ORIGINAL ARTICLE

The Primary Students' Understanding of Scientific Models through Epistemological and Ontological Perspective

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***Abstract**: Achieving the targets of science education mostly depends on the true understanding of the fundamentals where science and the scientific efforts are embedded through the realist ontology and epistemology that science is based on. Models have a special place in science education revealing to understand the nature and status of scientific knowledge. By considering this function of models, this research puts forward the views of the primary students on scientific models. The participants of this qualitative survey research are twenty-eight 7th graders of a primary school in Izmir, Turkey. The participants are given a questionnaire and a worksheet, which were developed by the researchers, addressing both epistemological and ontological character of models. The results showed that students have generally moderate understanding of models through perceptual and ordinary reality.*

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Introduction

MODELING is an evolving area for many science education researches and curricula emphasizing the scientific and technological practices based on inquiry (Turkish Ministry of National Education [TMNE], 2018); American Association for the Advancement of Science [AAAS], 1993; Erduran, 2006; Abd-el-Khalick et al., 2004; Boujaoude, 2002; The National Research Council [NRC], 1996, 2007, 2012). When learning science through inquiry as well as developing models, students should ask questions to define problems or to make sense of phenomena, plan an investigation, collect and analyze data to create explanations and solve the problem. Therefore, running models and modeling have been seen as an important element of scientific inquiry (Giere, 1999) and we cannot think of science through the history without them (Matthews, 2007).

Models and modeling are broadly known with its representational characteristics in the classroom settings in the pragmatic sense such as making understanding easier and clear. However, if teaching and learning with models involves constructing science concepts and processes it should also include the views about these efforts (Lee, 2017; Gobert et al. 2011; Prins et al. 2010). Moreover, studies have reported that understanding about various features of models and modeling is effective on science learning and scientific practices and inquiry (Lohner et al. 2005; Schwarz and White 2005; Lederman 2007). Therefore, researchers pointed that teaching models and modeling should also focus on sophisticated views of scientific models and modeling as well as science concepts (Gobert et al. 2011; Prins et al. 2010; Raghavan & Glaser 1995). Especially views and questions about reasons of scientific models stimulate students reflect on their understanding of science (Arons, 1990). This research aims to search for the views of students on models and modeling.

Models and Modeling

Models and modeling have an important place in various science disciplines from cosmology to biology, from geology to chemistry, from physics to mathematics etc. Some of the most known examples are the double-helix model of DNA, atomic models, various molecular models, system models, inflationary models in cosmology. Researchers, scientists, teachers and etc. construct scientific models for simplifying the comprehension of natural phenomena or systems by representing the target (Silva, 2007; Grosslight et al., 1991). Models help science and science teaching by different types each emphasizing different dimensions of the relation of the target and model object exists. For example, conceptual model, mathematical models, computerized models, scale models, mental models etc. Although they emphasize different aspects of the relation, they all facilitate understanding.

In pedagogical manner, modeling enables to activate many competences as it serves an intrinsic process of construction and use of science concepts (Lopes & Costa, 2007). It helps teachers for explaining scientific phenomena and students make their understanding through (Treagust et al., 2002). While, students in modeling classrooms experience learning by doing they also have the excitement of learning about the natural world resulting in sense making through representations and building representations. According to Chamizo (2013) these representations models and modeling gain meaning by who identifies them in a defined context. These help making meaning of the environment or the unknown, which makes representations important and valuable. Lehrer and Schauble (2010), emphasize that using models or modeling helps highlight the core components of phenomenon or object by establishing the special conditions of seeing. In another words, models and modeling help build scientific knowledge. For example, in teaching of atoms we do not focus on the existence of atoms at first but on the validity of an atomic model to explain the macroscopic properties of mater (Albanese & Vicentini, 1997). Therefore, in model-based science teaching models and modeling have important roles in producing (justification and formation of) knowledge (Tapio, 2007). Moreover, according to Justi & Gilbert (2002), the purposes of science can be satisfactorily realized when students also have a consistent understanding of "model" with the community of scientists' including the gain of modeling competence. Practicing modeling competence is seen in an important part of scientific literacy (Gilbert & Justi, 2016; Nicolaou & Constantinou, 2014; Louca & Zacharia, 2012).

Based on the literature, Chiu & Linn (2019) summarizes the modeling competence by dividing into three main heading: "models and modeling knowledge"; "practice" and "metacognitive knowledge of models and modeling." In the first heading there lie the knowledge of "ontology," "epistemology" and "methodology." The second heading includes "process" and "products" separately. The last heading has "planning," "monitoring" "executing" and "evaluating." Actually why this summary starts with models and modeling knowledge have roots extending down to Kuhn's (1996) understanding of paradigm and Halloun's (2006) ontological and epistemological tenets of a scientific theory that model belongs to revealing models and modeling.

