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Does Size Matter? Animal, Living and Non-Living Classification, Implications for Teaching

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Abstract: An empirical investigation of elementary school teacher candidates on classification activities dealing with animate and inanimate objects in terms of being living or non-living demonstrates that as the size of the objects increases, subjects are more likely to classify them correctly as either being an animal or having living characteristics. Despite a variety of misconceptions having an impact on the results, size magnitude is shown to play a significant role on proper classification. The subjects' performance on these activities at an advanced stage of their preparation suggests that their factual and procedural knowledge are deficient due to a lack of opportunities for conceptual development of the items tested. The identification of the role of size on the proper classification of objects in the activities bears significantly on the science curricular structure at the elementary school level. As the results of this study indicate, both pre-service elementary school teachers and by extension their prospective students need longer practice dealing with living and non-living classification activities, particularly in tasks where the microscopic features of matter can be investigated so that the proclivity to regard size as the defining characteristic is effectively addressed.

Keywords: *Classification, misconceptions, science teaching.*

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Introduction

Learning science involves challenging features of instruction that concern its content and how it is acquired. At the earliest levels of science education emphasis has been and continues to be placed on the learner's ability to properly view nature as more advanced practitioners do. To that extent, the degree of realism in the educational materials used with children has received considerable attention (Setoh et al., 2013; Waxman et al., 2014; Tarłowski & Rybska, 2021). A common thread found in studies of how children view animals is the prevalence of anthropomorphic features derived from educational materials, as well as those contributed by the learners (Bonus, 2019; Manfredo et al., 2020; Waxman et al., 2014). Attributing human-like features to other species is concerning as it hinders the proper development of an understanding of biology as a science (Villarroel & Infante, 2014; Özgür, 2018; Weisberg & Hopkins, 2020). Among the most serious impediments for proper science learning is the role of misconceptions in students' prior knowledge of various phenomena. The impact of such misconceptions becomes more crucial for effective teaching given the current emphasis on inquiry-based and constructivist approaches to science instruction by the National Research Council (NRC, 2012), and the American Association for the Advancement of Science (AAAS, 2009). The challenge for instructors is the well documented stubbornness and resistance to change, that misconceptions exhibit and that can greatly undermine creative approaches to science instruction. Particularly relevant to the study described in this paper is the persistence of certain intuitive concepts among students that have received prior instruction (Babai et al., 2010).

Misconceptions can be particularly relevant to integrated approaches where science content knowledge retention and the development of process skills are combined in teacher preparation. Documents from organizations such as the Next Generation Science Standards (NGSS) specifically include in the definition of content as factual information, the development of critical thinking skills such as measurement and classification (NGSS, 2021). In other words, effective science teacher preparation and student science learning at all levels must combine the acquisition of declarative knowledge with various ways to process it and apply it (Wüst-Ackerman et al., 2018).

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An integrated approach to science instruction ought to emphasize the interplay between factual and procedural knowledge to develop conceptual knowledge, as it has been demonstrated in mathematics education research (Byrnes & Wasik, 1991; Rittle-Johnson et al., 2001; Saxton & Cakir, 2006).

One of the more fundamental and appropriate process skills to implement at the earliest levels of science learning is that of classification since it is fairly easy to do, and it doesn't appear to be an innate feature of human cognition. Children as young as five years old appear to have a predisposition to attribute teleological features to certain living things like animals, but not to others such as plants, and it takes them a long time to properly categorize animals and plants (Opfer & Siegler, 2004). Instruction on classification ought to begin earlier; children need repeated exposure to opportunities where they can develop classification skills since they are not born with them (Martin, 2009). This is in contrast to other activities on the use of procedural knowledge that relies on the documented natural sense of numerosity (Brannon, 2002; Feigenson et al., 2002).

