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STUDENTS'AND TEACHERS' PERCEPTION OF SCIENTIFIC MODELS: TRANSITION FROM DAILY TO SCIENTIFIC LANGUAGE

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Abstract. *The use of scientific models has been regarded as an important skill for scientific enquiry. However, although many national curricula and major international science education reform movements have stressed the use of scientific models in science teaching and learning, students and teachers generally do not know how to perceive models properly. This research explores these perceptions about scientific models using the Perception of Models in Science (PMS), a self-developed instrument designed to collect participants' model perceptions, among 218 grade 4, 6 and 8 students, as including 57 of the science teachers in their respective schools, and treated these statistically with analysis of variance, post hoc analysis and cluster analysis. Results showed that the groups of students and teachers agreed that the most acceptable model representation is reality but remained uncertain on whether a model can be presented through nonreality representations (i.e., diagram, graph, symbol, writing and speech). Participants did not significantly differ in perception intensity of seeing each model representation and held three kinds of model perceptions: daily language, transitional and scientific language. This research thus proposes action plans in managing this transitional perspective in learning the concepts of scientific models.*

Keywords: *model representations, scientific model, students' view, teachers' view.*

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Introduction

Scientific models have a crucial and irreplaceable role in science exploration (Black, 1962; Odenbaugh, 2005) as they can be used to delineate what is known and unknown, develop conceptual frameworks, make predictions and generate causal explanations; however, defining models, especially in the context of scientific enquiry, has still proven itself to be difficult (Chittleborough, Treagust, Mamiala, & Mocerino, 2005).

According to Hodson (2014), scientific models can be a way for students to gain conceptual and theoretical knowledge (learn science), engage in scientific practices (do science) and develop an understanding of the characteristics of science as part of its nature. Thus, science educators have highlighted the importance of using models in teaching and learning science in schools, as seen in many science education materials all over the world (Gilbert, 2005; Gilbert & Boulter, 2000; Gilbert & Justi 2016; Grünkorn, Upmeier zu Belzen, & Kruger, 2014; Oh & Oh, 2011; Passmore, Gouvea, & Giere, 2014; Yildirir & Demirkol, 2018). Given how science education communities, researchers and teachers have had high consensus about the inclusion of the use of scientific models into science curricula and instruction, the United States, Germany, the United Kingdom, South Korea, Japan, Taiwan (Ministry of Education, Taiwan, 2018; National Research Council, 2013), and many more countries have now explored the integration of models into science lessons, making the use of scientific models a crucial element in the fields of science, technology, engineering and mathematics (STEM) education. Despite all these developments, however, perceptions of students and teachers have shown ambiguity and arbitrariness (Grosslight, Unger, Jay, & Smith, 1991; Lee, Chang, & Wu, 2017; Torres & Vasconcelos, 2015; Unal, Sadoglu, & Durukan, 2014; Van Driel & Verloop, 1999).

In students' early education, a model is understood, defined and used as a concrete concept similar to an actual solid object such as a fragile prototype, mock-up, etc. As students further their education, especially in science and mathematics, the way models are defined becomes more in-depth, and both students and teachers have to endure the conceptual change concerning the model's terminology (Posner, Strike, Hewson, & Gertzog, 1982). For teachers, if they cannot grasp this shift in understanding, it would be unrealistic to

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expect that they can teach and help students comprehend and use models. Therefore, unveiling this conceptual shift in the process of understanding models is crucial in improving the teaching and learning of models. In this research, primary and secondary school students and primary and secondary school teachers, as the stakeholders of learning and teaching in this setup, were asked to define a model under a specific representation (e.g., reality (physical), diagram (schematic), graph (statistic), symbol (picture), writing (text) and speech) and compared their answers. Given this, this research aimed to answer two research questions:

- RQ1: What are the differences in students' and teachers' model perceptions?
- RQ2: What kinds of perception traits do students and teachers have toward scientific models?

Theoretical Framework

Students' Model Perceptions

Several studies have attempted to identify students' conceptions of models and their use in science. Grosslight et al. (1991) interviewed grade 7 mixed-ability students and grade 11 students in an honours science class and found that most of the students carried a naïve realist epistemology and thought of scientific models as physical copies of reality. Based on how these students described the relationship of models with reality and the role that ideas play concerning models, they identified three levels for their scientific model perceptions: level 1, where students see models as either toys or simple copies of reality; level 2, where they see models as objects that can be altered depending on the 'modeler'; and level 3, where they see models as subjected to evolve and actively created to test ideas. However, results indicated that all students have only reached levels 1 and 2, indicating that no grade 7 student was able to have a holistic understanding of models.

Treagust, Chittleborough, and Mamiala (2002, p. 262) showed that for their definition of models as an exact replica, there are 36%, 21% and 43% of students who answered with disagree, not sure and agree, respectively. Students who responded with not sure or agree were regarded as having an incorrect concept of a scientific model, which constituted a large portion of the participants. On the other hand, Gogolin and Krüger (2018) proposed a five-aspect framework of model competence, and from those, the aspect of the nature of scientific models, as the most relevant to this research, had three levels: 1) a model is a replication of the original, 2) a model is an idealised representation of the original and 3) a model is a theoretical reconstruction of the original. Moreover, they found that a majority of the students in all grades (10, 11 and 12) see scientific models as an idealised representation of the original (level 2). However, their study did not focus on the different representative modes of models (e.g., graph, diagram, text, etc.); thus, models in their sample items were all real objects. Given this, further analysis of how students react to other models with nonreality representations is expected to produce more relevant findings.

Following the same goal as the other authors, Lee et al. (2017) studied grade 8 and 11 Taiwanese students' perceptions of scientific models, and their results shown that grade 11 students were more likely to recognize textual and pictorial representations as models compared to their younger counterparts. These results supported previous viewpoints (Bean, Sinatra, & Schrader, 2010; Schwarz, 2009) and stated that 'illustrative figures and more abstract forms of models appear to be more difficult for younger learners' (Lee et al., 2017, p. 315). They further concluded that their findings support the previous argument (i.e., Ainsworth, 2006) that the educational level may impact how students interact with different modes of representation.