Epistemological and Ontological Aspects

A model focuses on key features to explain and predict scientific phenomena through representations by abstracting and simplifying (Schwarz et al., 2009). These key features position models and modeling in a realist perspective with experimental consistency of the process through a match between theory and progression (Koponen, 2007). Extension of this ideas reflects that science and science teaching benefit from models and modeling through connections among various components of science contexts such as theory and objects or phenomena (Develaki, 2007; Silva, 2007). These relations are mostly based on analogical reasoning and established by considering the structural mapping between the model object and the target to be modeled (Unal Coban, 2009). The connection between model and modeled phenomenon is generally established in analogical manner within representational propositions. We name the object as a model which is used for representation.

As a natural consequence of discussing the degree of the similarity or representational power of various models and modeling procedures in educational settings rise questioning leading to a degree on philosophizing about models and modeling. Therefore, as stated in the previous section models, explanations, arguments, and reasoning supported by models and evidence are all included in science instruction in addition to concepts. (Penner, 2000). Similarly, Koponen (2007) argues that the philosophical concerns surrounding the relationship of theory to the reality as experienced or as accessed through experiments are strongly impacted by the epistemological and methodological questions relating to models and modeling. However, Séré et al. (2001) claim that the ontological dimension, which deals with scientific models and their experimental correspondences, and the epistemological dimension, which ensures the validity of explanations, are the two dimensions of the philosophy of science that determine the state of scientific knowledge. Similarly, Mahr (2015), argues that models depend on the presence of the steps that the model object is intended to reflect in the background and that models are used to explain the experience world from an epistemic viewpoint. The ontological dimension deals with how and under what circumstances the scientific entities addressed by models are defined, termed, and functionalized based on scientific realism (Eflin and et al., 1999). It also addresses our understanding of the universe, the world we inhabit, and even our own self. The epistemological dimension conceptualizes models and constructs images of objects or rules revealing the reality (e.g., Gentner & Smith, 2012; Johnson-Laird, 1983; Nersessian, 2008)

Enhancing scientific literacy is a goal of science education, and it depends on accurate scientific understanding and endeavors (Hodson, 1999). To achieve this goal, realist ontology (what models are made of) and epistemology should be introduced to scientific education along with the philosophical foundations upon which science is based (what models are for) (McCharty & Sears, 2000:376). Similar to Sere and et al. (2001), in her study about the models and modeling in physics education, Koponen (2007) put forwards three aspects to focus on; "empirically reliable models are our bridges to reality," "empirical reliability is established in the process of matchmaking." and "an authentic image of physics requires empirical reliability, but only minimal realism. Since there is not a one to one correspondence between models and reality they represented some misconceptions may occur (Grosslight et al., 1991; Harrison & Treagust, 1996, 2000). For example, using sticks to hold the clay balls in the model of a molecule may be misunderstood by the students representing the bonding just as then copies of sticks.

"Models and Modeling" in Science Education

When contemporary scientific education research is examined, it becomes clear that some scientists believe the nature of models and modeling to be both a component of the nature of science and a component of its epistemology (Gobert et al. 2011; Justi & Gilbert, 2002). Various studies have been done on this subject. For example, Grosslight et al. (1991), interviewed with 7th and 11th grade students about what models are and reported that most of the students thought of models either as toys or as copies of reality having aspects or parts of the real thing omitted and are produced to provide copies of objects or actions (level 1). Only minority of students thought of models as being created and tested for a purpose where the emphasis on some components therefore altered, but the template of reality still predominates (level 2). They also noted that none of the students realized that a model is created to test ideas, rather than as a copy of reality; the modeler has an active role in its construction for a specified purpose and a model can be tested and changed to inform the development of ideas (level 3). Similarly, Harrison & Treagust (1996) determined that more than half of the tenth graders they studied with were at level 1, the rest were at level 2 and none were at level 3.

Treagust et al. (2002) developed the Students' Understanding of Models in Science (SUMS) questionnaire to probe students' understanding of the role and purpose of scientific models. They found that students' interpretation of the term 'scientific model' depends on their experiences and personal understanding. Models as multiple representations were recognized as being necessary and useful by the majority students, and they appreciated the visual value of scientific models in helping generate their own mental models. Students showed good appreciation for the changing nature of scientific models which was linked to the changing nature of scientific knowledge. They also reported that students understanding of model more commonly fit into general models apart from scientific models and more generally they understood the descriptive role of models. There found to be a gap between this description in terms of the applicable role of models in scientific ways such as making predictions and testing ideas.

In their study, Schwarz & White (2005) designed a model-enhanced curriculum based on categorization tasks in a physics course in which the students learn about scientific models and engage in the process of modeling. They reached that the development of metamodeling knowledge can be effective in teaching students about scientific modeling, inquiry, and physics. For example, students got significantly better conclusions on the inquiry test and performed better on some of the far-transfer problems on. They concluded that model-based inquiry, accompanied by the development of metamodeling knowledge, can facilitate learning science content while also developing students' understanding of the scientific enterprise.

