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Extrapolating from Students' Preconception to "Scientific" Consensus: Singapore Secondary Students' Conversation on Earth

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The present study focuses on investigating the impact of commonly occurring ideas proposed by students on conceptual development during conversations on Earth's phenomena. More specifically, we examine the commonly used idea of "heat" as the starting point to explore students' mental models of Earth's phenomena and the process of students developing "scientific" consensus in the context of a small group discussion. The idea of "heat" was prevalent in the students' explanations of the occurrence of earthquakes and volcanic eruptions in both the previous study (Bezzi & Happs, 1994; Ross & Shuell, 1993) and the present study. We argue that the discourse around observable "heat"-related events is employed by students in their conversations to interpret and communicate the unobservable internal Earth dynamics, which might affect the students' conceptual development. Interviews were conducted with 20 Singaporean secondary school students to understand their preconceptions in Earth science by getting them to respond to open-ended questions through drawing and discussion. Based on the analysis of one group's (3 students) discourse, we found that 1) students' ideas of 'heat' are identified for facilitating their learning of the causality and dynamics inside the earth; and 2) the ideas of 'heat' facilitate students to develop more sophisticated and integrated explanations of the occurrence of earthquakes and volcanic eruptions. This was especially to make sense of the cause of plate movement and magma explosion - what Gobert (2000) called Integrated models. This paper presents students' preconceptions of the dynamics inside the earth, and provides information and implications on the development of an integrated model of Earth's phenomena.

Keywords: Earth Phenomena, conceptual understanding, preconceptions

Learning of scientific knowledge is not an easy matter. Researchers see that one of the main obstacles is students often entering a learning situation with preconceptions inconsistent with culturally-accepted scientific knowledge (Driver, Squires, Rushworth, & Wood-Robinson, 1994). Previous studies have suggested that preconceptions are often incorrect and impede deep understanding in formal science learning (Roschelle, 1995). The challenges are to understand the underlying meaning of preconceptions and find good ways to facilitate their change. Although previous studies have tried to identify students' existing ideas and find ways to facilitate conceptual change in various domains (such as physics, biology and chemistry), the research on existing ideas in earth science is limited (Dal, 2006).

Earth science has been perceived by students and educators as a complex aspect of geological learning. This is not only because the concepts of earth science are intangible and abstract, but also because the learning of these concepts is multi-dimensional, meaning that it requires an understanding of Earth's structure, materials, and processes. Especially, geological time and scales are the "critical barriers"

for students to develop scientific understanding (Dal, 2007). When learning complex topics in earth sciences such as plate tectonics and causes of volcanic eruptions, students may develop misconceptions. The concept of plate tectonics and causes of Earth's phenomena (i.e. volcanoes and earthquakes) are difficult to visualize solely through text and images presented in a textbook, and the problem is further compounded by how students often have their own preconceptions of Earth's systems.

This article attempts to describe how learners could develop their own ideas from preconceptions toward a "scientific" consensus in Earth science learning, in the case of Singapore secondary students' understanding of Earth phenomena (i.e., volcanoes and earthquakes). The findings are based on studying students' explanations of causes of volcanic eruptions and earthquakes. Volcanoes and earthquakes were chosen as the domain of this present study due to three reasons. First, the two natural phenomena are difficult topics in earth science which embody some 'unobservable' processes (i.e., convection currents, continental drift) (Dal, 2007). Second, they require thinking and understanding on larger scales than our everyday experiences, which are important for understanding other concepts (e.g., the formation of rocks) in Earth science (Dal, 2007). Third, they relate to tectonic plates which underpin most of the understanding of Earth's processes and are important to the causal reasoning of the "unobservable" mechanisms (Gobert, 2000).

Previous studies on students' preconceptions focus on what they are and how they are problematic in students' conceptual understanding (e.g., Novak, 1988; Ross & Shuell, 1993) . The present study moves one step further to perceive students' preconceptions as supportive resources for fostering students' conceptual understanding in Earth science learning. With the aim of supporting students' conceptual understanding, our study focuses on investigating the impact of commonly occurring ideas, generated by students, on conceptual development during conversations on Earth's phenomena. More specifically, we examine the commonly used idea of "heat" as the starting point to explore students' understanding of Earth's phenomena and the process of students developing their understanding toward a 'scientific' consensus in the context of small group discussions. Ideas of 'heat' are common in students' explanations of the occurrence of earthquakes and volcanoes in previous studies (e.g., Ross & Shuell, 1993) as well as in the present study. We argue that the discourse around observable 'heat'-related events, which might affect the students' conceptual development, is employed by students in their conversations to interpret and communicate unobservable internal Earth dynamics. 'Scientific' consensus in the current study indicates the collective opinions which are brought forward and formed by students together during focus group interviews rather than scientific ideas accepted by the scholarly community.

The present study attempts to contribute to earth science education research through investigating the process of developing ideas through group interactions based on students' preconceptions .This current study of students' conceptual development in Earth science learning, especially in an Asian context and a small group setting, may provide new insights as to how students interpret Earth's phenomena and transform their preconceptions into an accepted scientific consensus.

PREVIOUS RESEARCH ON STUDENTS' UNDERSTANDING OF EARTHQUAKES AND VOLCANOES

People of all ages perceive Earth phenomena and processes from various perspectives (e.g., belief in supernatural forces, scientific understanding, personal experiences, or stories handed down from generation to generation). Previous studies have documented the difficulties that learners have in understanding the Earth's processes (e.g., volcanoes, earthquakes, mountain formation) and have also revealed that preconceptions of Earth's processes are often developed early in childhood (e.g., Blake, 2005; Dal, 2007; Gobert, 2000; Tsai, 2001). Particularly, students have a number of preconceptions about the causes of earthquakes and volcanoes (e.g., Dove, 1998; Ross & Shuell, 1993) as it is both difficult and dangerous to have first-hand experiences (Dal, 2006). Students develop their own ideas, mainly non-scientific, of understanding these two phenomena before instruction (e.g., Dove, 1998; Ross & Shuell, 1993). A number of naïve ideas are often given by students to explain the causes of earthquakes. They believe that human activities (e.g., children lit a fire and forgot about it), myths (e.g., the earth is 'upset' or God wants it), weather or natural disasters (e.g., rain, wind, landslides,

etc) are the reasons (Ross & Shuell, 1993; Sharp, Mackintosh, & Seedhouse, 1995; Simsek, 2007). In addition to that, there is evidence that students tend to confuse the two natural phenomena (Dove, 1998). They define earthquakes and volcanoes by recognizing their observable attributes such as earthquakes shake but volcanoes don't; volcanoes erupt with lava but earthquakes don't (Ross & Shuell, 1993). Bezzi and Happs (1994) and Sharp et al. (1995), for example, indicate that students relate earthquakes to volcanic eruptions: a volcano gets hot and shakes to create an earthquake. This notion may have its origins in the fact that both these earth phenomena are violent natural disasters and happen in similar areas. Those responses indicate that students have a lack of understanding of the underlying processes of the causality of volcanic eruptions and earthquakes.

