Preservice Elementary Teachers' Understanding Of Standards-based Magnetism Concepts

Ronald K. Atwood, Department of Curriculum and Instruction,

and John E. Christopher, Department of Physics and Astronomy,

University of Kentucky, Lexington, KY 40506

Email: **rkatwo00@uky.edu**

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Rationale and Research Question

Magnets are commonly found in most of our homes. The use of magnets to attach notes, pictures and children's work to refrigerators is a common practice. Many young children conduct explorations with magnets in school (Tolman, 1998), frequently bringing a magnet near, or in contact with, a variety of materials and looking for evidence of interaction. Is this a physical science topic that is well understood by the masses? To the contrary, it is not. The surprisingly limited literature on magnetism suggests that basic, standards-based concepts on magnets and their behavior (National Research Council, 1996; American Association for the Advancement of Science, 1993) are poorly understood by a broad age-range of individuals (Hickey & Schifecci, 1999; Atwood & Christopher, 2000; Finley, 1986; Constantinon, Raftopoulos & Spanoudis, 2001). Perhaps the poor understanding of persons school age and older at least partially stems from deficiencies in elementary science textbooks (Barrow, 1990) and elementary science methods texts (Barrow, 2000).

As more science departments answer the call to provide special programming through courses serving preservice elementary teachers (McDermott, 1991; McDermott, Heron, Shaffer & Stetzer, 2006; Trundle, Atwood & Christopher, 2002) priorities have to be established. More specifically, decisions must be made on which science topics will be addressed both in depth and in a manner that promotes the needed conceptual change (Vosniadou, 1991, 2003). Documenting specific conceptual needs on magnets and the behavior of magnets for preservice elementary teachers is needed to establish the priority that should be assigned to this topic and to inform instruction provided on the topic. To address this need a descriptive study was conducted that included 245 preservice elementary teachers enrolled at five institutions of higher education in the central Appalachian region of three Mid-Atlantic States. The research question was: What scientific and non-scientific conceptions of standards-based magnetism concepts are held by a group of preservice elementary teachers?

Procedure

Members of the non-random sample completed the assessment tasks on their first day in a physical science course. Five multiple choice questions with non-scientific conceptions embedded in the distracter options (Hestenes, Wells & Swackhawer, 1992) were utilized to assess conceptual understanding of magnets and the behavior of magnets. The participants completed 27 additional assessment tasks dealing with other science topics, along with the five tasks on magnetism.

Results and Discussion

Each of the five assessment tasks is presented, followed by a table that shows the frequency with which each option A-E, was selected. An asterisk appears above the best answer in each table. Classification into high, medium and low subgroups was based on performance on the entire 32 item test. Task one and results for task one follow.

Task 1

The most likely reason magnets stick to refrigerator doors is because they are interacting with

A) iron in the doors.
B) the plastic or ceramic coating on the doors.
C) a lightweight metal, such as aluminum, in the doors.

D) a heavy metal, such as lead, in the doors.
E) electric charge on the refrigerator doors.

Table 1
Task One Results for Preservice Elementary School Teachers
Response Frequencies by Performance-level Subgroups and Totals as Frequencies and Percents

	* A	B	C	D	E	Omit	Total
High	27	1	27	9	16	1	81
Medium	15	0	42	16	10	0	83
Low	11	1	32	13	24	0	81
Totals as *f*	53	2	101	38	50	1	245
Totals as %	22	1	41	16	20	0	100

Examination of the results in Table 1 reveals poor performance across all subgroups, but particularly for the medium and low subgroups, where only 15 (18.5%) and 11 (13.6%) participants, respectively, responded correctly. Overall, only 53 of 245 preservice teachers (21.6%) showed evidence of understanding that iron is ferromagnetic and most other metals, including aluminum and lead, are not. Note the popularity of options C and D, which attribute ferromagnetic effects to non-ferromagnetic metals. Considering that multiple choice results tend to include false positives (Trundle, Atwood & Christopher, 2002), the situation likely is worse than these data indicate. The selection of option E by 20% of the sample may reflect confusion between the effects of opposite magnetic poles and opposite electric charge on two objects. Hickey and Schibeci (1999) found electric charge to be commonly included in explanations of how magnets attract and repel, including by

15 of 29 preservice elementary teachers. This non-scientific conception had been documented and discussed earlier by Malony (1985). On the positive side it is encouraging that only two participants selected option B, attributing ferromagnetic properties to plastic or a ceramic coating on refrigerator doors.