Al-Balushi (2011) mentioned that learners being studied' epistemological perceptions regarding the existence of natural entities. They proposed four levels about the existence of natural entities and phenomena; certainty level (the student believes that the natural entity or phenomenon is real and the textbook illustrations reflect how it really is); imaginary level (the student believes that the natural entity or phenomenon is real, but the textbook illustrations reflect the scientists' imagination of how it really is); suspicious level (the student believes that the natural entity or phenomenon is real, but scientists cannot imagine it, then these illustrations are far from reality) and denial level (the student believes that the natural entity or phenomenon is not real; it does not exist). They found that students tend to perceive entities, which are usually represented by photographs or micrographs such as meteors and meteorites, blood cells and bacteria and into the certainty-level category and the entities, which are usually represented by detailed sketches and rarely by micrographs such as animal and plant cells, fall into the certainty–imaginary combinational level category. There are other ways to depict things that were at the hypothetical level, like atoms, water molecules, enzymes, and chromosomes: drawings, symbolic representations, little two- and three-dimensional models, or historical models. More abstract models such as symbolic, iconic models and dots- and arrows-based diagrams (e.g. Lewis structures) are frequently used as a means of representation to illustrate entities that were in the imaginary–suspicious combinational level such as sub-atomic entities (electrons and protons). Theoretical entities such as e-cloud, photons, alpha rays, atomic orbits, and magnetic and electrical lines of force were at the imaginary–suspicious–denial combinational level. Students' perception of models and determined that they tended to associate more concrete representations, such as a photograph of bacteria, with certainty. On the other hand, students believed that concepts like photons or alpha rays, which were presented in a more abstract way; either "could not be conceptualized by scientists" or "did not exist."

Similarly, Krell et al. (2014) assessed students' different levels of understanding of models, multiple models, the purpose of models, testing models, and changing models. During their research, each item included a description of the original phenomenon and a model representing the phenomenon. The students had to rank the three levels of statements after viewing the model and phenomenon pair. The results showed that the students had "partially inconsistent" views of models across the five aspects. The researchers found that the students with a higher level of nonverbal intelligence and with good grades possessed a higher level of understanding.

Moreover, Gogolin & Krüger (2018) investigated students' understanding of the nature and the purpose of models in biology with respect to context- and grade-specific differences. They reached at most students in all grades see models as idealized representations of an original that have the purpose to show or to describe this original. The students' levels of understanding of the nature and the purpose of models increase only little across grades. Besides, they found that the students' understanding becomes more consistent in higher grades. In another study, Lee and et al. (2017) examined the potential impact of the representational characteristics of models and students' educational levels on students' views of scientific models and modeling through an online multimedia questionnaire. They found that the high school students were more likely to recognize textual and pictorial representations as models, while also being more likely to appreciate the differences between 2D and 3D models.

Barzilai and Eilam (2018) conducted a study including the epistemic criteria used by the students. They grouped the data collected into three major categories of communicative criteria (the relation between the visual representation and the viewer), the representational criteria (the relationship between the representation and the reference) and the epistemic affordance criteria (refer to whether the visual representation enables the viewers to achieve their epistemic goals). They found that different designs and the inclusion of information in the scientific visual representations could evoke different evaluative criteria. However, only a minority of students were concerned about the validity of information and the source trustworthiness of the scientific representations.

However, Lee et al. (2021) investigated students' views of model evaluation through the lens of personal epistemology. They developed an integrated analytical framework by combining a developmental framework, including absolutist, multiplist, and evaluatist, with a multi-dimensional framework, including limits of knowing, certainty of knowing, and criteria of knowing. They reported that the percentages of 11th-grade students choosing the evaluatist assumptions were higher than the eighth-grade students. For students choosing multiplist and evaluatist assumptions, the 11th-grade students were more likely than the eighth-grade students to think in terms of pragmatic and evidential criteria as the criteria of knowing.

In their study revealing the research reviews on models and modeling, Machado & Fernandes (2021) stated that model conceptions are mostly attributed with concrete, construct and mathematical models. They concluded that, in most of the researches concrete models ultimately consisted in providing ways to create and use material and pictorial forms of visualization of objects and events – therefore trying to make them more concrete – construct models, in contrast, tended to emphasize the abstract, idealized, conceptual nature of models. The researches in science education mostly emphasize the external visualizations in terms of the representations. Another interesting finding addresses about the lack of a universal and single definition of what a model is.