Interestingly, in several studies, the terms "hot", "fire" and "hot burning" are often used by students to describe volcanoes (Dal, 2006). "Heat" and "magma" are frequently given by students as the cause of volcanic eruptions (e.g., "volcanic eruptions are caused by heat buildup") (Gobert, 2000; Hemmerich & Wiley, 2002). We summarize the common interpretations related to "heat" mechanisms in existing studies and those seen in students' answers:

- Volcanic eruptions: Volcanoes get hot and shake to create earthquakes (e.g., Sharp et al., 1995);
- Magma: Magma is pushed up by heat/hot air and causes volcanic eruptions (e.g., Blake, 2005; Dal, 2007; Hemmerich & Wiley, 2002); and
- The core: the core acts as a heat source in causing volcanoes/earthquakes (e.g., the core gets hot and hits the surface; the core releases heat and causes a volcanic eruption to happen) (e.g., Bezzi & Happs, 1994; Ross & Shuell, 1993; Sharp et al., 1995).

Those studies suggest the close relationship between ideas of 'heat' and the notion underlying students' elaborations of earth phenomena. That most students employ heat related ideas to explain causes of earthquakes, volcanic eruptions, plate movements, and magma movements (Gobert, 2000; Hemmerich, & Wiley, 2002) implies that attention must be given to the impact of ideas of 'heat' that emerge in students' interpretations of the Earth's phenomena.

METHODOLOGY

The data for this paper comes from a larger research program "Voyage to the Age of Dinosaurs" (Kim, Miao, Chavez, Kim, & Shen, 2007-2010; Kim, Wang, Tan, Kim, & Pang, 2009) . The main objective of the research project is to explore ways to develop interactive media that support students' deep learning about Earth system science. The participants were Secondary One students (equivalent to US grade 7). Workshops and interviews were conducted in English as Singapore employs the English language as the medium of instruction in all government schools. Most of them had no prior school exposure to the relevant contents of the interview questions. The purpose of the extra-curricular interviews was to establish a deeper understanding of students' preconceptions of earth science ideas prior to being exposed to formal classroom lessons. Interviews were conducted with 20 Singaporean students to uncover and analyze their concepts of earth science by getting them to respond to a range of questions by drawing, writing and discussing their ideas. During the interviews, the participants discussed topics related to fossils, earth structure and the occurrence of earthquakes and volcanoes in sequence.

In this paper, we will concentrate our discussion on one group's (3 boys-Tony[1], Ben, and Harry from one school) discourse and artifacts about the occurrence of the two earth phenomena. The three-boy group was selected after we excluded those groups which had had formal lessons about relevant topics prior to the interview. Compared to the other groups, this particular group was actively engaged in the group discussion. Additionally, through observations of the discussions of other groups, we found that most of the groups shared common ideas; thus this group could represent other students involved in the project to a certain extent.

Data collection and analysis

We collected data from the focus group interview. For this paper we are focusing on two relevant questions to elicit students' ideas about the causalities of Earth's phenomena: 1) Draw and explain how earthquakes happen; and 2) Could you explain what a volcano is? Draw your ideas on the piece of paper provided.

During the one-hour interview, the facilitators gave the students the two questions and provided around 10

minutes for discussion of each question. The facilitators were not involved in the students' group discussion, but after the discussion, came back to the groups and asked them to present their ideas. This paper focuses on the students' ideas about the Earth phenomena that emerged in the 20-minute discussion.

The students' ideas are classified based on their conversations and drawings of the causes of the two natural phenomena. The drawings are used to support their explanations of the occurrences of earth phenomena.

Students' discourse including drawings

One of the studies relevant to the current study on students' conceptual understanding of earth phenomena was that of Gobert (2000) which identifies and characterizes the types of models held by students in the aspects of the dynamics and causes of earthquakes and volcanoes. Gobert's (2000) typology simplified the analysis of students' understanding of the complex concepts of causal and dynamic processes in earth phenomena by exploring what the relationship between heat related mechanisms (e.g., magma) and movement related mechanisms (e.g., plate movement and magma movement) emerged in students' ideas. It provided an effective way to 1) understand students' interpretations of earth phenomena in which our students associated heat, magma, and plates with earthquakes and volcanoes in their explanations and drawings; and 2) emphasize heat related ideas in the process of students' conceptual development which meets the purpose of the current study of exploring the influence of students' ideas of heat on their understanding of earth phenomena. In her study, students' ideas were classified into three types of models different in dynamics and causal processes involved in volcanic eruptions, namely, *Local models* (heat models and movement models), *Mixed models,* and *Integrated models*. These were progressively described as Type 1, Type 2 and Type 3.

Gobert (2000) summarized the types of causal and dynamic models based upon the two main mechanisms (heat and movement mechanisms) and their relationships as heat (i.e. magma) and movement (i.e. plate, ground movement and magma movement) related ideas emerged in the students' discourse. In Gobert's (2000) typology, Type 1 Local models include two models which are Type 1a Local 'heat' models and Type 1b Local 'movement' models. These reflect heat and movement related mechanisms as the only type employed to describe causal and dynamic processes in volcanic eruptions, respectively. Type 2 Mixed models include both heat and movement mechanisms, but heat mechanisms and movement mechanisms are not integrated well; for example, students who hold the mixed models lack the understanding of why and how plates move. Type 3 Integrated models are

Table 1
The Categories Scheme of Students' Ideas of Causes of Earth's Phenomena

Category	Description	Examples
Superficial ideas	Ideas are assigned to superficial ideas if the explanations of causality of earth phenomena are related to natural disasters or weather	*Avalanche *Hurricane
Movement related ideas	Ideas related to movement mechanisms; plate movement and magma movement	*Magma rising above the surface *Plate movement causes *Ground breakage
Heat related ideas	Ideas related to heat mechanisms; Heat, magma and heat currents push on magma.	*Occurrences of earthquakes are caused by heat build up *Magma is hot
Integrated ideas	Combine and well integrate the two mechanisms (heat and movement mechanisms); heat as causal agent.	Magma gets hot and heats up plates which causes the plates to move and then causes volcanic eruptions and earthquakes.

well elaborated and integrated in terms of the heat mechanisms and movement mechanisms.