Lee (2018) further explored the progression of students' understanding of scientific models and modelling by surveying 983 Taiwanese grade 7 to 12 students, and their questionnaire included 10 representations of models. The study's results showed that a majority of the students did not agree that the text, mathematical, or dynamic representations are models. As to the progression of their understanding of models, significant differences were seen between grade 7 and all grades above grade 10, and between grades 8 and 12, which pointed out that 'it possibly takes years of experience of learning science to develop a sophisticated view of models…' (Lee, 2018, p. 1424).

Teachers' Model Perceptions

Teachers' understanding of the instructional content is crucial in providing valid and effective learning for students. However, studies like that of Unal, Sadoglu, and Durukan (2014) showed how professors of pre-service teachers who taught science and mathematics to primary and secondary student teachers had deficiencies and were not at the expected level in terms of understanding the representations and the nature of models. Another

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study by Van Driel and Verloop (1999) assessed the knowledge of experienced secondary school science teachers' regarding scientific models and found that most teachers still view models as simplified or schematic representations of reality. They also found that science teachers 'allotted a large variety of representational modes to scientific models' (Van Driel & Verloop, 1999, p. 1148).

Justi and Gilbert (2003) interviewed teachers employed in 'fundamental' (6–14 years) and 'medium' (15–17 years) schools and universities, as well as student science teachers, about their notion of scientific models in seven aspects: nature, use, entities, uniqueness, time span, prediction and accreditation. Their results showed that the teachers' notion was too complex for them to be differentiated with the levels proposed by Grosslight et al. (1991), with the only pattern observed being how the teachers' simple view of scientific models was similar to Grosslight et al.'s level 1 (lowest). Soulios and Psillos (2016) experimented on model-based enquiry teaching to enhance student teachers' epistemological beliefs about scientific models and reported that the most prospective primary teachers held a naïve realistic belief about models. Moreover, a study by Torres and Vasconcelos (2015) evaluated prospective Portuguese teachers' views of models and reported that only 30% of the teachers reached an informed status, while others, 24.2% and 45.5%, are still situated at the intermediate and uninformed status, respectively.

These studies show that the views of teachers or student teachers on models are complex and sometimes inconsistent, naïve and problematic. Thus, it is impractical to expect that a valid view on the use of scientific models could be reflected in their science teaching or learning. Moreover, there is insufficient research that explores students and teachers as the stakeholders of the teaching and learning system, which has left a gap in the understanding of the knowledge ecology of views of models in schools, requiring further action.

Concept Formation of Scientific Models

Previous studies have shown that students' and teachers' views on scientific models have a large gap in terms of meeting the expectations of the science education community. There are multifaceted reasons behind this phenomenon, and one of which is the difficulty of forming a conceptual change from learners' prior understanding. Similar to learning scientific concepts such as sound, pressure, balance and so on (Eshach, Lin, & Tsai, 2018; Ozkan & Selcuk, 2016), learners need to move from an everyday concept to a scientific one. In many cases, the intended conceptual change happens, but others form a misconception (alternative concept), and some maintain their intact preconception.

'Model', as a term, is commonly used by students in and out of their classrooms every day to refer to a physical copy of an object, such as a toy car, gun, animal, etc. However, it has a different meaning when used in the context of science enquiry. This new conceptual formation of models in science learning needs to overcome the interference of not only its daily use but also how it is defined in other subjects. For example, in art classes, models may refer to plaster models, while in chemistry classes, they may refer to the ball-and-stick model representing molecules. Thus, models have multiple concepts that are sometimes exchangeable, compatible and interfering with each other. These preconceptions about models and the need to address them are shown in Grosslight et al.'s (1991) findings. Duit and Treagust (2003, p. 675) stressed that 'students will be able to learn science concepts and principles only if they are aware of the shift of their initial metaconceptual views toward the metaconceptual perspectives of science knowledge.' Not noticing and addressing students' everyday life languages and/or experiences would likely lead to futile instruction.

A study on vocabulary development also pointed out that attaching meaning to a new word is 'guided by implicit biases or expectations that lead them to favour some possible meaning over others' (Antia & Ianna, 2016, p. 64). Given this, when the concept of scientific models as a term is not well shaped among students and teachers in science education, they tend to choose the omnipresent and versatile meaning of models in everyday life. These have made the conceptual change of models in the proper direction more difficult (Gogolin & Krüger, 2018), thus requiring the identification of the most fundamental questions about how students and teachers see models.

Back to Basics: Representations of Scientific Models

Representation is a form of expression of an object or a concept. Oh and Oh (2011, p. 1112) stated that in everyday language, 'a model is something that represents something else'. An approach to understanding students' and teachers' concept of scientific models is to explore how they view the representations of models through a more straightforward and measurable means. Despite the acknowledgment of the science education community

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that scientific models could be represented in various ways, such as reality, symbol, diagram, etc. to the point that these are commonly found in textbooks and the like, many students and teachers remain unsure what scientific models are.

Various approaches have been developed to explore students' and teachers' views of scientific models. Grosslight et al. (1991) used an interview approach to elicit students' initial understanding of models. During the interview, they presented a toy airplane, a subway map, a picture of a house and a schematic diagram of the water cycle to students and asked if they think the representation was a model. On the other hand, Van Driel and Verloop (1999) developed open-ended questions wherein participants were asked whether items like a toy car, a picture of a house, Ohm's law, a water molecule, etc. are considered models and had them justify their answer. Treagust et al. (2002) developed a questionnaire in which students respond to each question with answers from strongly disagree to strongly agree on whether models should be considered as exact replicas. Likewise, Lee et al. (2017) designed a 12-item questionnaire to ask students whether something is a model or not through 6 modes of representation (i.e., textual, schematic, 2D, 3D, static and dynamic). Similarly, Lee (2018) designed a 10-item computer-based questionnaire wherein each item represents a model representation for students to express the degree of their agreement over how one object is considered a model. The 10 items include concrete (plastic model), verbal (text) and visual models (e.g., symbolic, drawing, mathematical, dynamic, etc.).