To summarize, models are based on evidence about the phenomena (Schwarz et al. (2009), they constitute representational criteria (Barzilai & Eilam, 2018), they are consistent with empirical evidence (Pluta et al. 2011) and therefore, powerful tools of thinking about reality, scientific knowledge and inquiry. As mentioned previously, many of the science education curriculums tend to cover modeling. However, research results in the field of science education regarding the views about models and modeling, overwhelmingly, address the epistemic nature of models in a varying and inconsistent spectrum as stated in the previous paragraphs. Taking the research results into account, it is seen that there is a discontinuity from inquiry to the nature of modeling such as the students' lack of concerning about the validity of information and the source trustworthiness of the scientific representations (Barzilai & Eilam, 2018), denying the existence of natural entities and phenomena (i.e. Al-Balushhi, 2011), thinking of models as being created and tested for a purpose (Grosslight et al., 1991), lack of describing models in scientific ways such as making predictions and testing ideas (Treagust et al., 2002), etc. Moreover, it is also noteworthy that as the students' grade level increases the inconsistencies in their understanding of models and modeling tend to decrease (Gogolin & Krüger, 2018; Lee et al., 2017).

These findings reveal that most of the researches deal with epistemic side of models and modeling and few research mentions about ontological part models and modeling refer to. Depending on this, it is thought that there are still some issues to be worked on such as the reality the models address and how models work in science especially in lower grades that may result in lack of an either conceptual clarity or consistency extending to the construct validity, theory development, and via leading prevention science education researchers and educators from focusing on the precise skills they wish to study as stated by Kahn & Zeidler (2017). Therefore, the aim of this study is, besides uncovering various aspects of students' perceptions regarding scientific models and modeling also finding out the students' epistemological and ontological positions regarding the models. Moving from this perspective, this research may contribute to science educators to organize, design and plan their courses by knowing how students think of model and modeling through the epistemological and ontological perspective.

Methodology

The research is in simple descriptive survey design. The study was conducted with twenty-eight 7th graders of a primary school in Izmir, Turkey. The participants are randomly selected by considering their voluntariness. The data were collected through a questionnaire and a worksheet qualitatively. The researchers created a questionnaire and worksheet that ask about the epistemological and ontological characteristics of models. The questionnaire has 12 questions in three parts namely "description and use of models" (4 questions), "scientific models" (3 questions) and "the reality of models" (5 questions). The worksheet is composed of an inquiry about the historical evolution of the atomic model with a textbook paragraph and 5 questions following it. The textbook paragraph gives information about the atomic theory starting from Dalton's to modern atomic theory and the models behind these theories. Following the text are some sample evaluation questions. Students are tasked with identifying historical models and their attributes, presenting their best and weakest arguments, and determining whether or not scientists agree on or acknowledge the existence of new things in the atom from an ontological point of view. The data collection instruments were presented to experts and piloted on another group of primary students for providing its validity and reliability.

Since the data were qualitative in character its content was analyzed. In the analysis, the structures toward particular meanings, concepts and relations were tried to be figured out where it is necessary to establish these structures over the categories with the codes identifying them (Buyukozturk et al., 2008). Therefore, the answers were examined to draw comparisons and distinctions according to their meanings to identify the codes. The answers were recorded by the two of the researchers. The level of agreement between the researchers as the reliability of the procedure was found as 0.91. After that, the codes addressing the same structures were categorized. The codes and categories were analyzed using an evaluation key which was derived by the researchers from the works of Kuhn, Cheney & Weinstock (2001), Smith et al. (2000), Carey & Smith (1993), Grosslight et al. (1991), Treagust et al. (2002). The evaluation key aimed at classifying the students' answers regarding the epistemological and ontological perspectives.

In the epistemological perspective, the rubric defines three levels of understanding of models addressing the "description and use of models," "scientific models" and "the reality of models." The explanations for each level are given in **Table 1**.

As seen from **Table 1**, Level 1 is the basic level in which students see the models as the one to one copy of the real things without any purpose or idea in the mind. Level 2 is more developed than Level 1 in realizing the effect of the ideas where the level 1 type relations are still dominant. Level 3

Table 1. The Explanations of Levels Given in the Evaluation Key for Epistemological Perspective.

	Level 1	Level 2	Level 3
Description and Use of Models	A model is the copy or reproduction of something (copy, scale models, toy car and etc.). A model only requires surface similarities (color, length, shape and etc.) A model is for only observable properties.	One starts to understand that geometrical shapes, set of numbers, graphs, diagrams, maps and stories and etc. are used for representing objects, events and processes. Even though one starts to understand the functional properties that models exhibit, fundamentally s/he concerns the surface properties dominantly.	One can classify the models and do the necessary changes. Besides the scale models, geometrical shapes, number sets, diagrams and maps one can use the mathematical models. The same target model can be represented by more than one model. One can decide which model to use considering the functional and structural properties of the model.
Scientific Models	One is not aware of the distinction between the ordinary and scientific models	Realizes that models are used in the scientific studies. It is enough to use a model in a scientific explanation to call it a scientific model. It does not require an experimental correspondence or effort. Scientific model is one which is accepted by most people. The only explanation is enough for a model to be correct, no need to support by experimental evidence. The correctness of a model is validated not for the correctness of the idea but the self-competence of the model.	Knows that models are vehicles for testing the ideas in scientific studies. Understands that models verify the results of the real observations or experiments.
The Reality of Models	The model is not real but can be used for obtaining information about real things. Only the objects having a physical appearance have model correspondence. Everything is already represented by only a model.	One can see the possible effects of the changes done on the model. One starts to be aware of that every model cannot respond to the reality including all details. One starts to think that events and processes have model correspondences as well as objects. Starts to think that the ideas of the model maker are important but the importance of the ideas are unclear yet.	Models are used for representing the processes that are very slow, very quick, at insignificant or large scale to observe directly or dangerous experiences. Although it gives almost true result it is not only that replace with the reality. The idea of modeling the modeling was developed and modeling the objects, events and processes.

is more sophisticated than the other levels representing that models are the product of idea and used as vehicles for testing the ideas. The codes grouped under each category are given in **Table 2**.