The present study adopts and modifies Gobert's (2000) coding scheme to analyze students' ideas of causes of earthquakes and volcanoes . The final coding scheme emerged from the data, and the results are shown in Table 1.We are tracing students' ideas as their resources to form conceptual understanding, so we use the term ' ideas' rather than 'models.' While Local models in Gobert's (2000) typology included two models–Local Heat and Local Movement models, our study did not combine them as Local models, but rather created individual types to emphasize the analysis of the ideas of 'heat' and movement, since we focus specifically on the ideas of 'heat' in the interpretation of the causality of earth phenomena. It would be much clearer to observe the development of students' ideas on what causes earthquakes and volcanoes by identifying their Heat related ideas and Movement related ideas separately. Additionally, we created the category of superficial ideas to account for the ideas we observed in our protocols (Hemmerich & Wiley, 2002). According to our coding scheme, the students' ideas about the causality of earth phenomena fall into the following categories (see Table 1).

As shown in Table 1, Superficial ideas include naïve ideas. Heat related ideas and Movement related ideas are simplistic and include heat mechanisms (i.e. magma, core and heated currents push on plates, and heat pushes on magma) and movement mechanisms (i.e. plate movement, magma rising above the surface), respectively. Similar to Gobert's (2000) typology, the Integrated ideas in the current study are those by which the students use many movement and heat related explanations. Students who form Integrated ideas start to perceive heat as a causal agent in the dynamic process of plate and magma movement (Gobert, 2000). However, in the current study, the Mixed models which emerged in Gobert's (2000) study are not shown in the students' conversations.

As mentioned, this study employs focus group interviews to elicit diversified views within a group context for investigating students' opinions and views on the causality of Earth's phenomena. While we used Gobert's (2000) typology to analyze the students' ideas of causes of earthquakes and volcanoes, this present study focuses more on understanding the relationship between students' ideas of 'heat' and their conceptual development in their group discussion.

Students' ideas about causalities of earthquakes and volcanoes

Based on an analysis of the students' discourse, including their drawings, four types of ideas of causes of earthquakes and volcanic eruptions were identified in the group: Superficial ideas, Movement related ideas, Heat related ideas and Integrated ideas. Tables 2 and 3 show how those ideas were reflected in their drawings of the causes of earthquakes and volcanic eruptions. We call these initial ideas because they are derived from everyday observations and personal experiences. The initial ideas were simplistic, representing students' naïve ideas, and preconceptions about the causes of earthquakes and volcanoes. According to their conversations and drawings, the occurrences of earthquakes were associated with ground shaking and are caused by natural disasters, plates "rubbing" and heat "rising"; likewise, the occurrences of volcanic eruptions are associated with magma explosion, and are caused by heat "rising" and magma.

IDEAS OF CAUSES OF EARTHQUAKES

We asked students to 'explain how earthquakes happen' before we asked them to explore the causes of volcanoes. The three types of initial ideas were proposed at the beginning of the students' conversation. Interestingly, the three boys in our focus group had different ideas (see Figure 1).

Table 2 shows the students' drawings of the causes of earthquakes which could reflect some of their ideas from their conversation about earthquakes. Figure 1 presents the dynamics in the group conversation. Superficial ideas emerged to explain earthquakes initially, as did the information of plate movement received from adults. However, the point was challenged by the question 'what causes plate to rub against each other?' proposed by Ben. To answer, the students proposed new 'ideas' derived from their preconceptions that 'volcanoes cause earthquakes.' The detailed group conversation is presented as follows:

Superficial ideas

The three boys stated that 'avalanches', and 'hurricanes' are reasons for earthquakes. Particularly,

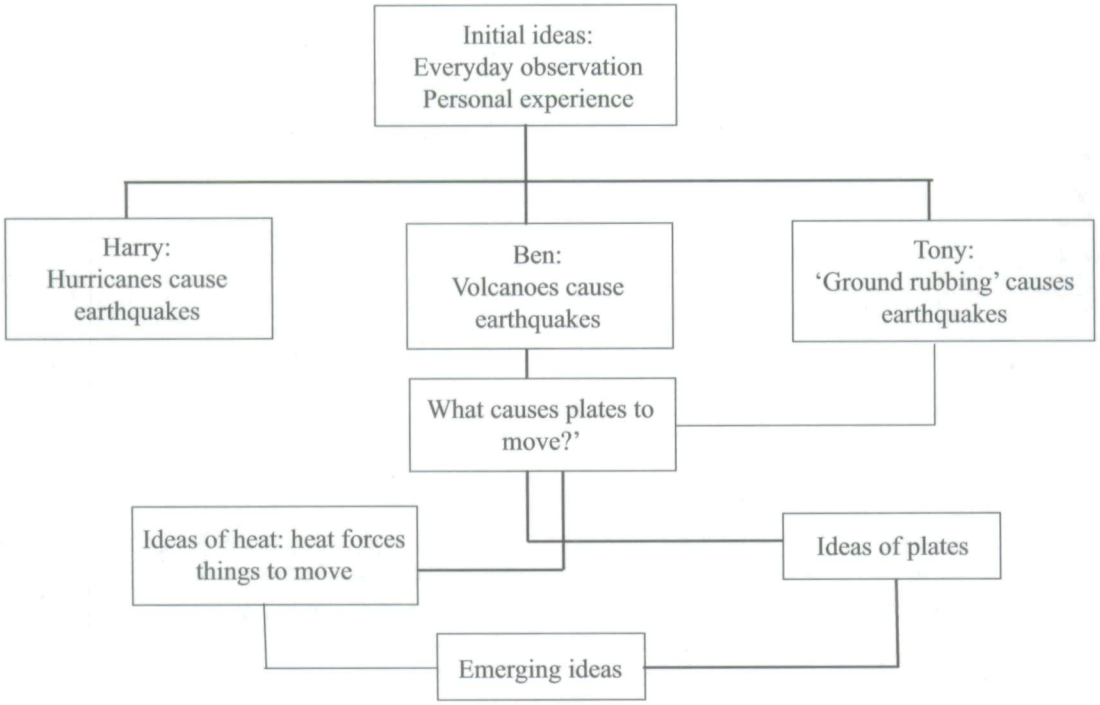


Figure 1. *Students' ideas of causes of earthquakes.*

Ben emphasizes that volcanoes are responsible for earthquakes. Next page are the relevant excerpts:

