

Understanding middle and high school students' views of model evaluation and model change

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Abstract: This study aimed to understand students' views of the nature of model evaluation and the nature of change of models in different context. A total of 102 eighth graders and 87 eleventh graders were surveyed. Two cases, the SARS and dinosaur extinction, were presented to prompt students' ideas about different models proposed by scientists. The statistical results showed different context of the model influenced how the students viewed model evaluation and model change. The students' answers also showed significantly differences between the high school level and the middle school level for their views of model change. The common reasons behind students' choice were related to students' understanding of the changeable nature of model and the science process. The students who chose that "one model is better than another" tended to justify their response by their understanding of the content. Interestingly, some students' views of the dinosaur extinction model were guided by their beliefs that information about the dinosaurs is unfathomable. The findings suggest that researchers should be aware that the models chosen for teaching and for assessment can interact with other factors, such as their familiarity of the content, their level of education and understanding of the nature of science. The results from written responses were further used to develop a multiple-choice survey and validated in the follow-up study.

Keywords: views of modeling, computer-based survey, model evaluation, change of models

1. Introduction

Researchers found that students held little understanding of the concepts of models (Carey & Smith, 1993; Grosslight, Unger, Jay, & Smith, 1991; Saari & Viiri, 2003); even with formal training in modeling, students still encountered difficulties in fully understanding the nature of models (Harrison & Treagust, 2000; Schwarz & White, 2005). Researchers stated the needs of tapping into the interaction between epistemic beliefs and the contexts in which the epistemic beliefs being measured and being developed (Franco, Muis, Kendeou, Ranellucci, & Sampasivam, 2012). Earlier studies used interviews or paper-and-pencil questionnaires to understand students' general beliefs of models and modeling. However, these studies provided students with little referential information to models. Thus the purpose of the study is to gain insight into the potential interaction of the views of models and the given context and the students' justification to their views. This study focused on two of the major aspects of views of model, that is, the nature of model evaluation and the change of models.

In sum, we posted the following research questions: 1) What are the students' view of model evaluation and model change in the two different context? 2) To which extent do the high school students' views differ from the middle school students' views in the given context? 3) How do the students justify their views of models in relation to the context?

2. Methodology

In this study, we surveyed 102 eighth graders and 87 eleventh graders. Two cases were presented to prompt students' ideas about different models proposed by scientists. The first case involved two routes of infection for SARS (Severe Acute Respiratory Syndrome) virus, and the second case included different explanations of the dinosaur extinction. Students were asked to answer the multiple-choice questions and then provide a written response to justify their answers. We also asked students to rate that to which extent they were familiar with the two content of the two cases.

We conducted a series of Chi-square analyses including independent tests and goodness to fit tests for understanding the differences within the same educational level or between educational levels. We also used McNemar tests and McNemar-Bowker tests (Elliott & Woodward, 2006) for examining the consistency of students' answers across different items. Opened coding methods were first applied to students' written justification to their choice of answers. Then a list of coding schemes were tested on the data and modified until the coding schemes were saturated.

3. Findings

3.1 Model Evaluation

In terms of model evaluation, after reading the two cases, students had to make a choice among three options: (1) one model is better than another; (2) cannot know which model is better unless new evidence supports one of them; (3) both explanations can be valuable; there is no need to decide which model is better. Results show that nearly one fifth of the middle and high school students believed that one model is better than another. However, in the SARS case, nearly 70% of the middle school students and 57.47% of the high school students thought that both explanations can be valuable. The majority of high school and middle school students chose this answer for the SARS case (middle school $\chi^2(2) = 62.00$, $p < .001$; high school $\chi^2(2) = 23.24$, $p < .001$). For the dinosaur extinction question, the most chosen answer for high school students was "cannot know which model is better unless new evidence supports one of them (45.98%)" and "both explanations can be valuable; there is no need to decide which model is better (44.55%)" for middle school students. However, the results of chi-square analysis showed no statistical significant relationships between students' educational levels and their views of model evaluation.

Further analysis with McNemar-Bowker tests also confirmed that the context of the item influenced students' views of whether a model is better than another ($p < .001$ for middle school students; $p = .004$ for high school students). Only 50.4% of the middle school students chosen the same answers between the two questions; even less percentage (40.2%) of the high school students had consistent answers between the two contexts. A high percentage of students who answered "both explanations can be valuable" for the SARS question shifted their views to "cannot know which model is better" when it came to the dinosaur extinction question. An interesting finding was revealed in students' self-reported levels of understanding of the two topics. For middle school students, students reported similar level of understanding; however, for high school students, they reported significant higher level of understanding of the SARS topic than the dinosaur topic (SARS mean = 2.64; dinosaur mean = 2.38; $p < .001$). This could be a possible explanation of why the high school students seemed to shift their answers between the two contexts and believed that they could not know which of the models of dinosaur appeared to be better.

Overall, the high school students were more likely than middle school students to provide meaningful justification to their choices in both cases. Students who chose "one model is better than another" mainly focused their explanations on the science content of the cases (e.g., "if SARS were air-borne, then everyone should be infected by now"; "I think climate changes sound like the cause [for dinosaur extinction]"). Their justification to the answer of "no need to decide which model is better" focused on the changeable nature of models.