These studies have shown that several methods have been used to explore how students or teachers perceive scientific models, which include the use of different data gathering techniques: interview approach (Grosslight et al., 1991), paper-and-pencil test (Treagust et al., 2002) and computer-based questionnaire (Lee, 2018); different answer types: Likert's type (Treagust et al., 2002; Van Driel & Verloop, 1999) and open item type (Van Driel & Verloop, 1999); and different model representations: concrete (real object, replica, plastic model), visual (e.g., symbols, drawing, graphs, illustrations, charts, mathematical, 2D, 3D, static and dynamic),and verbal (text; Lee et al., 2017; Lee, 2018; Treagust et al., 2002). As to the approach of presenting questions that will have participants practice their judgment, some studies like that of Van Driel and Verloop (1999) provided samples (e.g., real object, photo, graph, etc.), while others simply used words for description. Using the research of the above studies, the following six forms were finalised for use in the instrument of this research: reality (physical), diagram (schematic), graph (statistic), symbol (picture), writing (text) and speech, which are representations of models more commonly seen in primary and secondary school science curricula.

Research Methodology

General Background

This research was quantitative in nature. Students' and teachers' perceptions of scientific model were tested, collected and descriptively reported. The data were further analysed with ANOVA and cluster analysis methods to discover their differences and perception patterns. The research was conducted in 2018, and the data was collected in April of the same year.

Participants

As the scope of this research spans from grade 4 (ages 9–10), 6 (ages 11–12) and grade 8 (ages 13–14), both primary and secondary schools were involved. In Taiwan, *primary school* is labelled *elementary school*, which includes education for Grades 1–6, and *secondary school*, which includes grades 7–12. In most cases, primary and secondary schools are separated, so the participants of this research included a primary school and a secondary school with similar middle socioeconomic status. Participants were made up of primary students in grade 4 and 6 and their science teachers from one primary school, as well as secondary students in grade 8 (ages 13–14) and their science teachers from another secondary school. With this, a total of 247 students and teachers joined. Students included 73 grade 4, 48 grade 6 and 69 grade 8 students, from 3, 2 and 3 classes, respectively, selected via convenience sampling from their respective grades. Teachers were 29 primary school science teachers (PSTs) and 28 secondary school science teachers (SSTs; see Table 1) who were not limited to those who teach these grade 4, 6 and 8 students, because science teachers in other grades can also teach such research subjects during their schooling years. This research refers to 'science teachers' as teachers who taught science subjects in primary or secondary schools. Selection of schools was intentional for a more general representation of schools in Taiwan.

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The first author received consent from the schools' administration and teachers, and participation was done voluntarily. All participants remained anonymous. The ethical guidelines for educational research (Cohen, Manion, & Morrison, 2009, p. 77) were followed. All teachers and students were aware of the goal of the data collection, who the researchers and their institutes were, and how the information would be used. Students were further assured that their results would not influence their grades or class standing in any way. Participants' confidentiality and privacy were respected and protected at all times, and only aggregated data were reported.

Table 1. Participants of this research: Students' and teachers' groups.

Subject	Male	Female	Total
Grade 4	38	35	73
Grade 6	26	22	48
Grade 8	32	37	69
PST	11	18	29
SST	17	11	28
Total	124	123	247

Note. PST = Primary school science teacher; SST = Secondary school science teacher.

Research Instruments

An instrument, the *Perception of Models in Science* (PMS), was developed in this research based on the epistemological representation of models (Lee et al., 2017; Lee, 2018; Treagust et al., 2002). The PMS contains six forms of representations: reality (physical), diagram (schematic), graph (statistic), symbol (picture), writing (text) and speech. This research did not include representations such as dynamic, 3D and mathematic, as included in a study by Lee et al. (2017), because our participants included grade 4 and 6 students, and such derivative forms would be beyond young students' understanding. The construct of the PMS is shown in Table 2. The six forms of presentations belong to three categories: reality, visual and linguistic. Each form has 2 questions, totalling 12 items in the questionnaire with the theme of 'Saving energy and reducing carbon'. This theme was chosen as it was science-related and is familiar to students and teachers. In the PMS, each item presents an example of a model (Table 3) and asks the participants to what extent they regard a certain item as a 'scientific model'. The subjects expressed their perception through a 4-point Likert scale (i.e., 1 point for 'strongly disagree'; 2 points for 'disagree'; 3 points for 'agree'; and 4 points for 'strongly agree'). The face validity was examined by two science education experts. The PMS was pretested on 31 grade 4 students and 49 grade 6 students, with a post-test conducted after 2 weeks. With the assumption that if the instrument is understandable and usable for grade 4 and 6 students, it should then be applicable in collecting relative data from older students and their teachers. This research only pilot tested the PMS among grade 4 and 6 students. The test-retest reliability was obtained with Spearman's rank correlation analysis. Given the nature of the lack of agreement in one of the student's responses toward the six forms, the correlation coefficients in all forms were separately measured. Although the results of Spearman's correlation coefficients in each form of representation—reality (.72 and .65, for grades 4 and 6, respectively), diagram (.83; .41), graphs (.63; .70), symbol (.49; .67), writing (.36; .62) and speech (.70; .67)—did not show consistently high values, considering the vague definition of models and the minimum acceptable values of test-retests being situation-dependent (Crocker & Algina, 1986, p. 133), this research believes that the PMS served the need of this research.

Table 2. The construct of the Perception of Models in Science (PMS).