Elementary school science teacher preparation correspondingly needs to emphasize classification skill development due to expediency, as the content preparation of many candidates in such programs often tends to be limited in scope and depth. Classification tasks also present ideal opportunities to combine the use of science content with process skill development, and to elicit student prior knowledge of phenomena to be incorporated into a constructivist environment for teaching and learning (Alanazi, 2019).

Nevertheless, despite the promising aspects of such a learning environment the role of misconceptions looms large, particularly those based on prior exposure to science in coursework, or having been obtained through a variety of other sources. Two such misconceptions have been categorized as conceptual misunderstandings-incomplete, oversimplified, or inappropriately constructed knowledge from previous science courses, and factual misconceptions-ideas learned at an earlier time and incorrectly retained (Borgerding & Raven, 2017; Committee on Undergraduate Science Education, 1999).

The topic of classification naturally exposes future elementary school teachers to opportunities where their prior misconceptions can be addressed and hopefully overcome as they have a limited amount of course preparation where such activities can occur.

Therefore, the research questions selected in this study were:

1. What is the understanding among prospective elementary school teachers of what can be considered an animal in classification tasks?
2. To what extent do prospective elementary school teachers possess misconceptions about what is considered living and non-living?

Methodology

Determination of pre-service Elementary School teachers' classification skills

A sample of elementary school teacher candidates was used in the empirical investigation of the salient features of two classification activities. These were obtained from the National Science Teachers Association's (NSTA) Assessment Tasks (Keely et al., 2005). One consisted of a classification of items from a list as either being an animal or not; the other was a distinction made from another list of items between those considered living from those considered non-living.

Data Collection

Data were collected during three years as part of the activities undertaken in a required course for elementary school teacher candidates: Methods of Teaching Mathematics, Science, and Technology. Prerequisites for the course are two science courses with laboratory components, and a course in college algebra. The students worked in groups of four, with variations in the number of groups depending on the enrollment in the course, the range being from four to seven groups. Collaboration was emphasized within-groups, one student being chosen to present each group's classification results, followed by a general class discussion with between-groups discussions emphasized. The results from all the groups were then averaged for the three years and plotted as histograms for each activity in terms of the frequency of choices made by the groups.

Analysis

The performance on the tasks was averaged for six semesters and the mean score reported in Figures 1 and 3. The reliability of the assessments for both tasks was determined by an analysis of the performance on the items in the figures where the score is neither 100% nor 0%; these are the responses where the numbers of correct and incorrect responses were averaged to the reported score in both figures. The consistency in the performance for both tasks was very similar; 38.9% of the responses for Is It an Animal? were correct, while 41.7% of those for Is It Living? were correct. In addition, the determination of statistical measures of significance for the results of the assessments of the two tasks is reported in Table 1.

Table 1. Performance data breakdown of scores considered passing (>70%) and those considered failing. A two-tailed test of significance and Cohen's *d* value for measuring Effect Size between the means yield considerably large values.

Task	Pass Mean	SD	Fail Mean	SD	t-test value	p value	Cohen's <i>d</i>
Is it an Animal?	80.77	12.57	26.10	14.44	-6.35741	.000132	4.04
Is it Living?	87.50	13.10	41.03	26.35	-4.95348	.000422	2.23

The validity of the data collection tools was established with high school biology teaching candidates who performed the same tasks in their respective methodology of teaching science courses. They evaluated the relevance and appropriateness of the items to test for assessment of classification, and a comparison was made between their own performance on the tasks, and that of the elementary teacher candidates, as well as the answers provided by NSTA. A subset of these tasks yielded 4 items where the performance of the high school teaching candidates matched that provided by NSTA in terms of their correctness, while the performance by the elementary teacher candidates was uniformly incorrect for those same items. This served to illustrate that more science content preparation, such as that of biology majors produces performance on these tasks that resembles the expertise expected by NSTA.

The assessments demonstrate fitness to the assumptions based on the result of a Shapiro-Wilk test that yields a p-value of .611690 thus accepting the hypothesis of normality (H_0).

