like this (diagram)* ***(emphasis)****. But, if you pull the rubber band, what will happen to the particles?* ***(prompting)***
52.	*Ss: Become longer*
53.	*T: Ok when you pull the particles, or this rubber, the particles will de.. (hint)* ***(prompting)****?*
54.	*Ss: Become longer*
55.	*T: Detached.* ***(emphasis)***

Conclusive: When teacher prompt series of question or explanation but not in rhetorical sense

There are three discourse moves that appear during this episode: extend, further details and consolidate. In Excerpt 3 below, the teacher talked about the relationship between force and length during elasticity. The conversation is guided to ensure that students are able to comprehend the ideas of Hook's law. From line 145, the teacher sought a causal relationship between variables. In the following sequence (line 149), the teacher begins to prompt for a hypothetical statement about the relationship between variables. Frequently, students could not provide an accurate sentence as demanded by the teacher.

Excerpt 3: Describing causal relationship between variables

Line	Utterances
145.	*T: Ok, when we pull with a small amount of force, what about the elongation?* ***(extend)***
146.	*Ss: Small*
147.	*T: Small, ok. If we use A huge amount of force, the elongation will be more…?* ***(extend)***
148.	*Ss: Lengthy*
149.	*T: Greater (emphasis). Ok, so what is the relationship between spring and force?* ***(prompt)***
150.	*Ss: The greater the force, the lengthier the spring can be.*
151.	*T: The higher the force, and…?* ***(consolidate)***
152.	*Ss: …the greater the elongation (reading answer)*

The teacher paid specific attention to the answer, as she prompted the question again in line 151 to achieve conclusive remarks. At this utterance, the discourse resembles rhetorical ways of imposing a correct answer. During this time, students might wonder or unaware why 'the lengthier the spring' is perceived as a correct answer. In contrast, the teacher's discourse moves are obviously intentional, as she realised the difference meaning between "elongation (extension of spring)" and "lengthier the spring (length of spring)". Both variables are significant in explaining Hook's law but behave differently during the phenomenon. Teachers might acknowledge students' ideas if the answer is correct and used it their own following utterance like Line 147. We coded the discourse move in line 147 as extending because the idea is used in a different circumstance. She made a comparative situation by manipulating the qualitative feature of force (e.g., what happens when a small force is exerted?). In line 151, she attempts another move, which is consolidating discussion. A closure is made as a reasoning attempt for students to accept the logic about the relationship between force and extension of spring. Discourse moves that constitute seeking further details did not happen in the excerpt above. This discourse is encountered when teachers prompt or provide a warrant to their claim.

Discussion

Planning a learning environment with a range of students' ideas and references is beneficial to reach an equitable classroom culture. Working with this notion requires a deep understanding about the epistemic equity established in the classroom. "Seeking for info" and "prompting" provide a freedom of thinking at an early stage, which allows students with different kinds of ideas background to share the same opportunity for brainstorming. Teachers used these moves to carefully elicit the information without giving pressurising students to give the correct answers. The discourse moves establish a norm that has frequent engagement with the students' ideas. Students at this stage are considered to receive the most equitable access to the knowledge construction process. Hence, equity can be reached when teachers are prioritizing fairness when students' ideas are used as the basis for knowledge progression.

When analysing the rhetorical norm, we become very cautious on how "emphasizing" is delivered to students. A discourse move that is used to emphasize can be interpreted as persuading or imposing. Emphasizing can be used as a method to impose knowledge through persuasion or to reach a mutual consensus. Matusov (2009) mentioned persuasion as a fundamental element for a good argument during discussions. Imposing is often shown when the teacher did not negotiate with the students. In line 51, the teacher persuades students using an alternative argument about the condition of a particle before it is stretched and later prompted about the following phenomenon. This move itself is a negotiation, but the teacher does not communicate the students' ideas. The persuasion becomes self-reasoning, as it only surfaces at the teacher's personal level with students. According to Villaroel et al. (2016), it is necessary for teachers to look not only for ideas that satisfy their own reasoning. The emphasis move that tends to impose meaning is seen to marginalize students' learning capacity. It is because teachers train students to think alike. From the findings, it can be concluded that a rhetorical learning environment can easily be orchestrated to privilege certain ideas and cause inequitable engagement during knowledge construction.

Following the rhetorical element, the teachers aimed to reconcile competing ideas among students and themselves, but in most ineffective way. The social condition established by the conclusive norm is quite argumentative, but it did not proceed the way argumentation should. For instance, during the consolidating move, in line 151, this teacher tagged the desired response which she expected from the students. The social condition that initially creates an opportunity for equitable access at a social level is impaired by the teacher's discourse move. Assessing the situation, we realized that directing the discussion to the desired outcome occurs because the teachers did not recognize the major feature of scientific argument existed in the classroom. At the same time, they did not have a consensus to manage multiple contributors during discussions. Without knowing these features, often they directed the argumentation process by tagging hints or the desired outcome to obtain a correct answer. This explains why the teachers' position becomes very authoritative despite the teachers' great efforts to engage with students during teaching.

To improve the learning environment, the rhetorical norm must tap into and negotiate the unappealing ideas for students to experience the argumentation process. Therefore, an argument shall not be taken as a means to justify correct ideas only because it will lead to bias to another participant. Without this consensus, teachers might overlook students attempt to provide an argument and impair the argumentation process. It is the same way with students, where they might reject the teachers' argument as it contradicts their own ideas. Therefore, teachers must escape the poor consequences of having confirmation bias by acknowledging students as the knowledge producers. The rhetorical and conclusive norms identified in this study are the checkpoint which requires plenty of instructional support that can nourish the foray into the social level of argumentation.

Direction for Further Study

The discourse moves are identified to shape the moment-to-moment progress of episodes during teaching and learning. The analysis yielded a few differences in teachers' discourse moves and how these moves are dominantly practised on a daily basis among physics teachers. These findings offer a cultural perspective which can be used to transform the learning environment. In order to facilitate educational transformation through ICT, further study is needed on how to use epistemic equity-oriented science teaching during the stage of instructional design.

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