Representation	Perceptions tested	Item no.
A. Reality	A model can be an actual physical object.	1, 2
B. Visual		
a) Diagram	A model can be a schematic diagram.	5, 6

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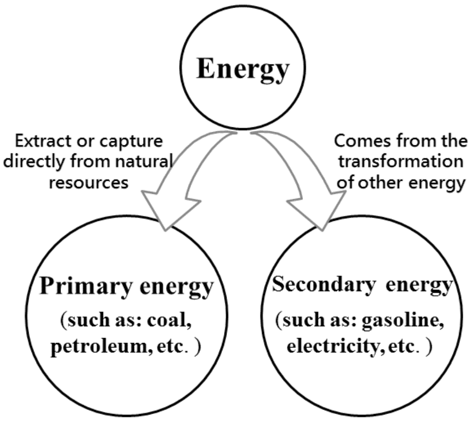
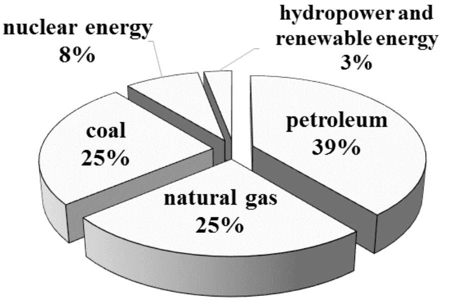
Representation	Perceptions tested	Item no.
b) Graph	A model can be a graph of data.	9, 10
c) Symbol	A model can be a symbol.	7, 8
C. Linguistic		
a) Writing	A model can be a writing text.	3, 4
b) Speech	A model can be an individual, a scientist and a general public view of something.	11, 12

Table 3. Sample items of the Perception of Models in Science (PMS).

Item no.	Representation	Content
1	Reality	A toy car is a model.
10	Visual (Diagram)	This is an infographic regarding energy.  It is a model.
5	Visual (Graph)	This is a statistical graph of the energy consumption on the planet.  It is a model.

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Item no.	Representation	Content
8	Visual (Symbol)	This is an energy-saving stamp.  It is a model.
3	Linguistic (Writing)	'In the circulation of oxygen and carbon dioxide in the atmosphere, plants take in carbon dioxide and produce oxygen during photosynthesis, which is then taken in by humans and animals'. This sentence is a model.
12	Linguistic (Speech)	An expert said: 'Carbon dioxide on Earth blocks solar heat from returning to space, resulting in the earth serving as a layer of quilt and forming a greenhouse effect'. The expert's words are a model.

Data Analysis

For RQ1, the means of the perceptions of different students' and teachers' groups toward different model forms were first calculated. The ratio of the total number of consents (including agree and strongly agree) was also calculated and reported. Afterward, the model representation was further analysed with one-way analysis of variance (ANOVA) if a significant difference was detected, and the Tamhane's T2 post hoc test was performed to locate the differences among different pairs of groups.

On the other hand, for RQ2, the data from the students' and teachers' responses to the 12-item questionnaire were analysed with cluster analysis techniques to classify their perception traits toward the concept of model, for which a 2-step approach was used. First, the hierarchical cluster analysis using Ward's method with Euclidean distance (Borgen & Barnett, 1987) was employed to decide the number of clusters based on its dendrogram and the demarcation point in its agglomeration schedule, and second, the k-means cluster analysis was used to group students and teachers into this designated number of clusters (Ng, Liu, & Wang, 2016). Once each student and teacher were classified, a contingency table that displays the frequency distribution of each group of subjects in each cluster was built. In this table, the proportions of cells in the different columns and rows were statistically tested with Pearson's chi-squared test. Post hoc analyses will precede if the chi-square showed a significant difference between the observed and expected counts. Moreover, adjusted residuals in each cell served as an indicator of significance (van Belle, Fisher, Heagerty, & Lumley, 2004), the threshold value was set to 1.96 and all statistical analyses were processed using the SPSS 20.0 software (SPSS Inc., Chicago, IL, USA).

Research Results

Quantitative Analysis of Students' and Teachers' Model Perceptions

The means of perceptions of different groups toward each model form were shown in Table 4. It showed that reality was much highly perceived as models than any other nonreality representations (i.e., diagram, graph, symbol, writing and speech) across all groups of students and teachers. The ratio of the total number of consents (including agree and strongly agree) further indicated that the perception of reality as models is high (75% to 98%), while that through its nonreality forms is relatively low.

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Table 4. A descriptive analysis of model perceptions among five groups of students and teachers.

Subjects	Mean of representations (% of consent)					
	Reality	Diagram	Graph	Symbol	Writing	Speech
Grade 4 (*n*=73)	2.92(75)	2.45(47)	2.58(51)	2.04(30)	1.81(18)	1.82(27)
Grade 6 (*n*=48)	3.07(77)	2.53(50)	2.49(50)	2.22(36)	1.99(20)	2.01(22)
grade 8 (*n*=69)	3.19(91)	2.64(56)	2.33(38)	2.39(43)	2.09(29)	2.15(28)
PST (*n*=29)	3.38(98)	2.76(64)	2.53(50)	2.22(34)	2.31(38)	2.03(17)
SST (*n*=28)	3.25(91)	2.77(70)	2.36(50)	2.16(38)	2.21(32)	2.20(29)
All (*n*=247)	3.12(84)	2.59(55)	2.46(37)	2.21(36)	2.03(26)	2.02(25)

Note. a) 1 point for strongly disagree, 2 for disagree, 3 for agree and 4 for strongly agree; b) Percentage refers to the ratio of the total number of people whose answers are agree and strongly agree to the number of people in the group.

Table 5. ANOVA analysis of model perceptions among five groups.