Findings / Results

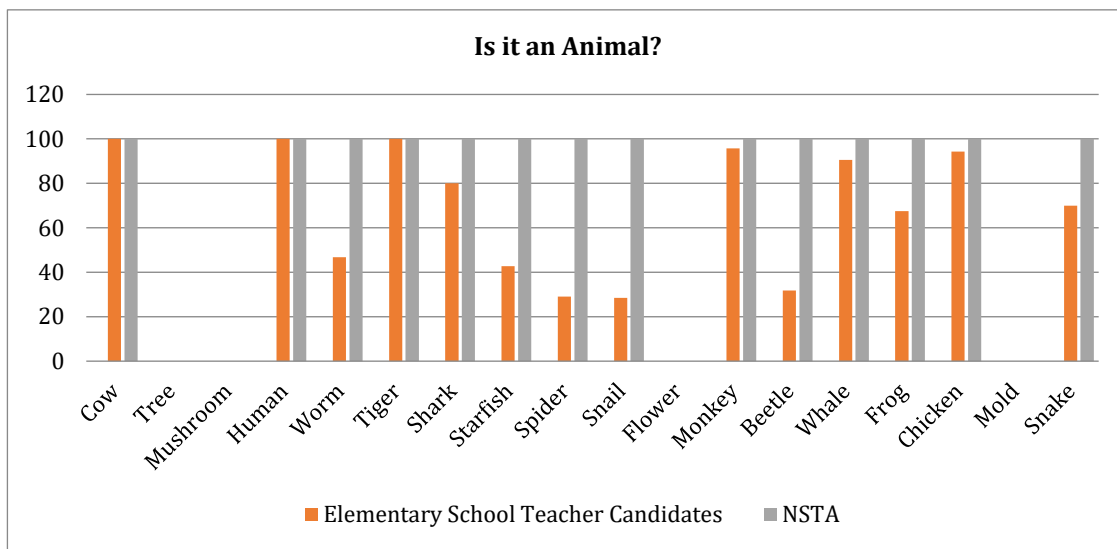


Figure 1. Performance on the animal classification activity: Comparison between the performance of elementary school teacher candidates and the answers provided by NSTA.

Figure 1 shows the data results for the animal classification activity. The data represent the choices made by the students, compared to the answers provided by NSTA. The proper answers would be a column for the item considered an animal with the same value for all the groups, and zero value for those not considered animals. There is consistency between the students' answers and those provided by NSTA for some items, but not for all. When the data are plotted using the deviation from the correct answer for each item as a percentage, and then arranging the items in order of approximate size, a pattern emerges that can be quantitatively analyzed.