Examples of students' responses included "models can change when the new one is better," and "there could be more than one explanation or possibility." Compared with students' responses to the SARS case, the percentages of choosing the second option (cannot know which model is better unless new evidence supports one of the two) were higher in the dinosaur extinction case. Interestingly, one special set of responses to the dinosaur questions was unforeseen in the responses to the SARS case. Because "the dinosaur extinction happened long time ago; no one really knows" and "dinosaurs are dead", many students believed that there is no way to know which model is better. We found that 43% of high school students who chose this option because that "dinosaur do not exist anymore" and only 18% of students who chose this answer really thought about the importance of finding new evidence. In the SARS case, students who chose the second option tended to justify their answers based on understanding of the scientific process (e.g., "if an error is found, scientists should correct it immediately"), science content (e.g., "I think it is air-borne"), or changeable nature of models (e.g., "if necessary, a model should change to respond to a new question").

3.2 Change of Models

Based on the same SARS and dinosaur extinction context, we also asked students whether a model changes often. In the same context of the SARS and dinosaur extinction cases, students were asked whether models need to change often. Students could choose among the three options: (1) need to change often; (2) no need to change often; (3) it depends. For the SARS case, the most chosen answer was "it depends (44.55% for middle school; 55.17% for high school)". A large percentage of students also chose "need to change often". However, only 3.45% of the high school students chose "no need to change often" while nearly 15% of the middle school students preferred this option. There was significant relationship between students' views of change of models and the two educational levels ($\chi^2 = 7.42$, $p = .024$) regarding the SARS question.

When answering the same question in the context of dinosaur extinction, nearly 52% of the high school students and about 41% of the middle school students believed that it depends. Less than 30% of the students chose either "need to change often" or "no need to change often" for both groups. The majority of students were unsure about whether models about dinosaur extinction need to change often. The results of McNemar tests showed that the context of the two questions had an impact on students' views of whether models need to change, but only for high school students ($p = .002$). About 54% of the high school students held the same views of models between SARS and dinosaur questions. The percentage of the high school students who chose "no need to change" increased in the dinosaur case.

For the SARS question, students who chose "it depends" or "need to change often" tended to provide reasons related the changeable nature of models (e.g., "there must be more than one pathway to spread the viruses" or "virus is always mutating") and then scientific process (e.g., "it change when new evidence is found"). Students also gave similar explanations for the dinosaur question, but more students provided reasons related to the scientific process than changeable nature of model. A large percentage of the students to chose "no need to change often" did not provide a meaningful explanation. As for the students who provided justification, some of them stated "no need to change unless there is new evidence (coded as "science process")" or "no need to the change the current model because multiple models can co-exist (coded as "changeable nature of model")".

4. Discussion

Students' views of model evaluation can be interpreted from a personal epistemological point of view (Justi & Gilbert, 2002; National Research Council, 2007). Based on different levels of personal epistemology (Yang & Tsai, 2010), the answer of "one model is better than another" is close to an absolutist perspective; the answer of "both explanations can be

valuable; there is no need to decide which model is better” is closer to a multiplist perspective; and the answer of “cannot know which model is better unless new evidence supports one of them” is similar to an evaluator perspective. One interesting observation is that according to our data, students who chose an absolutist view of model seemed to focus on factual reasons. This can be interpreted as a way to support their judgment by evidence. Students who took a multiplist or evaluator perspective, tended to think in terms of the nature of science (e.g., changeable nature of model).

In summary, we found that the different context of the model influenced how the students answered the questions of model evaluation and model change. The students’ answers also showed significant differences between the high school level and the middle school level for their views of model change in the SARS case. The common reasons behind students’ choice were related to students’ understanding of the changeable nature of model or the science process. For the students who chose that one model is better than another tended to justify their response by their understanding of the content. Interestingly, some students’ responses to the dinosaur extinction case were guided by the beliefs that further information about the dinosaurs is unfathomable. These findings confirmed that students’ development of personal epistemology can be dynamic and somehow unstable influenced by factors such as the context, affection, or cognitive ability (Bendixen & Rule, 2004). The findings suggest that researchers should be aware that the models chosen for teaching and for assessment can interact with other factors, such as their familiarity of the content, their level of education and understanding of the nature of science.

5. References

- Bendixen, L. D., & Rule, D. C. (2004). An integrative approach to personal epistemology: A guiding model. *Educational Psychologist*, 39(1), 69-80.
- Carey, S., & Smith, C. (1993). On understanding the nature of scientific knowledge. *Educational Psychologist*, 28, 235-251.
- Elliott, A. C., & Woodward, W. A. (2006). Statistical analysis quick reference guidebook: With SPSS examples. Thousand Oaks, CA: Sage Publications, Inc.
- Franco, G. M., Muis, K. R., Kendeou, P., Ranellucci, J., & Sampasivam, L. (2012). Examining the influences of epistemic beliefs and knowledge representations on cognitive processing and conceptual change when learning physics. *Learning and Instruction*, 22, 62-77.
- 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.
- Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education*, 22(9), 1011-1026.
- Justi, R. S., & Gilbert, J. K. (2002). Science teachers’ knowledge about and attitude towards the use of models and modelling in learning science. *International Journal of Science Education*, 24(12), 1273-1292.
- National Research Council. (2007). Understanding how scientific knowledge is constructed. In R. A. Duschl, H. A. Schweingruber & A. W. Shouse (Eds.), *Taking Science to School: Learning and Teaching Science in Grades K-8*.
- Saari, H., & Viiri, F. (2003). A research-based teaching sequence for teaching the concept of modelling to seventh-grade students. *International Journal of Science Education*, 25(11), 1333-1352.
- Schwarz, C. V., & White, B. Y. (2005). Metamodeling knowledge: Developing students’ understanding of scientific modeling. *Cognition and Instruction*, 23(2), 165-205.
- Yang, F.-Y., & Tsai, C.-C. (2010). Reasoning about science-related uncertain issues and epistemological perspective among children. *Instructional Science*, 38, 325-354.