Representations		*SS*	*df*	*MS*	*F*
Reality	Among groups	5.83	4	1.46	4.22**
	Within groups	83.63	242	.35	
	total	89.46	246		
Diagram	Among groups	3.56	4	.89	1.48
	Within groups	145.48	242	.60	
	total	149.04	246		
Graph	Among groups	2.71	4	.68	.93
	Within groups	176.89	242	.73	
	total	179.60	246		
Symbol	Among groups	4.43	4	1.11	2.31
	Within groups	116.09	242	.48	
	total	120.51	246		
Writing	Among groups	7.12	4	1.78	2.73*
	Within groups	157.96	242	.65	
	total	165.08	246		
Speech	Among groups	4.95	4	1.24	2.25
	Within groups	133.22	242	.55	
	total	138.17	246		

*Note. *p<.05, **p<.01, ***p<.001*

A one-way ANOVA was conducted to examine whether students and teachers and students of different levels have different intensities of model perceptions in each of the six representations. Table 5 shows the ANOVA results of perceptions toward each model representation across different subject groups. It indicated no significant differences in terms of diagram, graph, symbol and speech, while significant differences were detected in terms of reality (F = 4.22, p < .05) and writing (F = 2.73, p < .05). For the representations that were observed as significant with ANOVA analysis, further Tamhane's T2 post hoc test was conducted to detect significant differences among each pair of subject groups. These pairwise comparison results (Table 6) showed that there were only two significant differences detected in the reality form: between grade 4 and 8 students, and between grade 4 students and primary school science teachers (Mean(I) – Mean(J) = –0.27 and –0.46, p < .05, respectively).

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Table 6. The post hoc test of model's perceptions among five groups (Tamhane's T2).

Representations	Group(I)	Group(J)	Difference (I–J)	*SE*	*p*
Reality	Grade 4	Grade 6	−0.16	0.13	.92
	Grade 4	Grade 8	−0.27	0.10	.05*
	Grade 4	PST	−0.46	0.11	.01*
	Grade 4	SST	−0.33	0.13	.11
	Grade 6	Grade 8	−0.12	0.12	.99
	Grade 6	PST	−0.31	0.13	.19
	Grade 6	SST	−0.18	0.15	.93
	Grade 8	PST	−0.19	0.10	.44
	Grade 8	SST	−0.06	0.12	1.00
	PST	SST	0.13	0.13	.98
Writing	Grade 4	Grade 6	−0.18	0.14	.87
	Grade 4	Grade 8	−0.28	0.14	.41
	Grade 4	PST	−0.50	0.19	.11
	Grade 4	SST	−0.41	0.17	.18
	Grade 6	Grade 8	−0.10	0.14	1.00
	Grade 6	PST	−0.32	0.19	.66
	Grade 6	SST	−0.22	0.17	.88
	Grade 8	PST	−0.22	0.20	.95
	Grade 8	SST	−0.13	0.17	1.00
	PST	SST	0.10	0.22	1.00

*Note. *The average difference in the level of .05 is significant; PST: primary school science teacher; SST: secondary school science teacher.*

Cluster Analysis of Students' and Teachers' Perception Traits

For RQ2, based on students' and teachers' model perceptions, three perception traits were clustered and named (Table 7), with the first cluster named as the daily language perspective and the second as the transitional perspective. In the first cluster, students and teachers only agree that the reality form is a model (Mean = 3.22) and disagree that all other representations are models (Mean = 1.36 to 1.96), which indicate that they still held a daily language concept about models. A total of 32.8% of the students and teachers held this perspective. On the other hand, the second cluster has a similar perception of the reality form but with the other five forms higher than those of the first cluster (Mean = 1.96 to 2.72) and lower than those of the third cluster (Mean = 2.82 to 3.28), which indicates that students and teachers in this cluster are in a transition state of perception from the daily language perspective to the scientific language perspective. It is notable that they do not show a positive perception that models can be all other representations other than the reality form given the fact that this is the largest group composed of 46.2% of students and teachers. The third cluster was named as the scientific language perspective for its highest means in each of the representation form, which ranged from 2.92 to 3.32. This means that students and teachers in this cluster see model beyond mere reality (physical form) and that it could be visual and linguistic, which are both nonreality forms (diagram, graph, symbol, writing and speech). However, only 21.0% of students and teachers reached this intended perception trait toward models.

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Table 7. Cluster analysis of students' and teachers' model perceptions.

Model representation	Cluster		
	First (daily language perspective)	Second (transitional perspective)	Third (scientific language perspective)
Reality	3.22	2.95	3.32a
Diagram	1.96	2.72	3.28
Graph	1.72	2,68	3.14
Symbol	1.56	2.39	2.82
Writing	1.36	1.96	3.19
Speech	1.45	2.01	2.92
No. of subjects	81 (32.8%)	114 (46.2%)	52 (21.0%)b

Note. a) 1 for strongly disagree, 2 for disagree, 3 for agree and 4 for strongly agree; b) The total number of subjects = 247.

The frequencies of different groups of students and teachers distributed in these three clusters were shown in the contingency table below (Table 8). For example, among grade 4 students, there were 29 (39.7%), 34 (46.6%) and 10 (13.7%) scattered in the first, second and third clusters, respectively; while for SSTs, the distribution was 9 (32.1%), 10 (35.7%) and 9 (32.1%). Pearson's chi-squared test for the cross-tabulation analysis was 16.719 ($df = 8$, $p = .033$), which indicated that the variable proportions of students in clusters of different groups of students and teachers did not happen by chance. The results of post hoc analyses were thus further reported in brackets in each cell in Table 8 wherein grade 6 students in the scientific language perspective and transitional perspective clusters reached a significant threshold (*adj. resid.*: −2.0 and 2.9, respectively). All adjusted residual values of each cell are shown in Figure 1 to represent the phenomena of changes.