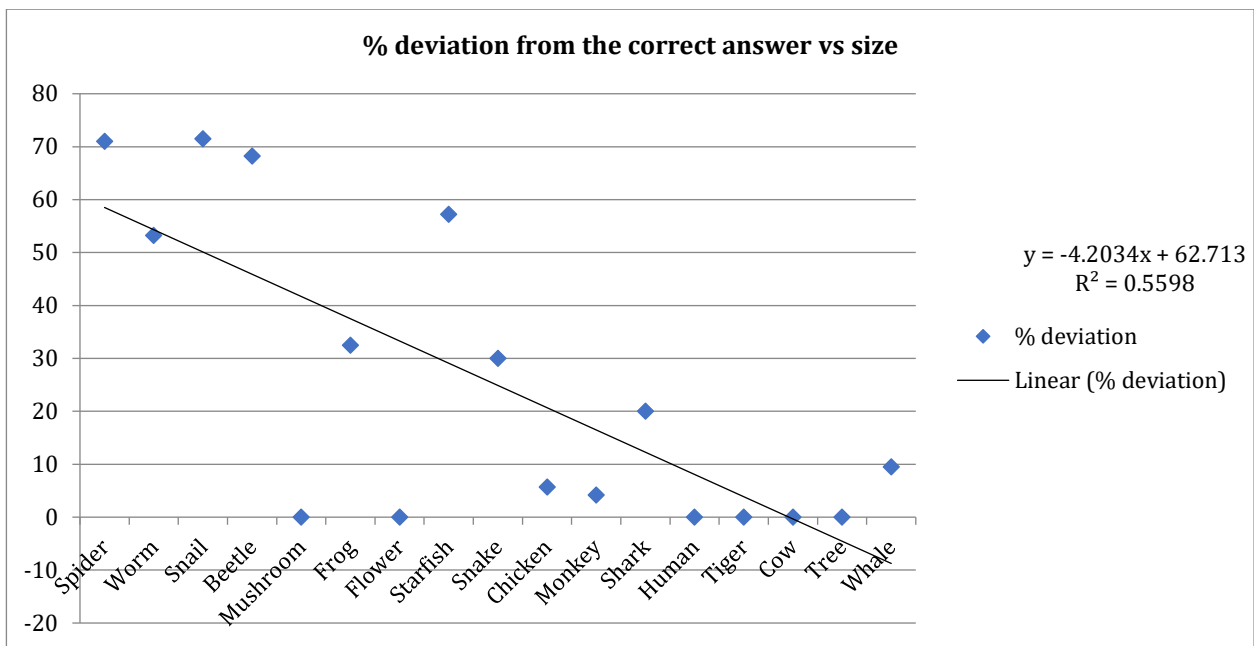


Figure 2. Graph of the deviation in student performance from the correct answer (NSTA: 0 for those items not considered animals, and 100 for those considered animals), and the size of the item. As the size of the item increases, the amount that the answer deviates from the correct answer decreases. The high correlation of the data ($r = .748$) yields a t -test of significance $t_{(15df)} = 4.39$, $p < .001$, $\alpha = .05$

Figure 2 shows the data using the % deviation from the correct answer as a function of the size of the item to be selected as an animal. The % deviation is taken as the absolute value of the difference between the NSTA answer (either 0 or 100%) for the items not considered an animal, or for those that are, and the mean groups' % value of classification. It is apparent that the larger the size of the item to be classified, the smaller the deviation from the correct answer. In other words, the groups correctly identify items as either not being an animal, or as being one, provided the size scale is fairly large, by everyday standards. Those items that are small by comparison tend to exhibit a larger deviation from the correct answer. The curious absence of some items from the animal classification was clarified through the class discussions that followed each group's presentation of results. These indicated that items not classified unanimously as animals that are fairly small, and those at the other extreme, such as the whale and the shark, were considered to be insects, invertebrates, etc. This suggests that some students regard those items as belonging to sub-categories, not that they ought to be excluded from the animal kingdom. This is evidence of an unclear and inappropriate understanding of taxonomy from previous coursework, where categories of classification appear to have been conflated.

The three items not considered animals are correctly identified and thus show no deviation from the correct answers, resulting from the lack of locomotion as clarified during the discussions. Additionally, with the exception of the starfish perhaps due to its perceived lack of mobility, the average deviation from the correct answer for the small items not being considered animals is nearly four times that of the larger ones. This suggests that the size of the animal appears to play a role in the inappropriate understanding of its classification in the animal kingdom; a snake is misclassified much less than a snail. Additionally, it is evident that the concept of an animal is much more restricted to mammals, which correlates very well with their size.

Despite the variability resulting from such misconceptions, the data from Figure 2 exhibit a statistical significance in terms of the size scale pattern identified. The data are highly correlated, where the high correlation value ($r = .748$) yields a t -test of significance $t_{(15df)} = 4.39$, $p < .001$, $\alpha = .05$.

This identified dependence of classification features on the size scale can be supported by the results from the other activity. The groups also undertook a task where a differentiation between living and non-living items was required.