1. Ben: *Maybe it's like there is a volcanic eruption then shake shake shake until the earth right cracked.*

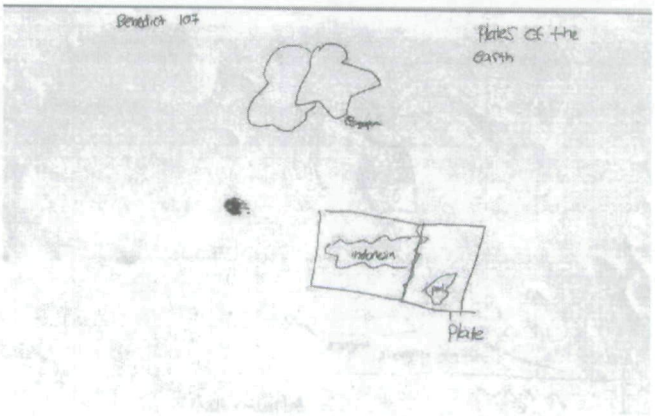
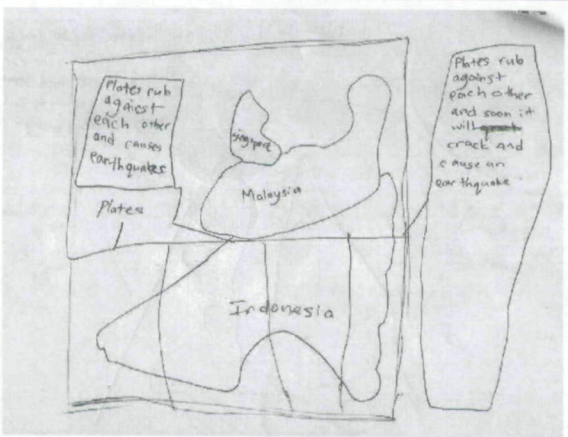
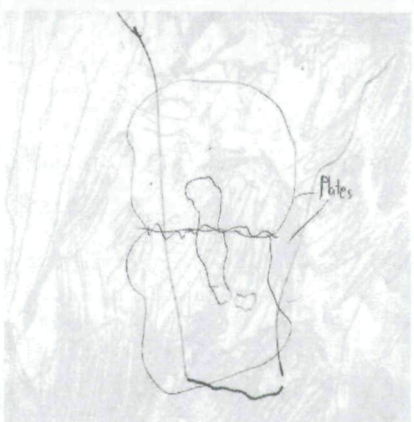
This was similar to Ross and Shuell's (1993) findings that students perceive the occurrence of earthquakes to be caused by energy. It was because students are trying to look for sources of energy which have enough power to crack the ground open and spew magma.

(Plate) Movement related ideas

Movement related ideas emerged in the students' conversation earlier than Heat related ideas. A few ideas of plate movement emerged in their conversation, although they did not understand the cause of the plate movement. Tony initially raised the "plates" idea (see turn #5 and Tony's drawings in Table 2) as being responsible for earthquakes. Later, Tony informed the group that he had heard the information from his parents (see turn #11). At first, the ideas of "friction" and "ground rubbing" were generated by Tony to explain the occurrence of earthquakes. He perceived the plate as 'ground', although he identified the scientific term "plate" and replaced "ground rubbing" with "plate movement" later. He suggested,

2. Tony*: But I heard is like that you see actually maybe it's not really split up. At first it crashes then it starts crumbling into each other. It starts rubbing each other rub after rubbing rubbing rubbing it slowly comes up then crack then slowly when it comes up slowly behind it cracks then later cannot withstand the friction any more then the earth inside just breaks lor. Then the earth here just breaks open lor. That's how it hole. And then when we do friction that time it's like crashing.*
3. Tony:……*The ground rubbing against each other, how to say it's like rubbing your own hand like that until your hand later like how to say*
4. Harry: *Eh what pieces of land are you talking about? Land , any land?*
5. Tony: *No not every land. In the earth ah got different different plates (?) plates. Then Singapore is on a plate. Some countries they are like you see the plates is like see ah the plates is like that right. Ok ok like that….. These plates will start rubbing against each other lah. So actually it doesn't happen*

Table 2.
Students' Drawings of Causes of Earthquakes

Students' names	Drawings	**Causal components/ Written descriptions**
Ben		Plate movement
Harry		Written descriptions: Plates against each other and seems it will crack and cause an earthquake Plates against each other and cause earthquake
Tony		Plates movement

everywhere lah only happens here, but I don't know how it moves lah.

6. Harry: *Plate ah*
7. Tony: *They call it the plate lah earthquake*
8. Ben: *plates right you see before ah*
9. Tony: *Never see but people not very sure what the shape is. it's just (?)*
10. Ben: *But how you know*
11. Tony: *My parents told me then I also learn*

At this point, Tony understood that the causality of earthquakes is related to movement related mechanisms, whereas he didn't seem to understand the heat-related mechanisms involved in plate tectonics. More specifically, he did not understand the reason for plate movement (see turn #5).

Heat related ideas

Students' ideas were placed in this category if the responses include the perceptions that the causes of Earth's phenomena are associated with heat mechanisms (i.e. heat and magma). Failing to find the reason for plate movement, the group tried to look for another kind of energy to explain the causes of Earth's phenomena. At this point, the ideas of "heat" were proposed by Ben to describe the causality of earthquakes. In his opinion, "heat" is a kind of energy which is underground and forces ground breakage. Ben's ideas were as follows:

12. Tony: *This causes the shaking of the earth*
13. Ben: *But what causes them to rupture? [Tony: Hmmm some tidal waves or]*
14. Harry: *Maybe no lah not tidal waves maybe like*
15. Tony: *The earth is unstable*
16. Ben: *Maybe there's too much heat on the ground then it forces this one to open it.*

However, the students did not depict the ideas of "heat" in their drawings (see Table 2) though they did start to think about and discuss the ideas of 'heat' at this moment.