Task 2 served to probe participants' understanding of the relationship between a magnetic compass and earth's magnetic field.

Task 2

You may use a magnetic compass to find your way,

A) since the compass needle will always point in the direction you are facing.
B) during the day but not during the night.
C) since the compass needle aligns in a north/south direction.
D) if there aren't too many trees or mountains nearby.
E) because compass needles don't move.

Table 2

Task Two Results for Preservice Elementary School Teachers

Response Frequencies by Performance-level Subgroups and Totals as Frequencies and Percents

	A	B	* C	D	E	Omit	Total
High	5	0	73	0	3	0	81
Medium	20	1	62	0	0	0	83
Low	29	5	37	6	4	0	81
Totals as *f*	54	6	172	6	7	0	245
Totals as %	22	2	70	2	3	0	100

The selection of option A by 54 (22.4%) of the preservice elementary teachers was surprising, although in working with elementary children we frequently have encountered explanations consistent with option A. We expected even more participants to jump on option C, even if they did not understand how the north/south alignment of a magnetic compass could be used to 'find your way'. Still, it is encouraging that 172 members of the sample, or 70.2%, selected the correct response. Performance on Task 2 was the best of the five tasks. However, only 37 of 81 in the low performing subgroup, or 45.7%, selected the correct response, while 35.8% selected option A.

Barrow's (1990) report on elementary children's conception of magnetism noted that bar and horseshoe magnets are most commonly used to study magnetism in schools, but the refrigerator magnets encountered around the home usually are neither bar nor horseshoe magnets. The disconnect is unlikely to be helpful for in-school instruction. Task 3 provides five choices about bar magnets and their behavior. School experiences may have served as the major data source for constructing the understanding tapped in responding to this task.

Task 3

A bar magnet

A) has the strongest magnetic effect in the middle of the bar.
B) interacts with all metallic objects.
C) will not influence a magnetic compass.
D) can repel any other magnet.
E) interacts with heavy metals like lead, brass, and gold.

Table 3
Task Three Results for Preservice Elementary School Teachers
Response Frequencies by Performance-level Subgroups and Totals as Frequencies and Percents

	A	B	C	* D	E	Omit	Total
High	15	28	2	31	5	0	81
Medium	19	22	2	22	18	0	83
Low	16	22	9	16	18	0	81
Totals as *f*	50	72	13	69	41	0	245
Totals as %	20	29	5	28	17	0	100

Note the popularity of option B across all subgroups and option E across the medium and low-subgroups. These results are consistent with Task 1 results, indicting a lack of understanding that most metals are not ferromagnetic. In selecting option A fifty participants (20.4%) provided evidence of not understanding about the lack of a magnetic effect in the middle of a bar magnet. This lack of understanding seemed to be essentially evenly distributed across the three subgroups. Only 69 preservice teachers, or 28.2%, from the entire sample selected the correct response, casting doubt on the efficacy of investigations with bar magnets in which these preservice elementary teachers may previously have been engaged.

Options A, C and E of Task 4 provide opportunities to express the non-scientific understanding that the relative strength of two magnets can be predicted by the size or shape of the magnets

Task 4

Which of the following statements about bar, horseshoe, and round refrigerator magnets is most accurate?

A) Large magnets are stronger than small magnets.
B) Magnets have a N-pole and a S-pole.
C) Horseshoe magnets are stronger than bar magnets which contain the same amount of material.
D) Round magnets have *only* a N-pole or *only* a S-pole.
E) A bar magnet will pick up more paper clips than a round refrigerator magnet.