In the ontological perspective, the key has 5 parts namely perceptual realism, ordinary realism, structural realism, entity realism and scientific re-

Table 2. Codes for Categories Defined for Epistemological Dimension.

Level	Description and Use of Models	Scientific Models	The Reality of Models
Level 1	Maquette, writing, drawing, design, similarities, observation, appearance	No model, that is model, (ordinary) model	The copy of the reality, Very close to reality in appearance similarity, the appearance is important, only one model represent one thing
Level 2	Used for better understanding, can be used in everywhere, symbolic representation, a shape, everything cannot be modeled	Scientists use, model that is based on science and used for science, helps inventing, drawn by scientists	Models may not one to one copy of reality since it represents similarity (the similarity is unclear), models scale the original one, models may have rules, anything can be modeled with more than one model, models cannot produce knowledge
Level 3	Help making works and researches easier, everything can be modeled	Universally accepted models (i.e. Bohr's atom model), proven to be true by scientists through experiments, used for scientist's idea testing	No one to one copy of reality, models , models can help producing knowledge, represents the realistic elements

Table 3. The Categories and Codes for Ontological Dimension.

Category	Explanation	Codes
Perceptual Realism	For understanding the real-world representation of the things and events around us, the things or models that we sense are sufficient.	Seeing, touching, checking physically (i.e. with microscope.), using technology
Ordinary Realism	Understanding reality and models depend on the efforts. These efforts may be in a range of from conducting research, developing instruments and collecting data. However, the qualities of these efforts are unclear. The reality of the event or object which is represented with model may only be known if the efforts turn out to successful.	Conducting research, investigating, arguing, comparing, developing an instrument, being inadequate for explaining
Scientific Realism	Understanding objects and events require scientific efforts. The events and objects explained by science are real. We can only achieve true understanding of events and objects by using scientific efforts. Scientific thoughts are important to design the scientific efforts and models. For an entity to be proven scientifically requires correct experimental results and theoretical explanations at the same time.	Scientific research, proving scientifically, checking the fort he effects the objects and events on the others, the model (knowledge or information) is revised according to the true results, model (knowledge or information) is falsified, circumstances are affective on the scientific efforts.
Structural Realism	Successful experimental results are not needed for any explanation or theory to be true. What important is the explanations and theories postulating the unobservable entities even the experiments conducted with them give wrong results. That the correctness of the explanations is important not the entities.	Explanations (information), which are always improving, can nevertheless be given for things that no longer exist.
Entity Realism	Scientific theories that assert the reality of some unobservable entities are not what support their existence; rather, experimental findings do. While the approach to entities is realistic, the approach to explanations is not always realistic.	It still exists, it is present as it can be experimented, the explanation is insufficient, nothing happens to the object

Table 4. Students' Views on Models from Epistemological Perspective.

	Description and Use of Models N (%)	Scientific Models N (%)	The Reality of Models N (%)
Level 1	22 (79)	9 (32)	15 (54)
Level 2	4 (14)	15 (54)	11 (39)
Level 3	2 (7)	4 (14)	2 (7)
Total	28 (100)	28 (100)	28 (100)

Table 5. Students' Views on Models from Ontological Perspective.

Category	N, For all 5 of the Questions	%, Rate
Perceptual Realism	46	33
Ordinary Realism	43	31
Scientific Realism	12	9
Structural Realism	8	6
Entity Realism	1	1
No Answer	30	21
Total	140	100

alism. The explanations for each component of ontological categories with the identified codes are given in **Table 3**.

The categories in the ontological frame are based on realism. Perceptual realism, ordinary realism and scientific realism address the realistic perspective evolving from rough realism to scientific realism. However, structural realism and entity realism address an incomplete realistic or anti-realistic understanding.

The two researchers also assigned codes to the various groups. The level of agreement for code assignment was found to be 0.89. The level of agreements obtained at both describing codes (0.91) and assignment of codes into the categories (0.89) provide that the data is analyzed at reliable rate. The data is analyzed descriptively by giving the number of students on each category.

Findings

The finding of the research is given in two main parts: epistemological and ontological dimensions.