IDEAS OF CAUSES OF VOLCANIC ERUPTIONS

With respect to the question "Could you explain what a volcano is?", several questions were raised in the students' group conversation which encouraged them to look into their preconceptions and find more explanations. To answer those questions, the students put forward ideas about magma and volcanoes (i.e., magma is volcanic material; magma is associated with heat, and magma rising above the surface). The detailed conversation is as follows:

Heat related ideas

By answering the question (proposed by Harry) "where is lava from?" Ben and Tony associated magma with heat. Additionally, they stated that magma and heat are both Excerpts follow:

17. Harry:*...I mean, but, where does the lava flow come from?*
18. Tony: *underground*

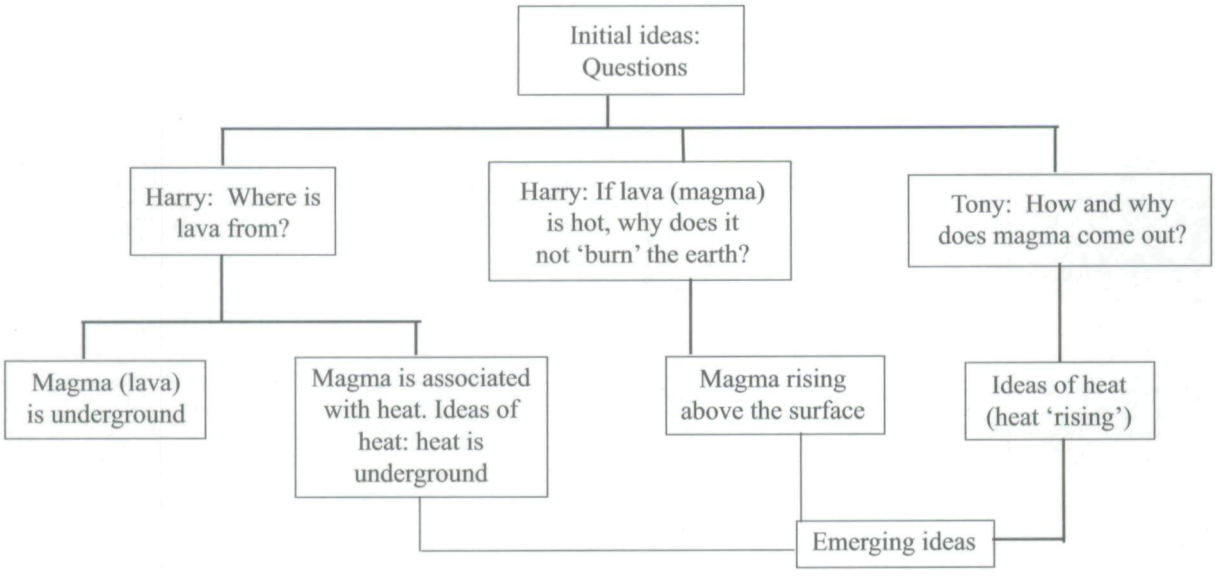


Figure 2. *Students' ideas of causes of volcanic eruptions.*

19. Ben*: The lava flow is under the ground*
20. Tony: *The magma is underground*
21. Ben: *This is for example this is the magma and here is all heat*

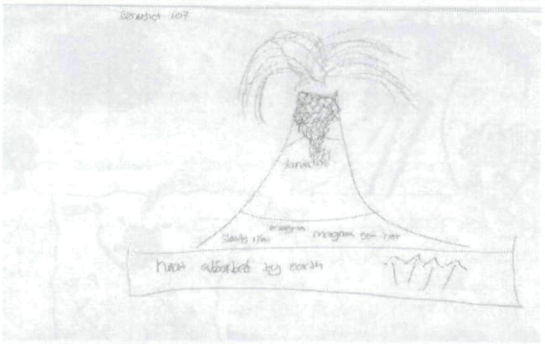
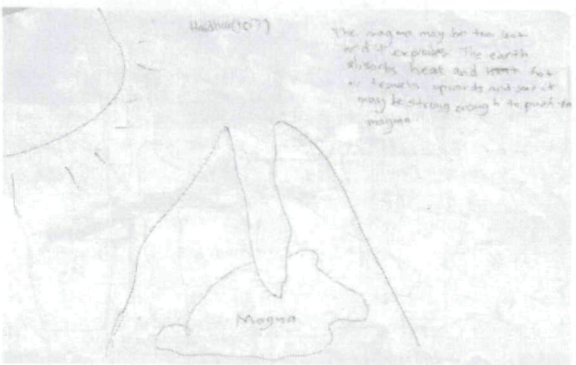
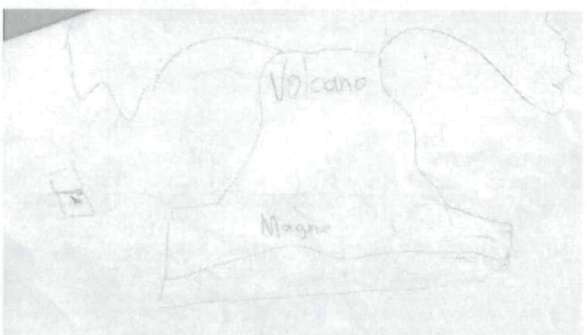
Likewise, the students' drawings depicted the location of heat and magma as well (see Table 3).

(Magma) Movement related ideas

The students' ideas were placed in this category if the responses focus on magma movement. To explain Harry's question "why does magma never burn the earth?" Tony raised the idea of "magma rising above the surface". Additionally, Tony inquired about the causes of magma explosions. Ben employed the ideas of heat (i.e. heat "rising") to explain the causes of magma explosions. Excerpts from their conversation follow:

22. Tony*: ....The magma stores somewhere. I don't know how they being caused why the lava come out*
23. Ben*: The heat is very hot very hot. then heat don't come out then it will gush out so it just heat up the magma the magma gets hot then it keeps rising rising rising.*

Table 3.
Students' drawings of causes of volcanic eruptions

Students' names	Drawings	Causal components / Written descriptions
Ben		Heat rises from the bottom Heat pushes on magma Magma rises above the surface Magma is underground
Harry		Magma is underground Heat rises from the bottom Written descriptions: The magma may be too hot and it explodes. The earth absorbs heat and hot air travels upwards and … it may be strong enough to push the magma
Tony		Magma is underground Magma rises above the surface Plate movement

24. Tony: *One thing I don't understand. You know why the magma right why would it want to why would it suddenly just come out like that*
25. Ben: *Magma is not. The one that come out like that that one is lava*
26. Harry: *It's called magma*
27. Tony: *Lava is magma ,same lah*
28. Ben: *Cause it's like expand already ...don't know lah*
29. Tony: *But I don't know how the magma, right, want to escape for what. There's some reason*
30. Ben: *Expands. Expands until like too hot too hot then it must, cannot stand that heat.*

Similar evidence could be found in the students' drawings. Harry wrote down and explained the relationship between "heat" and magma movement in his drawings (see Harry's drawing in Table 3).