Table 4
Task Three Results for Preservice Elementary School Teachers
Response Frequencies by Performance-level Subgroups and Totals as Frequencies and Percents

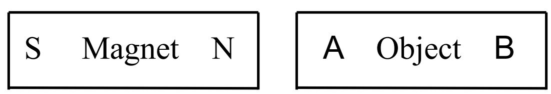
	A	* B	C	D	E	Omit	Total
High	8	58	5	9	1	0	81
Medium	9	47	5	8	14	0	83
Low	19	27	10	6	19	0	81
Totals as *f*	36	132	20	23	34	0	245
Totals as %	15	54	8	9	14	0	100

Collectively, 90 participants, or 36.7%, selected one of those options. Note that 48 of the 90 responses came from the low-subgroup, and only 14 from the high performing subgroup. Options B and D allow a choice of whether magnets have a N-pole and S-pole, or a round magnet has only one or the other. As expected, a large number of persons, 132 (53.9) selected option B, the correct answer. The fact that 23 participants selected the “round magnets have only a N-pole or only a S-pole” option perhaps could be due to limited investigations of the interactions one can observe with two round magnets.

Task 5 provides an opportunity to apply an understanding that unlike magnetic poles attract and so do a magnetic pole and a ferromagnetic material. Note that the term, ferromagnetic, is not used. Rather, "iron or a material that behaves magnetically like iron" is used. The thinking here was that a lot more people have observed iron interacting magnetically than have been introduced to the term, ferromagnetic.

Task 5

Consider the diagram below



The N-pole of a bar magnet is brought near end A of an object which looks very similar to the bar magnet in shape, size, and color. If end A of the object is attracted to the N-pole of the magnet, you could

A) be sure that the object is another bar magnet and A is the N-pole.
B) be sure that the object is another bar magnet and A is the S-pole.
C) conclude that the object is either a bar magnet and A is the N-pole or the object is not a magnet but contains iron or a material that magnetically behaves like iron.
D) conclude that the object is either a bar magnet and A is the S-pole or the object is not a magnet but contains iron or a material that magnetically behaves like iron.
E) You cannot make any of the above conclusions.

Table 5
Task Five Results for Preservice Elementary School Teachers
Response Frequencies by Performance-level Subgroups and Totals as Frequencies and Percents

	A	B	C	* D	E	Omit	Total
High	3	17	7	52	2	0	81
Medium	13	32	3	33	2	0	83
Low	13	35	19	8	6	0	81
Totals as *f*	29	84	29	93	10	0	245
Totals as %	12	34	12	38	4	0	100

Thus, we would predict using ferromagnetic instead of "iron or a material that magnetically behaves like iron" would make the task considerably more difficult. For these adult learners, likely future teachers of magnets and the behavior of magnets, it was disappointing that only 93 of 245 (38.0%) were able to do the required application. The strikingly poor performance (approximately 10%) of the low subgroup in selecting the best answer is particularly cause for concern. As one might be expected to predict, option B was the most popular distracter, especially for the low and medium subgroups. Many participants were apparently aware that unlike magnetic poles attract. Perhaps some read no farther than option B. The 29 participants who selected option A apparently lacked the awareness that like magnetic poles repel, and perhaps some of the additional 29 who selected option C did also.

Collectively, results for these five tasks reflect a poor understanding of magnets and the behavior of magnets. The tasks do not attempt to assess understanding of what causes magnetic effects. Rather, the tasks focus on properties and phenomena that can be, and probably should be, directly investigated in an elementary classroom. The performance of the low subgroup, selecting only 9.9% to 45.7% correct responses across the five tasks, was especially weak.

Conclusions and Implications

The performance of this sample of preservice elementary teachers clearly indicates magnets and the behavior of magnets should be included in physical science coursework preparing them to effectively practice as elementary teachers. The instruction should be designed to promote the desirable conceptual change (McDermott, 1996; Vosniadou, 2003) these results suggest are needed.

The finding that many in this sample seemed to believe most metals are ferromagnetic adds to the literature revealing the popularity of this non-scientific conception. Reflecting on the practice we have observed of elementary classroom teachers providing opportunities for students to "test" many objects around the classrooms with a magnet has led to the following conjectures. First, we infer both teachers and students find this hands-on activity to be both interesting and worthwhile. Second, the students typically find several objects permanently located in the classrooms that will interact with a magnet, as well as some objects set out especially for this activity. Frequently the objects that interact, which can easily be the majority of metallic objects in the classroom, are coated with paint, chromium, zinc, brass or some other material which masks the appearance of iron or steel. In our experience these lessons typically end with identification of the objects that interact but not the material, iron, which is a material almost certainly included in the manufacture of the objects. It is very improbable that ferromagnetic objects in a classroom contain cobalt or nickel. Our view is that students, both young children and mature adults, need help in interpreting their observations during this hands-on activity. Thus, it seems really important to prepare elementary teachers who have the understanding needed to provide important interpretation, and understand the need to do so.