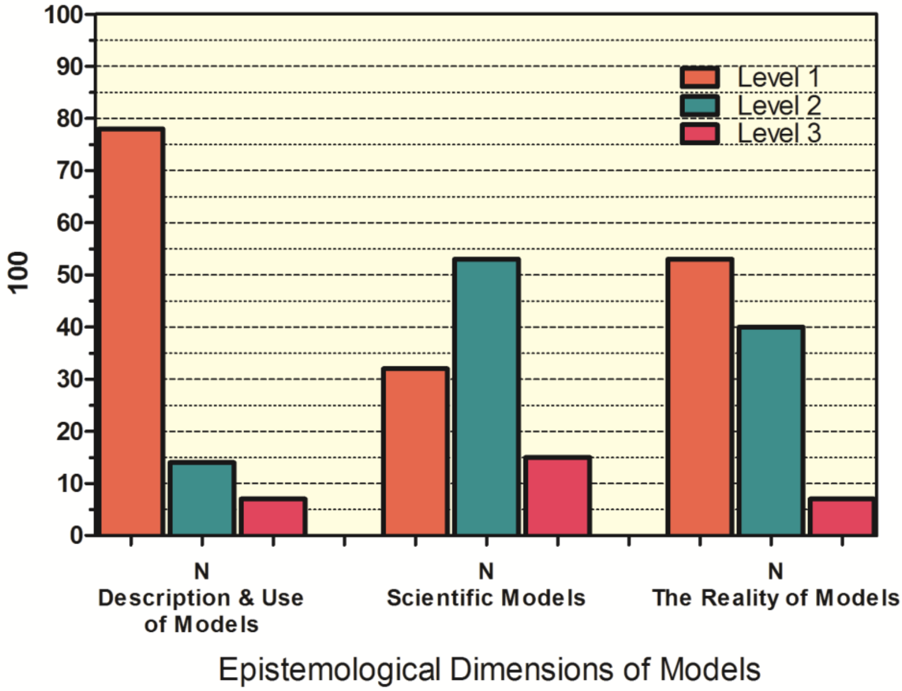

Figure 1. The Epistemological Profiles of Students' Ideas about Models.

Epistemological Dimension

The students' views about models from epistemological perspective were given in **Table 4**.

The data is also piloted into the below graph of **Figure 1** in a clear way.

As both **Table 4** and **Figure 1** show, almost all the students' descriptions and use of models are at level 1. However, for scientific models and the reality of models more than half of the students' understanding of scientific models is at level 2. Typically, the level 3 understanding of models at every dimension is observed to be the least. Some examples of students' expressions are given below.

On descriptions and use of models":

"... the models are used by scientist, science teachers and students to understand what an atom is like." Level 1 (Student A)

"... model is a maquette of a thing" Level 1 (Student B)

"... if anything can be designed than it can be modeled" Level 1 (Student R)

"... it comes my mind the shape of an atom like this (drew the model of an atom that is given below). Level 1 (Student L)

"... model is used to understand and tell well what thing is and can be used in every area." Level 2 (Student H)

"... model make easier the way we use while doing research,... everything can be modeled by various ways" Level 3 (Student Y)

Students mostly relate models to on "scientific models":

"... I have never seen a scientific model. ... the scientific models should have correspondences in the real life." Level 1 (Student H)

"... the scientific models are the models used by scientists for scientific works" Level 2. (Student A)

"... a scientific model is based on a scientific event, for example atom model is based on atoms, they are important because experiments are conducted on models." Level 2 (Student N)

"... a scientific model means that it is accepted by a scientist from worldwide, for example the Bohr's atom model in the textbook...they guide scientists in their scientific studies,... they are formed by scientists. Level 3 (Student U)

On "reality of models":

"... the models are the copy of the real things; they reflect everything in a one correspondence." Level 1 (Student H)

"... any model should look like whatever it represents." Level 1 (Student S)

"... models are not the copy of what they represent." Level 2 (Student B)

"... anything can be modeled by various models; in each representation some points should be considered" Level 2 (Student N)

"... models reflect the reality of what they represent in various forms for producing knowledge" Level 3 (Student V)