The performance is displayed in Figure 3; there is agreement between the students' performance in classifying some items as either living or non-living, and the answers provided by NSTA. However, as with the animal classification task, there are deviations from the correct answers for more than half of the items.

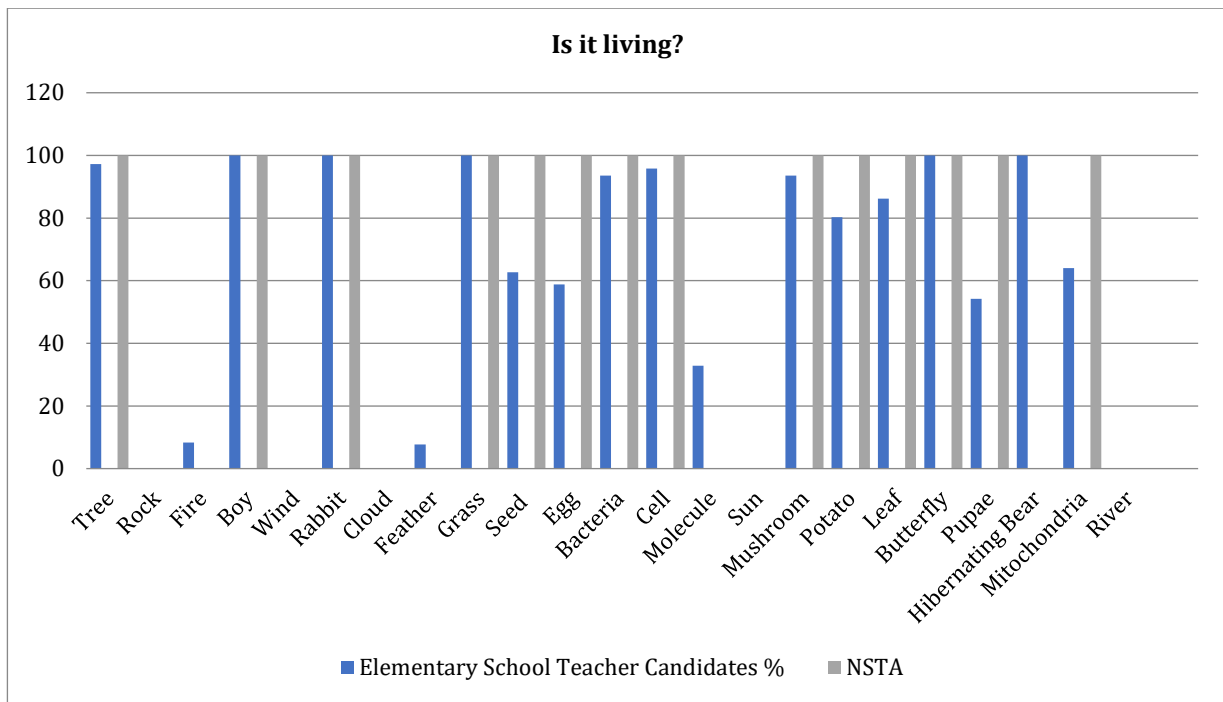


Figure 3. Results of classification activity on whether the items in question are living or not; comparison between the candidates' performance and the answers provided by NSTA, either 100% for living or 0% for non-living.

There are several items not considered living according to the NSTA answers that were chosen as living by several groups, although the animistic features identified in studies of young children's misconceptions do not appear to be present. For instance, the sun, the river, and the cloud are not selected as living, despite all these sharing motion features that have been identified as a probable reason for children's attribution of living characteristics to them. Instead, the types of misconceptions apparent in the responses can be attributed to improperly learned concepts in previous coursework or other exposure to them, such as the feather, seed, and egg.

Arranging the items in order of increasing size and plotting the deviation from the correct answer as a function of size scale shows a similar pattern to that found in the animal classification activity. As shown in Figure 4 the variables are negatively correlated, as the size of the item in question increases the % deviation from the correct answer decreases; the high correlation of the data ($r = .686$) yields a t-test of significance $t_{(21df)} = 4.21, p < .001$.