We hypothesize that having preservice teachers use a magnet to test several labeled metals that are not coated or otherwise disguised (including iron, copper, aluminum, brass, lead and chromium) and comparing the results with their previous understanding during interpretive, sense making discussions would be very fruitful. This activity would provide direct observations that contradict a popular non-scientific conception and raise the level of meta-cognitive awareness of the disconnect between a popular non-scientific understanding and the direct observations (Vosniadou, 2003). This activity could be followed with the kind of exploration with a magnet elementary teachers frequently use with their students (Tolman, 1998). However, going beyond the usual practice to inform the investigators that all objects located in the room which interact with a magnet almost certainly contain iron in disguise could be a valuable instructional strategy to promote the needed conceptual understanding and teacher preparation. This kind of non-traditional instructional strategy should be developed and tested for other magnetism concepts, utilizing the results of this study, the research literature, as well as experience in teaching the topic and observing others teach it.

The findings of this study are most relevant to the science faculty who teach the physical science courses taken by preservice teachers at these five institutions of higher education and the science education faculty who collaborate with the science department faculty to provide effective programming for preservice elementary science teachers. The findings should be used collaboratively by these faculties for both formative and summative purposes. That is, the results can be used as one basis for designing instruction and also as a baseline for judging the effectiveness of instructional interventions. Although we can not generalize to other teacher education institutions, we have no reason to think this is an isolated problem. Our findings are consistent with the literature cited earlier that non-scientific conceptions on this popular topic are pervasive. Thus, at the very least science and science education faculty colleagues at other colleges and universities should engage in the assessment of their students to determine the extent of the problem locally, and the extent to which the problem is being addressed in their teacher education programs.

References

American Association for the Advancement of Science (1993). Benchmarks for science literacy. New York: Oxford University Press.

Atwood, R., & Christopher, J. (2000). Conceptual change in an inquiry-based physics course for preservice elementary teachers. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Barrow, L. (1990). Elementary science textbooks and potential magnet misconceptions. School Science and Mathematics, 90, 716-720.

Barrow, L. (2000). Do elementary science methods textbooks facilitate the understanding of magnet concepts? Journal of Science Education and Technology, 9, 199-205.

Constantinou, C., Raftopoulos, A., & Spanoudis, G. (2001). Young children's construction of operational definitions in magnetism: The role of cognitive readiness and scaffolding the learning environment. Paper presented at the Cognitive Science Conference..

Finley, F. (1986). Evaluation instruction: The complementary use of clinical interviews. Journal of Research in Science Teaching, 23, 635-650.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. The Physics Teacher, 30, 141-158.

Hickey, R., & Schibeci, R. (1999). The attraction of magnetism. Physics Education, 34, 383-388.

McDermott, L. (1991). Milikan Lecture 1990: What we teach and what is learned: Closing the gap. American Journal of Physics, 59, 301-315.

McDermott, L. (1996). Physics by inquiry. New York: Wiley.

McDermott, L., Heron, P., Shaffer, P., & Stetzer, M. (2006). Improving the preparation of K-12 teachers through physics education research, American Journal of Physics, 74, 763-767.

National Research Council (1996). National science education standards. Washington, D.C.: National Academy Press.

Trundle, K., Atwood, R., & Christopher, J. (2002). Preservice elementary teachers' conceptions of moon phases before and after instruction. Journal of

Research in Science Teaching, 39(7), 633-658.

Vosniadou, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. Journal of Curriculum Studies, 23, 219-237.

Vosniadou, S. (2003). Exploring the relationship between conceptual change and intentional learning. In G. M. Sinatra & P. R. Pintrich (Eds.), Intentional Conceptual Change (pp. 377-406). Mahwah, New Jersey; Lawrence Erlbaum Associates.