INTEGRATED IDEAS OF CAUSALITIES OF EARTHQUAKES AND VOLCANOES

The students developed more sophisticated explanations at the end of their discussion of earthquakes and volcanoes. Tony and Ben assimilated "new" ideas from each other into their ideas of dynamics inside the earth. We could see that they include more heat-related mechanisms and movement related mechanisms in their explanations. Their descriptions integrated ideas of "heat", "magma movement", and "plate movement." Tony and Ben explained the causes of Earth phenomena together when they presented their ideas to the facilitator. Excerpts follow:

31. Ben: *Like the [Tony: I think the heat] magma gets hot lah then the, gets hot then [Tony: maybe the earth start] the earth start [Tony: shaking] yah just like heated the plates and the plates just crack the earth just crack lor*
32. Tony: *and also cause volcano happens lah*

The concepts of "heat" generated by the students played a role of causal agent which is responsible for magma explosions and plate movement. At this point, they had "Integrated ideas" of causal mechanisms responsible for the causes of volcanoes and earthquakes as they have integrated heat related mechanisms and movement related mechanisms in their ideas.

We noticed that, by the end of the students' conversation, their initial ideas were developed into Integrated ideas to some extent without formal learning (e.g., reading text), that is, the students have integrated heat related ideas and movement related ideas through focus group discussion to elaborate the causes of Earth's phenomena. There may be a process of students developing their own ideas from preconceptions toward a "scientific" consensus.

Additionally, we noted that the students who participated in the present study continued using the ideas related to "heat" and tended to employ those ideas to reason the causes of plate movement and magma explosion. These three students were exposed to words and concepts such as "plate movement", "magma", and "lava" outside of the school context (i.e., parents) and had awareness that these words may have a connection with the occurrence of earthquakes and volcanic eruptions, even though they have little knowledge about why. At this point, existing ideas of "heat" (i.e., heat "rising") may serve to integrate these pieces of knowledge and reasons about the causality of the natural phenomena addressed here. These findings encouraged us to explore further how ideas of "heat" might help them to make sense of the causes of volcanoes and earthquakes. We attempted to observe the process of constructing Integrated ideas, in other words, *how students' Heat related ideas and Movement related ideas integrate* became the focus of the following discussion.

Discussion: the concept of "heat" as an aid in developing ideas about Earth

In this section, we investigate the process of students developing ideas about Earth by exploring the relationships among the preconceptions about the two Earth phenomena that emerged in their discussion. We noted that, in the students' conversation, magma and plates are significant in portraying the causes of volcanic eruptions and earthquakes. As in Gobert's (2000) and Hemmerich and Wiley's (2002) protocols, heat related mechanisms are mostly conceptualized with the idea of hot magma, while movement related mechanisms are conceptualized as plates. In order to understand how students make the connection among heat related mechanisms, movement related mechanisms and the two Earth phenomena, in the present study, we created the two key concept groups

(*magma and plates*) separate from the volcano and earthquake concept groups. This made it clearer to explore the process of how the students developed their thinking from their initial ideas to integrated ideas. Finally, concepts related to the occurrence of earthquakes and volcanic eruptions were identified and classified into the four groups based on the students' conversation: plates, magma, volcanoes and earthquakes, as shown in Figure 3.

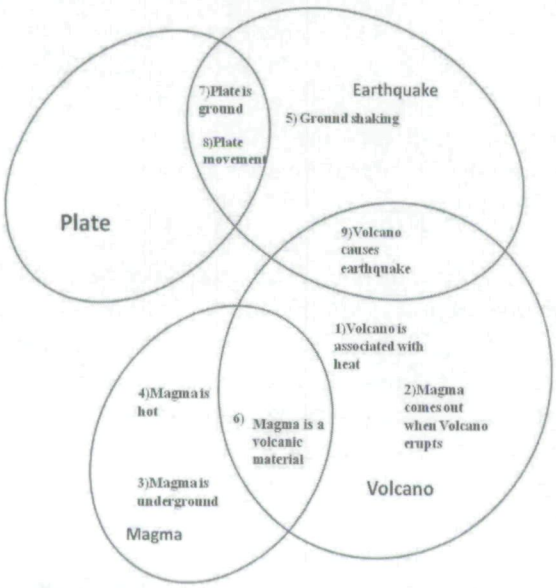


Figure 3. *Initial relationship among concept groups of magma, plate, volcano, and earthquake.*

From analysis of the initial ideas (Superficial ideas, Heat related ideas and Movement related ideas), we noted that several ideas emerged in the students' minds before constructing Integrated ideas. The perspectives of *1) volcano is associated with heat, 2) magma comes out when a volcano erupts, 3)magma is underground, 4) magma is hot* and *5) ground shaking when an earthquake occurs* were manifested in the students' discourse and fall into the relevant concept groups, respectively. Moreover, the ideas of *6) magma is a volcanic material, 7) plate is ground, 8) plate movement (but without causality ideas)* and *9) volcanoes cause earthquakes* connected the four concept groups separately. However, from Figure 3, it is interesting to note that initially there were no intersections between magma and plate, which means that the causal relationship between Heat related ideas and Movement related ideas (i.e. heat as a causal agent in forming convection currents which push plates to move) are not reflected in the students' discourse. Given that, we concluded that 1) students at this grade level have some exposure to the basic information of volcanoes and earthquakes before formal instruction; 2) Integrated ideas are difficult to build through simple exposure to information about the phenomena, as the students were not conscious of the connection between movement related mechanisms and heat related mechanisms (plate and magma).

In order to develop more sophisticated explanations of the occurrences of earthquakes and volcanoes, and especially to make sense of the causes of plate movement and magma explosion, the students used the idea of "heat" to interlink those four concept groups (see Figure 4).