Ontological Dimension

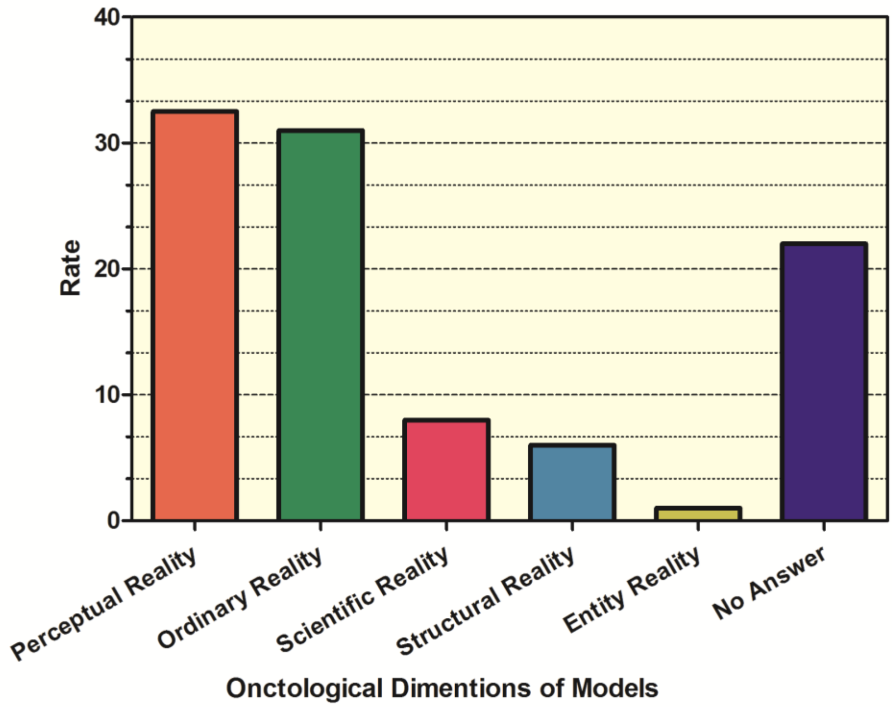

Figure 2. The Ontological Profiles of Students' Ideas about Models

The students' understanding of models from ontological perspective was evaluated using the categories and codes given in **Table 5**. The data was analyzed for all 5 questions by introducing the rate of the category among the answers for all the questions (for 5 questions N become 140, as equal to 5 times N that is 28). First, the number of students agreeing on a category for all the questions was defined. Afterwards, the rate was calculated for a category as the percentage of the students whose answers fall in that category in total answers.

The distribution of the rates to the categories are also represented in **Figure 2**.

Figure 2 shows that students' ontological understanding of the models address perceptual and ordinary realities at most. However, a considerable number of students had no idea about the subject. Scientific realist views are less than 10% among the other views. Structural and entity realistic views have the least rates.

Some examples from students' expressions are given below.

"... atoms are not present actually and do not correspond to anything since they are not alive." Perceptual Realism (Student G)

"... atoms do have correspondence in real life as we figure out what we see under electronmicroscopes." Perceptual Realism (Student E)

"... atoms are proven models by works, researches of scientists." Ordinary Realism (Students L)

"... atoms can be understood by the works of scientist" Ordinary Realism (Students A, I and E)

"... the scientist changes the atomic model when he or she tests the idea and get different result apart from the model offers. Scientific Realism (Students U, N and W)

"... the raisin pudding model of the atom constituted by Thomson was checked by scientists for several times and finally it falsified. Scientific Realism (Students H)

"... Dalton's atomic model still exists although it was unsatisfactory in explaining the mass relations. Structural Realism (Student S)

"... the scientists explanations are progressing all the time." Structural Realism (Student F)

"... scientists conducted experiments by using the models, ... sometimes they (models) failed but the atom is still there..." Entity Realism (Student C)

Discussion

This study, which is expected to contribute to the literature in the field, intended to present 28 seventh grade students' perspectives on the ontological and epistemological foundations of scientific models. Although the results are not encouraging, they do indicate the need for further thorough research.

Most students' views on description and use of models and their reality address level 1 understanding. This means students mostly believe that a model is the copy or reproduction of something (copy, scale models, toy car and etc.). Moreover, they also highlight only surface similarities (colour, length, shape and etc.) and emphasize observable properties and evaluate model attributions according to the physical appearance. Similar research findings from Harrison & Treagust (1996) and Grosslight et al. (1991) indicate that children perceive models as physical representations of reality. This finding supports Cheng & Lin's (2015) research on students' perceptions of scientific models and their capacity to create their own models (where they mostly lie on observational models to provide an explanation). This research has shown that middle school and high school students tend to have a narrow understanding of scientific models, considering them as physical replicas of target things. There is additional research with equivalent results to this result (Gobert et al., 2011; Treagust et al., 2002). However, the participants mostly have ideas about scientific models at level 2. They realize that models are used in the scientific studies, but do not have idea how they are used. Additionally, they appear to undervalue the experimental data that supports or refutes a scientific model. As the level 2 understanding of model reveals, the correctness of a model is validated not for the correctness of the idea but the self-competence of the model. Corroborating the results of this study, Carey & Smith (1993) also discovered that pupils' traditional views of science may exist despite the constructivist program. Models and real, unchanging, and absolute knowledge are always produced by science, according to the traditional understanding of science (Aikenhead, 1997). It may be concluded that they still think of depending on concrete elements. They seem not to be aware of the effect of ideas for producing a model. Another result that should be paid attention is that models are vehicles for helping scientists or others during testing of their ideas. The students' omission of critical scientific study concepts like hypothesis testing, fair testing, variable control, or scientific method abilities may account for this result (Chin & Brewer,1993; Sandoval, 2005).