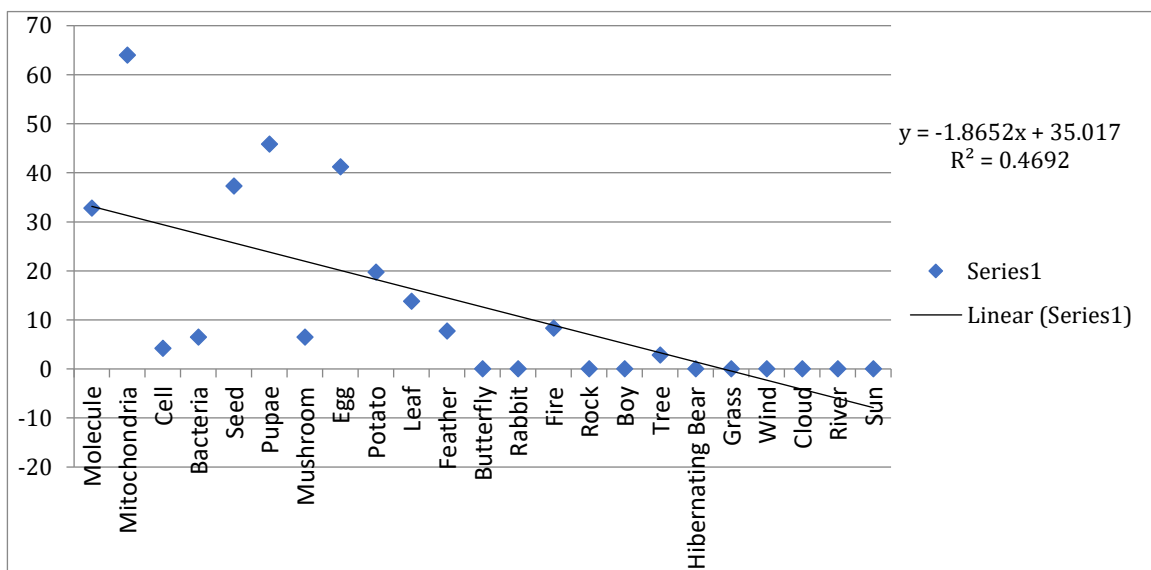


Figure 4. Performance on living classification activity: as the size of the item in question increases the % deviation from the correct answer decreases; the variables are negatively correlated. The high correlation of the data ($r = .686$) yields a t-test of significance $t_{(20df)} = 4.21, p < .001$.

The mushroom can appear to be an interesting 'outlier' if one bases the student's recollection of its typical size without including exotic types that would be larger, as can be found in some supermarkets and grocery stores. Nevertheless, if this were to be considered, the correlation would be even more significant by placing the mushroom further along the size scale. The cell and the bacteria are also curious outliers perhaps due to teleological considerations; despite their small size students seem able to properly classify them as living by clearly identifying these with purpose-driven behaviors associated with motion and reproduction.

Discussion

The findings of this study can be incorporated into those that have determined the existence of a variety of anthropomorphic features among elementary school students (Chyleńska & Rybska, 2018; Weisberg & Hopkins, 2020; Tarłowski & Rybska, 2021). Thus, supplementing the current emphasis on students' pre-instructional knowledge. The findings of students' attribution of human features to other animals results in poor performance in tests of biological knowledge; the verbal and pictorial descriptions found in some instructional materials, as well as in media representations likely contribute to that. A particular dilemma appears in the simultaneous emphasis on the unity as well as the diversity of life, which comprise a great deal of the curriculum materials at the elementary school level.