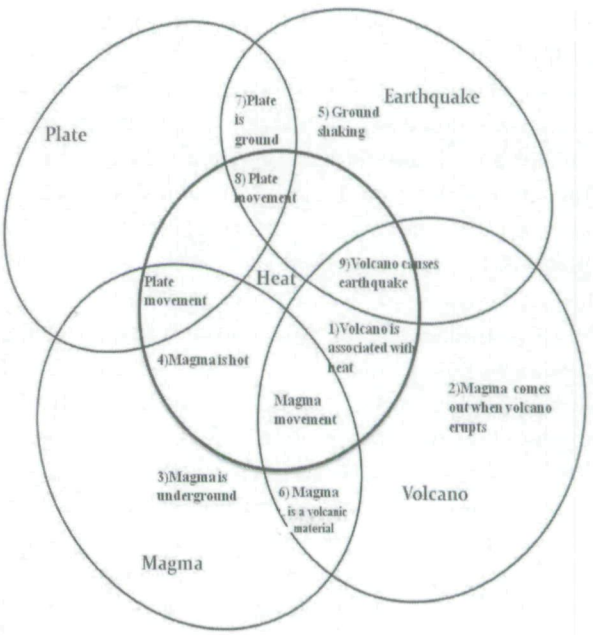


Figure 4. *Relationships between ideas of "heat" and the four concept groups.*

During the students' conversation about the causes of volcanic eruptions, the preconceptions of 'heat's' location came up when they were looking for the answer to the location of magma - *Heat is underground* (see turn #20 and #21). As well, preconceptions of the two characteristics of 'heat' emerged in the students' minds when they were discussing how 'heat' causes earthquakes and volcanic eruptions –*Heat forces things to move* (see turn #16) and *Heat makes things rise/expand* (see turn #23 and turn #30).

We noticed that the initial ideas (Superficial ideas, Heat related ideas and Movement related ideas) and ideas of 'heat' support and facilitate the integration of ideas and a group-level extrapolation. This includes the following four aspects:

1. The extrapolation students made is about *magma movement.*

This was based on their ideas that "*heat is underground*" and "*heat makes things rise*", which were facilitated by the questions the students raised themselves. Ben developed and improved his ideas by considering and responding to the questions posed by Tony about "why would it (magma) suddenly just come out like that?" and "where does lava flow come from?" We noted that those questions helped them to search their existing knowledge and integrate it for their sense making. With that, Ben stated that heat is responsible for pushing magma to explode. We noticed that although some of Ben's ideas are superficial, he is starting to integrate the preconceptions of magma (i.e. magma is underground together with heat) with his ideas of "heat" (i.e. heat makes things rise, heat is underground) (see turn #23 and turn #30).

2. Another extrapolation they made is about *plate movement.*

This was based on their idea that volcanoes cause earthquakes and preconceptions of "heat forces things to move". This question of "what causes them (plates) to rupture?" posed by Ben (see turn #13) and Harry facilitated Tony to generate sophisticated reasons by integrating the preconceptions. Tony started to link magma and heat with plate movement due to the preconception that *volcanic eruptions cause earthquakes*. He also adopted the idea of "heat forces things to move" from his group member (Ben) to make sense of the reason for plate movement. More specifically, he may think that plates are forced to rub together by the "heat" from hot magma. Excerpts follow:

33. Harry: *I don't know what makes the plates rub against each other.*
34. Tony: *I still got the ideas of volcanic eruption. Maybe the magma makes the plate hot and start to rub....*

3. Students generated *an indirect relationship between earthquakes and 'heat'.*

This was based on the previous inferences of the causal relationships among volcanoes, earthquakes, and plate movement. By incorporating Ben's ideas of the relationship between earthquakes and volcanoes (i.e., volcanoes cause earthquakes), Tony stated that earthquakes happen because there is an enormous amount of pressure caused by volcanic activity. His interpretation demonstrated that an earthquake is a kind of "volcanic eruption", but without the outflow of magma. Then, based on the previous inferences of the cause of magma movement and the cause of plate movement, he explained that magma explosion is responsible for plate movement which causes earthquakes (see turn #31).

4. The ideas of "heat" created *a relationship between the magma and plates.*

This relationship was not present in earlier conversations (see Figure 4). The students reasoned that "heat" and magma movement are responsible for plate movement. More specifically, they reasoned about the causal relationship between "heat", magma and plate movement, incorporating the heat mechanisms and movement mechanisms into an explanation (see turn #31, turn #34 and turn #35). Based on our definition of Integrated ideas (see Table 1), it was reasonable to infer that they are developing Integrated ideas.

35. Ben: *Maybe as the volcano erupts then the magma wants to come out then the volcano is very (safe) and then it just presses the pressure then plates just move then [Tony: Maybe the pressure causes it to move]*

OTHER FACTORS AFFECTING STUDENTS' IDEAS

Sequence of questions

Open-ended questions are designed to elicit students' ideas about Earth's interior, earthquakes and volcanoes. The sequence of the open-ended questions is designed to create the connection among fossils, plate movement, and Earth phenomena to facilitate students' comprehension of relatively inaccessible phenomena. Students are asked to draw and explain the question about the layer of Earth (without orientation or text reading) prior to the questions regarding Earth

phenomena. Similar to Gobert's (2000) study, students' understanding of Earth' interior could encourage them in reasoning about the causal and dynamic process, e.g., the location of magma and heat (see turn # 20 and #21). Likewise, the sequence of the questions about the two Earth phenomena (earthquakes and volcanoes) could have an influence on their conceptual development. More specifically, ideas which emerged in the students' conversation about the cause of earthquakes could support the knowledge integrating and inference making which is needed in order to explain the cause of volcanic eruptions. In the current study, students' conversations regarding earthquakes facilitated them to bring forward ideas of plate movement, "volcanoes cause earthquakes", "heat is underground", etc. , which affect or shape the means of thinking , discussing, and reasoning about the cause of volcanoes and the relationship between heat related mechanisms and movement related mechanisms (see turn#5, turn#16, and turn#21). Additionally, if the question about the cause of volcanic eruptions were asked prior to the question about the cause of earthquakes, the students might have brought in the ideas of heat earlier than the ideas of plate movement as they tended to directly associate 'heat' with volcanoes (according to their conversation). It may push students to bring forward different ideas of causes of Earth's phenomena and may go through a different process of forming the "consensus" compared to the current study.