Table 8. Cross-tabulation of students' and teachers' groups and their clusters (perception traits toward models)

Cluster (Perception Trait)	Students' and teachers' groups: Grade 4	Grade 6	Grade 8	PST	SST	No. of subjects
First: Daily language perspective	29 a (39.7%) b [1.5] c	12 (25.0%) [−1.3]	22 (31.9%) [−0.2]	9 (31.0%) [−0.2]	9 (32.1%) [−0.1]	81
Second: Transitional perspective	34 (46.6%) [0.1]	31 (64.6%) [2.9] *	29 (42.0%) [−0.8]	10 (34.5%) [−1.3]	10 (35.7%) [−1.2]	114
Third: Scientific language perspective	10 (13.7%) [−1.8]	5 (10.4%) [−2.0]*	18 (26.1%) [1.2]	10 (34.5%) [1.9]	9 (32.1%) [1.5]	52
No. of subjects	73	48	69	29	28	247

*Note. a) Number of subjects, b) Percentages in the subject group and c) Adjusted residuals; * for significance that reaches the threshold of 1.96, p = .05.*

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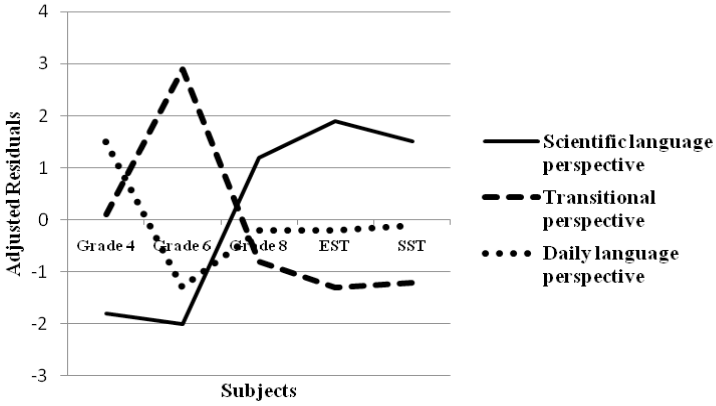

Figure 1. Adjusted residuals for each perspective across groups of students and teachers.

Discussion

From the results following RQ1, at least two findings need to be stressed. First, as seen in the descriptive data in Table 4, the mean of reality was higher than other nonreality representations (i.e., diagram, graph, symbol, writing and speech) for each group of students and teachers as they all saw reality (physical) as a predominant model representation. Moreover, with all means of nonreality representations in each of the subject groups lower than 3 (agree), it is notable that students and teachers still did not well acknowledge that a model can exist in other representations, such as diagram, graph, symbol, writing and speech. This phenomenon demonstrated that students' and teachers' model perceptions remain limited to reality only, without adequate awareness that nonreality forms (i.e., visual and linguistic representations) are also forms of scientific models, as found in previous findings 15 or 30 years ago (Grosslight et al., 1991; Treagust et al., 2002).

Second, the research detected only a few differences between students' and teachers' intensities of perceptions on model representation (Tables 4, 5 and 6). Based on the results of ANOVA and post hoc analyses, the only significant differences found were for grade 4 students with a weaker perception of models as the reality form than that of grade 8 students and PST. Other than these, all the grade 4, 6 and 8 students, as well as PSTs and SSTs, had similar intensities of model perceptions as reality, diagram, graph, symbol, writing and speech. Previous studies seldom explored and compared students' and teachers' perceptions together and were mainly reporting how students or teachers perceived the conceptions of models separately. The findings of this research showed the poor conception of models in both counterparts of students and teachers highlighted a problem that requires further attention, which has only been partially reported in previous studies (e.g., students: Grosslight et al., 1991; Lee et al., 2017; Lee, 2018; Treagust et al., 2002; teachers: Justi & Gilbert, 2003; Soulios & Psillos, 2016; Van Driel & Verloop, 1999). With these, there is a stronger need to advocate and implement the use of models into science, as the decades-long way of discussing such has had little impact on students' and teachers' fundamental understanding of what a model is.

With the exploration of RQ2, this research had a more in-depth understanding of how students and teachers perceive models by looking at the three perception traits the stakeholders have toward models: daily language, transitional and scientific language perspectives (Table 7), from low to high. Results revealed that most students who started their science learning with a preconception of models in the daily language perceptive and strived to move to the scientific language perceptive did not satisfactorily succeed. In contrast to the studies of Grosslight et al. (1991) and Gogolin and Krüger (2018) in which they based their levelling of their subjects' understanding of models not only on how they see its representation but also on its function, this research further divided the model perceptions of students and teachers into three levels based on the representations of model, which allowed this research to reveal students' and teachers' understanding toward models in a more fundamental manner. Furthermore, the present study identified that a big portion of students and teachers are in the second level or the transitional perspective stage. This existence of the transition state was also found in a study by Grosslight et al.

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(1991) and was stressed by Harrison and Treagust (2000) when they interviewed and found that some experienced secondary school science teachers were in transitional states among the three levels.

It is notable that the proportions of students in each perception trait revealed a serious problem as most of the students and teachers hold the first (daily language) and second (transitional) perspectives (32.8% and 46.2%, respectively; Table 7), which are regarded as unsatisfactory model perceptions. In particular, only 34.5% and 32.1% of primary and secondary school science teachers (Table 8), respectively, have held the scientific language perspective toward models; in other words, two-thirds of them do not have a proper scientific perspective toward models. Other studies like that of Grosslight et al. (1991) found that students in grades 7 and 11 are all in the lower levels of 1 and 2. Moreover, Van Driel and Verloop (1999) found that even experienced secondary school science teachers still view models as simplified or schematic representations of reality. After decades of efforts of introducing models into science classrooms, it can still be seen that students and teachers hold a very low level of understanding and perception, whether following the levelling system of Grosslight et al. (1991) or that of this research.

These phenomena pointed out a severe problem that has existed in primary and secondary science teaching and learning about models. At present, the understanding of models of both students and science teachers has not changed significantly when compared with that decades ago. Furthermore, the status in which our science teachers did not possess an adequate perception of models, which would certainly put students' success of using and learning models in question continuously.