The results of both activities demonstrate that as the size of the objects increases elementary school teaching candidates are more likely to classify them correctly as either being an animal or having living characteristics. Despite a variety of misconceptions having an impact on the results, it seems that size magnitude plays a significant role on proper classification. This could also afflict the integrity of the representations the students are exposed to in the instructional materials they encounter. The evident misconceptions held by the groups of pre-service elementary science teachers at a fairly advanced stage of their preparation suggests that their factual and procedural knowledge are deficient due to a lack of opportunities for conceptual development of the items tested. The persistence of such misconceptions can be attributed to their limited science content preparation where the concept of an animal and the attribution of living characteristics require that students engage in more extensive practice to cause conceptual change (Marrs et al., 2003; Venville, 2004). This conceptual change is necessary if we expect that they will properly instruct those elementary school students that studies have demonstrated are unduly influenced by improper media representations, especially when a variety of media-driven instructional tools are being recommended.

The types of misconceptions possessed by the participants in this study are clearly different from those found among young children, described as intuitive or naïve (Inagaki & Hatano, 2002), although they are still problematic. Remaining as conceptual misunderstandings despite prior instruction renders them quite stubborn and resistant to improvement in the development of conceptual change, as they lead these prospective teachers to an unrealistic sense of understanding likely to have detrimental consequences.

The identification of the role of size on the proper classification of objects in the activities analyzed bears significantly on the science curricular structure at the elementary school level, particularly when it concerns the introduction of microscopic properties (Elmesky, 2013). The development of an understanding of the particulate theory of matter has been shown to exhibit a gap in time between instruction and young students' use of it in applications (Stavy, 1991). Introduction to the concept of matter earlier in the curriculum and the use of classification activities should engage young students in looking for common defining attributes by emphasizing the perceptual features of items selected. An example would be to elicit an intuitive notion when presenting students with processes of dissolving solids into liquids (Stavy, 1990).

The concept of an animal being restricted to land mammals has been shown to be prevalent in other studies of biological knowledge among elementary school teachers and 10 and 15 year old students, despite having received instruction (Osborne et al., 1985). There is a long history of anthropomorphic features and other attributions to non-living entities commonly found among young children (Brumby, 1982; Monteiro & Reis, 2020).

Conclusion

The science content knowledge of elementary school teachers needs to be carefully examined since these individuals will be responsible for teaching science among several other subjects, and insufficient preparation exposes them to the pernicious and deleterious role of misconceptions about natural phenomena widely documented to be found among their students. These teachers need more exposure to and preparation in engaging their students in activities since we do not want the teachers' own misconceptions to hinder the conceptual development of their students.

Recommendations

Difficult concepts need to be revisited many times so that more prolonged exposure to them can give learners and teachers opportunities to uncover misconceptions about them and thus facilitate the process of conceptual change. It is clear that as the Next Generation Science Standards advocate, there are certain unifying and important concepts that need to be emphasized and *repeatedly* dealt with so that persistent misconceptions can be effectively addressed and ultimately resolved. As the results of this study indicate, both pre-service teachers and by extension elementary school

students need longer practice dealing with animal, and living and non-living classification activities, particularly in tasks where the microscopic features of matter can be investigated so that the proclivity to regard size as the defining characteristic can be properly understood as not always being so. The findings of this study ought to be confirmed with larger populations of elementary school teacher candidates, and in various countries, so that the prevalence of such misconceptions can be effectively confirmed and addressed.

Limitations

A particular limitation of the study is the varying level of content preparation that elementary school teacher candidates may experience in other countries. Among the mandates that have produced the NGSS standards in the US is the need for uniformity in the science preparation of students in all states of the union, something that also afflicts their teachers in many instances. Nevertheless, as science misconceptions have been universally documented, more opportunities for conceptual change may be beneficial for all despite extensive content preparation. The validity of the assessment tools can be enhanced by increasing the size of the assessment group and to include a Lawshe scale measure of validity. In addition, correlations between the responses of teacher candidates and those of elementary school students can extend the consistency of the assessments.

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