Socio-cultural background

The geographic location of Singapore makes it relatively safe from seismic activity compared to its neighbors (e.g., Indonesia) as it is far away from the nearest fault line in Indonesia. In 2004, several regions of Asia were affected by the Indian Ocean earthquake and resulting tsunami, while Singapore was safe. People living in Singapore frequently receive information from media coverage of natural disasters happening in neighboring countries. Particularly, some students or their friends immigrated to Singapore from these countries (e.g., Indonesia), which may make them pay attention to related information of these countries and their natural disasters. These special experiences may provide more information of Earth's phenomena and lead the Singaporean students to view and interpret the Earth phenomena from particular perspectives. In the current study, the three boys mentioned neighboring countries (Indonesia and Malaysia) frequently when they were drawing and discussing the topic of earthquakes and plates (see turn #36 to turn #47, also see Harry's drawing in Table 2). According to their conversation, whether the earthquake happened in the neighboring countries is the rationale for the students to decide the location of plates in Southeast Asia.

36. Tony: *I think Indonesia got a lot of plate leh. Not everywhere got earthquakes one. Not everywhere leh only the middle part the thing will have earthquake leh and around it lah but have the rumbling lah. When it cracks open obviously the island near will start breaking up the land here lah*
37. Ben: *Malaysia*
38. Tony: *Draw anything (?) Singapore is not near so we are lucky.*
39. Ben: *(?) I think so lah I think my idea is ok*
40. Tony: *Malaysia I don't think is on the plate leh because Malaysia don't have earthquake leh*
41. Ben: *Sometimes leh*
42. Tony: *Eh Harry [Harry: This is part of Indonesia right] Harry, Harry [Harry: What?] Malaysia got earthquake before or not I can't remember.*
43. Harry: *I don't know*
44. Tony: *Have lah (?)* [Ben*: Malaysia is here] I know Indonesia have lah Malaysia have because like that maybe Malaysia is also on a plate*
45. Ben: *Plate. Plate of the earth ah?*
46. Tony: *Yah plate lah. I don't know how to spell*
47. Ben: *Then here is maybe Philippines or whatever*

In summary, the two additional factors could affect students' conceptual development during their group conversations: 1) The sequence of open-ended questions may have an influence on students' conceptual development by means of indirectly facilitating them to integrate their preconceptions of Earth's interior, earthquakes and volcanoes; and 2) The socio-cultural background may impose an effect on students' interpretation of Earth phenomena.

"SCIENTIFIC" CONSENSUS IN FOCUS GROUP DISCUSSION

The findings in this case study imply that focus group discussion helps students to develop 'integrated' ideas toward 'scientific' consensus. In this focus group discussion, all of the students were provided with the opportunity to share their responses and ideas with their group members. During their discussion, the learners negotiated the dissonances and similarities between their own ideas. Meanwhile, students could obtain requisite preconceptions which are needed to understand causal and dynamic concepts from other group members. An example could be found in the discussion of earthquakes. As shown in Figure 1, Tony initially put forward the idea of "ground rubbing" as the reason for earthquakes. Ben, who has the idea that "volcanoes cause earthquakes", proposed that heat is an energy forcing the ground to crack. Having different ideas, Ben queried Tony's idea of plate related mechanisms by probing the question of the cause of the ground rubbing. To make sense of and support his own ideas, Tony looked into his preconceptions or knowledge and generated the idea of "plate movement" when he cannot respond to Ben's question. By negotiating the differences between, and making inferences based on, their ideas, Tony further used Ben's heat mechanism idea to develop his initial idea of plate movement to make sense of the cause of plate movement and the occurrence of earthquakes. The interactions of the group disclosed that they are developing a 'scientific' consensus in the group discussion context through the processes of presenting initial ideas, peer review, and incorporating the "new" ideas. Compared to previous studies that used text reading or instructions to change individual students' preconceptions (e.g., Gobert, 2000), a group of Singaporean students in this study revised their preconceptions and shaped their understanding together, without external assistance.

In summary, our explorations of the process of students developing their ideas suggested that 1) the progressive revision of students' ideas is facilitated by their posing questions to each other, such as 'why / how does magma come out', 'what causes them (plates) to rupture?' and 'where is lava from?'; and 2) ideas about 'heat' contribute to the integration of their scattered preconceptions to develop more sophisticated explanations. These findings may indicate that conceptual understanding, especially for Earth science, could be developed through students' own preconceptions and questions without formal instruction.

CONCLUSIONS

This paper presents students' preconceptions about dynamics inside the earth, and illustrates their development of Integrated ideas about Earth phenomena. Based on the analysis of one group's (3 students) explanations and drawings, we find that 1) students' ideas of 'heat' are identified for facilitating their learning about the causality and dynamics inside the earth; 2) the idea of 'heat' helps students to develop more sophisticated and integrated explanations of the occurrence of earthquakes and volcanoes. This especially helps to make sense of the causes of plate movement and magma explosion - what we call Integrated ideas; and 3) social interaction, such as conversation or discussion, may shape the understanding of earth sciences. Students, in motivated circumstances, can bring their ideas together with prior experiences to make progress in thinking. The students who participated in this study were given an unusual opportunity to express their own ideas to explain phenomena, to assimilate additional ideas to their current theories and to reason about how a certain phenomenon happens.

This implies an effective strategy for developing students' ideas of the causality of Earth's phenomena and developing conceptual understanding, starting from students' preconceptions. Following are some suggestions for teaching the relevant topics, based on the findings of this paper:

- Create an opportunity for students to express their preconceptions, even misconceptions;
- Encourage students to explain the phenomena using verbal communication, and share their explanations with peers to produce constructive criticism, revise preconceptions and develop understanding; and
- Identify students' preconceptions about 'heat' to create the concept of the relationship between plates and magma; and take advantage of students' preconceptions and everyday experiences to promote conceptual development.

It may sound daunting for teachers to prepare and practice such strategies. However, the students in this study were able to develop some integrated ideas within a short period of discussion. More use of our strategy will help students to make sense of Earth phenomena and create their own knowledge in much more meaningful ways.

As mentioned, our possible implications for classroom practice are to have students explain their ideas and use their own ideas for learning rather than merely treating the preconceptions as obstacles. Group activities and open-ended questions related to the topics can be implemented in a classroom to encourage them to share their ideas and create an opportunity for students to solve problems with group members. These kinds of strategies may be applied to other topics in geography and Earth science in which students are likely to have some ideas of their own. A study which employs these strategies in classroom practice is currently in progress to promote students' development of their ideas in the classroom for various topics in geography. Finally, future research is needed to focus on 1) how to take advantage of students' preconceptions to facilitate their conceptual understanding in other topics of science learning; 2) how to encourage students to share their ideas in an Asian context in which teachers are considered to have all the right answers; and 3) how to design and implement the relevant teaching strategies and activities.

NOTE

[1] Students' names (Tony, Ben, and Harry) are pseudonyms.

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