Further results of Pearson's chi-squared test indicated that different groups of subjects have different distributions of perception traits. The post hoc analyses and those adjusted residuals showed in Table 8 indicated that the significant differences were found in the grade 6 students who held the scientific language and transitional perspectives. Previous research on students' learning of scientific concepts (terminology) showed that students need a stage to experience transition, and the existence of such a transitional perspective stage of learning the concept of scientific models was identified by this research. Based on the theory of cognitive developmental psychology of Piaget (1977), the transition stage, which has a characteristic of dissonance, could drive the cognitive change and is, thus, crucial in the transition of students' perceptions from daily science to school science. Figure 1 shows how the adjusted residuals across students' and teachers' groups fluctuated. The significantly higher value of students in grade 6 demonstrated that they have a significantly higher proportion with the transitional perspective of models compared with that in grades 4 and 8. This indicated that the transitional perspective of models is largely formed in grades 4 to 8; however, based on subsequently low values of grade 8 students, PSTs, and SSTs, this also indicated that the transition from daily to scientific perspectives was not satisfactorily developed. These findings point out two implications. First, science curriculum and teaching should give heavy consideration to the transitional perspective stage from grades 4 to 8 and use that period to promote the cognitive change of their understanding of models, and second, for grade 8 students, PSTs, and SSTs, who have a low proportion of the transitional perspective stage, ways to provide cognitive conflicts and gradual processes should be established (Duit & Treagust, 2003; Limón, 2001; Waxer & Morton, 2012) to those who still held the daily language perspective and the transitional perspective, so that they can be more prepared in establishing the scientific language perspective.

The participants in this research (grade 4, 6 and 8 students, PSTs and SSTs) were different from the participants in other studies as these studies were more focused on the understanding of models of students who are in grades 7–10 (e.g., Krell, Upmeier zu Belzen, & Krüger, 2012; Treagust et al., 2002) and grades 10–12 (e.g., Gogolin & Krüger, 2018). This difference has restricted the comparability of this research and others. However, the study selected teachers and their students as research subjects to see the contrasting views of such stakeholders on models, which also allowed the researchers to know how the notion has existed in the knowledge ecosystem. Although many findings have been revealed in this research, future studies should include a broader random sampling and/or more schools with different languages to reach a wider understanding of models.

The unsatisfactory condition about the scientific model perception of students and teachers might be strongly related to the fact that the word 'model' in many languages presents a literal meaning that implies it as a real thing or object. For example, where the study was implemented, a dictionary published by the Ministry of Education, Taiwan, which is the most widely used reference for both students and teachers, defined 'model' as imitating the original shape of an object by reducing the size with a certain ratio and is often used for exhibitions or experiments (e.g., aircraft models displayed in a science museum, etc.; Model—模型, 2015). This definition reflected exactly how people commonly perceive models in their everyday life and how they use models in almost every subject except in science. Agreeing that there is a 'need for greater emphasis on the teaching of the role and purpose of the concept of scientific models' (Treagust et al., 2002, p. 357), the results of this research urges science educators to directly

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face how the terminology of models strongly attaches itself to the everyday (daily language) concept, which has persisted in science teaching. In addition to efforts of improving curricula, for teaching and teachers' education, it is also possible to re-evaluate and attempt to develop clearer standard terminologies or definitions for models in science education so that students and teachers can move away from their daily language perceptions and cultural frameworks, and so that the stakeholders can have simpler definitions and goals to use and operationalise.

Conclusions

Previous studies have pointed out that using models is important for students to learn science but also acknowledged the failure or difficulty of applying it in teaching and learning. Therefore, this research referred to early studies and developed the Perception of Models in Science (PMS) questionnaire to investigate and understand students' and teachers' perceptions toward the terminology of 'model' and answered two research questions.

For RQ1, this research concluded that each group of students and teachers all tended to see the reality form as a scientific model representation; in contrast, they remained unsure whether models can be in other nonreality (visual and linguistic) representations, such as diagram, graph, symbol, writing and speech. When different groups of students and teachers were examined to understand how they perceive each representation of models, it can be concluded that most of the students in grades 4, 6 and 8, as well as primary and secondary school teachers (PSTs and SSTs), have similar intensities in how they perceive each representation.

For RQ2, this research concluded that the stakeholders (students and teachers) held three perception traits toward scientific models: daily language, transitional and scientific language perspectives. Students and teachers enter a science class with a preconception of scientific models from the daily language perspective. They strived to move to the scientific language perspective through the transitional perspective stage, but this is not a certain progression for everyone. These findings showed that efforts of using models in schools are in a status of risk and need to be improved. Given these findings, this research suggests the following: a) with the results in which PSTs and SSTs held an unsatisfactory perception of models, there is a need to develop contents that can help science teachers develop a more in-depth understanding of the use of models in the context of science; and b) with the findings wherein grade 4 and 8 students are seen to be in the daily language and transitional perspective stages, with the majority failing to form the scientific language perspective, there is a need to re-examine primary and secondary schools' curricula and teaching methods, and develop instructional materials and activities that can help students successfully transition; moreover, the definition and use of the word 'model' in everyday usage and in science learning should be further scrutinized and finalized to remove confusion and to ensure proper instruction, especially for primary and secondary school students' learning.

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References

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183–198. doi:10.1016/j.learninstruc.2006.03.001.

Antia, B., & Ianna, B. (2016). Theorising terminology development: Frames from language acquisition and the philosophy of science. *Language Matters*, *47*(1), 61–83. doi:10.1080/10228195.2015.1120768.

Bean, T. E., Sinatra, G. M., & Schrader, P. G. (2010). Spore: Spawning evolutionary misconceptions? *Journal of Science Education and Technology*, *19*(5), 409–414. doi:10.1007/s10956-010-9211-1

Black, M. (1962). *Models and metaphors: Studies in language and philosophy*. Ithaca, NY: Cornell University Press.

Borgen, F. H., & Barnett, D. C. (1987). Applying cluster analysis in counseling psychology research. *Journal of Counseling Psychology*, *34*(4), 456–468. doi:10.1037/0022-0167.34.4.456.

Chittleborough, G. D., Treagust, D. F., Mamiala, T. L., & Mocerino, M. (2005) Students' perceptions of the role of models in the process of science and in the process of learning. *Research in Science & Technological Education*, *23*(2), 195–212. doi:10.1080/02635140500266484.

Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education,* 5th edition. London: Routledge.