The students' ontological perspectives on models show that they mostly possessed perceptual and common sense understandings associating models to the things we see through sight, touch, and other senses. Also, they believe in that models and modeling can be understood by efforts in a range of from conducting research, developing instruments and collecting data unclearly. Besides, understanding reality and models depend on the efforts for understanding. These efforts may be in a range of from conducting research, developing instruments and collecting data. However, the qualities of these efforts are unclear and using technology. Less than 10 percentages of students had understanding based on scientific realism. It is also worth noting that structural realistic and entity realistic ideas are represented at very lower rates. The model evaluation of the students was the subject of a study by Lee et al. (2021), which discovered that beliefs that "one model is better than another" were supported by true/false and pragmatic criteria of knowing, while beliefs that "both models are valuable" were supported by certainty of knowledge and pragmatic criteria, and beliefs that "depends on the evidence" tended to be informed by evidential criteria of knowing and the bounds of knowledge. As a result, it is assumed that students lack the necessary content knowledge or methods that make an issue scientific. Additionally, this might be the outcome of the fact that distinguishing a model in realistic way requires cyclic modeling activities identifying the features of this model as well as its strong and weak points for dealing with phenomena involving causal mechanisms as (Soulios & Psillos, 2016) offer. The studies conducted with model-based learning show that modeling help students' understanding of reality and the reality of model's representation (Barab and et al. 2000; Coll & Treagust, 2003; Taylor, 2003). Some studies have hypothesized that students' modeling practices may be influenced by their comprehension of scientific models (Schwarz et al., 2009), or that students' modeling practices may be shaped by their understanding of models (Crawford & Cullin, 2004; Nicolaou & Constantinou, 2014). For example, Mashhadi & Woolnough (1998) determined that secondary school students had scientific realistic views when true modeling occurs in the classroom.

As modeling-based activities occur in the classroom, students develop and improve their epistemological understanding of models and modeling (Tasquier et al. 2016), as well as their knowledge of science-related material (Soulios & Psillos 2016; Treagust et al. 2002). Therefore, models and modeling should be firstly considered in the classroom than they need to be implied carefully. Models are validated by comparing them to actual observations and data, and model evaluation should be based on and the goals of modeling (Grosslight et al. 1991; Schwarz et al. 2009). Students' focus on certain representational affordances when deciding what information should be included in a model might also result in a more simplistic understanding of modeling (Lee et. al., 2017). Therefore, the models given in the curriculum should be investigated in terms of modeling procedure. Besides, teachers' views on models and modeling should be investigated for better student understanding. The illustration presented above may be the outcome of students' experiences in the classroom, when they are frequently handed information without being explained the procedures that have led to consensus on a certain model (Mohanan, 2000). Therefore, due to their faith in the teacher as an authoritative figure rather than due to reasonable considerations (those they have not heard of), many students start to believe in scientific models (Hansson, 2018). They can create their own mental models with the aid of the models, which are physical representations of the concepts. This is very pertinent and practical for abstracting concepts in science education (Treagust et al., 2002). Nowadays students use new technological tools such as computer animations, simulations, mobile applications when they learn some science concepts. These visual tools may affect students' understanding of scientific models. So, it can be investigated that there is a significant difference between the students who use this tool heavily and who don't use them.

Conclusion

The purpose of this straightforward survey study was to learn more about how different students perceive scientific models and modeling from different epistemological and ontological perspectives. The results showed that the students' description and use of models addressed surface similarities and appearance mostly for observable properties. However, they overlooked what scientist do and how they use and test models. They did not tend to view that models are vehicles for verifying; instead they see models as they are just explanations without a need for experimental evidence. Additionally, they do mention the rules or the process in the representation.

They also have understanding that models are true images of the objects as long as we perceive them through perceptual and ordinary realism. However, students are the lack of scientific or structural realist view that are mostly about the theory-evidence coordination revealing the reality through model and modeling.

These findings show somehow consistent with research findings of the other research reports. The learner should examine models logically. Many pupils believe in scientific theories because they have faith in the authoritative figure (the teacher), rather than because of logical justifications (those they have not heard about). Therefore, more research especially including the validation processes of models based on scientific evidence including science process skills such as observations, gathering data and inferring should be conducted to understand how to overcome the confirmed or classical interpretation of models as the copy of the real world. Schwarz & White (2005) recommended explicit modeling training in order to develop scientific models and an epistemological grasp of their nature and function. Moreover, with age or more education in school, pupils' knowledge of models and modeling would get more advanced (Lee et al., 2021), the results of this study needs to be compared with the elder students' views of modeling within the same framework since the epistemological and ontological views may be context depended (Krell et al. 2014; Lee & Tsai, 2012).

This study has two major constraints that we believe will be taken into account in future studies. The first limitation of this study is gathering the data based on only paper-pencil questions. As a suggestion for further researches, the students' understanding of models and modeling should be intervened by the practical models and modeling questions. The other limitation is the number and the grade level of participants. We believe, expanding the number of participants and including different class levels can yield more valid results for further researches.

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