Crocker, L., & Algina, J. (1986). Introduction to classical and modern test theory. New York, NY: Holt, Rinehart, and Winston.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*(6), 671–688. doi:10.1080/09500690305016.

https://doi.org/10.33225/jbse/19.18.892

Eshach, H., Lin, T. C., & Tsai, C. C. (2018). Misconception of sound and conceptual change: A cross-sectional study on students' materialistic thinking of sound. *Journal of Research in Science Teaching*, *55*(5), 664–684. doi: 10.1002/tea.21435.

Gilbert, J. K., & Boulter, C. J. (Eds.). (2000). *Developing models in science education*. Dordrecht/Boston/London: Kluwer Academic Publishers.

Gilbert, J. K. (Ed.). (2005). *Visualization in science education*. Dordrecht, NL: Springer.

Gilbert, J. K., & Justi, R. (2016). *Modeling-based teaching in science education*. Cham, CH: Springer.

Gogolin, S., & Krüger, D. (2018). Students' understanding of the nature and purpose of models. *Journal of Research in Science Teaching*, *55*(9), 1313–1338. doi:10.1002/tea.21453

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching*, *28*(9), 799–822. doi:10.1002/tea.3660280907

Grünkorn, J., Upmeier zu Belzen, A., & Krüger, D. (2014). Assessing students' understanding of biological models and their use in science to evaluate a theoretical framework. *International Journal of Science Education*, *36*(10), 1651–1684. doi:10.1080/09500693.2013.873155

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education*, *22*(9), 1011–1026. doi:10.1080/095006900416884

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, *36*(15), 2534–2553. doi:10.1080/09500693.2014.899722.

Justi, R., & Gilbert, J. (2003). Teachers' views on the nature of models. *International Journal of Science Education*, *25*(11), 1369–1386. doi:10.1080/0950069032000070324.

Krell, M., Upmeier zu Belzen, A., & Krüger, D. (2012). Students' understanding of the purpose of models in different biological contexts. *International Journal of Biology Education*, *3*(1a), 1–34.

Lee, S. W.-Y., Chang, H.-Y., & Wu, H.-K. (2017). Students' views of scientific models and modeling: Do representational characteristics of models and students' educational levels matter? *Research in Science Education*, *47*(2), 305–328. doi:10.1007/s11165-015-9502-x

Lee, S. W.-Y. (2018). Identifying the item hierarchy and charting the progression across grade levels: Surveying Taiwanese students' understanding of scientific models and modeling. *International Journal of Science and Mathematics Education*, *16*(8), 1409–1430. doi:10.1007/s10763-017-9854-y

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, *11*(4–5), 357–380. doi:10.1016/S0959-4752(00)00037-2.

Ministry of Education, Taiwan. (2018). 12-Year Basic Education Curriculum (Science). Retrieved March 11, 2019 from https://www.naer.edu.tw/ezfiles/0/1000/attach/63/pta_18538_240851_60502.pdf (in Chinese).

Model—模型. (2015). 教育部重編國語辭典修正本 [Mandarin Dictionary—Revised Version. Ministry of Education, Taiwan]. Retrieved March 11, 2019 from http://dict.revised.moe.edu.tw/cgi-bin/cbdic/gsweb.cgi?ccd=uxaVzQ&o=e0&sec=sec1&op=v&view=0-1.

National Research Council (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press. doi:10.17226/18290.

Ng, B. L. L., Liu, W. C., & Wang, J. C. K. (2016). Student motivation and learning in mathematics and science: A cluster analysis. *International Journal of Science and Mathematics Education*, *14*(7), 1359–1376. doi:10.1007/s10763-015-9654-1.

Odenbaugh, J. (2005). Idealized, inaccurate but successful: A pragmatic approach to evaluating models in theoretical ecology. *Biology and Philosophy*, *20*(2–3), 231–255. doi:10.1007/s10539-004-0478-6.

Oh, P. S., & Oh, S. J. (2011). What teachers of science need to know about models: An overview. *International Journal of Science Education*, *33*(8), 1109–1130. doi:10.1080/09500693.2010.502191.

Ozkan, G., & Selcuk, G. S. (2016). Facilitating conceptual change in students' understanding of concepts related to pressure. *European Journal of Physics*, *37*(5), 055702. doi:10.1088/0143-0807/37/5/055702.

Passmore, C., Gouvea, J., & Giere, R. (2014). Models in science and in learning science. In M. R. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 1171–1202). Dordrecht, NL: Springer.

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. New York, NY: Viking.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. doi:10.1002/sce.3730660207.

Schwarz, C. V. (2009). Developing preservice elementary teachers' knowledge and practices through modeling-centered scientific inquiry. *Science Education*, *93*(4), 720–744.

Soulios, I., & Psillos, D. (2016). Enhancing student teachers' epistemological beliefs about models and conceptual understanding through a model-based inquiry process. *International Journal of Science Education*, *38*(7), 1212–1233. doi:10.1080/09500693.2016.1186304.

Torres, J., & Vasconcelos, C. (2015). Nature of science and models: Comparing Portuguese prospective teachers' views. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(6), 1473–1494. doi:10.12973/eurasia.2015.1407a.

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education*, *24*(4), 357–368. doi:10.1080/09500690110066485.

Unal, S., Sadoglu, G. P., & Durukan, U. G. (2014). Teacher educators' views of "model" concept and their mental models. *Journal of Baltic Science Education*, *13*(5), 674–694.

van Belle, G., Fisher, L. D., Heagerty, P. J., & Lumley, T. (2004). *Biostatistics: A methodology for the health sciences* (Vol. 519). Hoboken, NJ: John Wiley & Sons.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Van Driel, J. H., & Verloop, N. (1999). Teachers' knowledge of models and modelling in science. *International Journal of Science Education*, *21*(11), 1141–1153. doi:10.1080/095006999290110.

Waxer, M., & Morton, J.B. (2012) Cognitive conflict and learning. In Seel N.M. (Ed.), *Encyclopedia of the sciences of learning*. Boston, MA: Springer.

Yildirir, H. E., & Demirkol, H. (2018). Identifying mental models of students for physical and chemical change. *Journal of Baltic Science Education*, *17*(6), 986–1004.

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