

Are Inservice Elementary Teachers Prepared to
Teach Fundamental Concepts of Magnets and
the Behavior of Magnets?

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Rationale and Research Question

Magnets are commonly used around the home to hold children's school work, family photographs and decorative items to the refrigerator door. And, exploration with magnets commonly occurs in school by young children (Tolman, 1998), frequently involving tests to see which objects in the room will interact with a magnet. So, conceptually is this an easy physical science topic that is widely understood? The surprisingly limited conceptual understanding literature on magnets and the behavior of magnets indicates it is not. To the contrary, standards-based concepts on magnets and the behavior of magnets (National Research Council, 1996; American Association for the Advancement of Science, 1993) are poorly understood across a broad range of individuals (Hickey & Schibeci, 1999; Atwood & Christopher, 2000; Finley, 1986; Constantinou, Raftopoulos & Spanoudis, 2001). Perhaps deficiencies in elementary science textbooks have contributed to the problem (Barrow, 1990) for the masses, and deficiencies in methods textbooks for preservice elementary teachers (Barrow, 2000) may have been detrimental to their efforts to construct the needed understanding.

If magnetism is perceived to be an easier topic than other physical science topics, children are perceived to enjoy exploring with magnets, and magnets and the behavior of magnets are included in local, state and national science education standards for the elementary level, it seems very important to ask: Are inservice elementary teachers prepared to teach fundamental concepts of magnets and the behavior of magnets? And, that is the question addressed through this descriptive study.

Procedure

In order to document the conceptual understanding of magnets and the behavior of magnets for a sample of inservice elementary teachers, multiple-choice tasks with

popular non-scientific conceptions embedded in the distracter options (Hestenes, Wells & Swackhamer, 1992) were utilized. In addition, teachers were asked to provide a written explanation justifying each multiple-choice selection and a confidence rating for the selection and explanation combined. More specifically, following each of five multiple-choice tasks three full lines of space were provided for an explanation that justified the option selected as the best answer. Then the teachers responded to a five-point confidence scale, from highly confident to no confidence, in order to provide an indication of their level of confidence in both selecting the best answer and explaining their choice for each of the five tasks. In an attempt to minimize anxiety, assessment tasks were completed anonymously.

The 20 inservice elementary teachers in the non-random sample had self-selected to participate in a professional development institute. They represented four school districts in central Appalachia. The assessment tasks were administered, along with tasks addressing other physical science topics, at the beginning of the institute and before any professional development instruction was provided.

Results and Discussion

The results will be discussed by task. Tables 1 and 2 summarize the multiple-choice results and the confidence results by task, respectively. The confidence level descriptions and corresponding numerical ratings follow:

1. Highly confident.
2. Somewhat confident.
3. Neutral in confidence.
4. Somewhat lacking confidence.

5. No confidence.

Each time a participant's explanation response is quoted in the paper, the confidence level selected by the participant is included in parentheses immediately following the quote. The first task and corresponding discussion of results follows.

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.

Task 1 provides an opportunity for a respondent to show an understanding that iron interacts magnetically, or is ferromagnetic, while rejecting materials that are not ferromagnetic, including the other metals identified in the options, as well as rejecting electric charge as a cause of magnetic attraction. Note in Table 1 that only 7 of 20 participants (35%) selected A, the correct answer. Eleven persons opted for an option, C or D, that offers a lightweight metal in the doors, such as aluminum, or a heavy metal in the doors, such as lead. The non-scientific understanding that most metals are ferromagnetic has been found to be commonly held (Hickey & Schibeci, 1999). However, the written justifications provided by the participants seem to verify that only three of eleven persons held that non-scientific explanation. One person provided no justification and two others indicated their response was a guess. Two persons who selected C indicated a

lightweight material must be used in the door. The fact that a non-ferromagnetic metal, aluminum, was given as the example of a lightweight metal apparently was not as important to these two respondents as the weight of the metal, and by extension the weight of the door. One of the persons selecting D did so because “it would take a heavy metal to attract the magnet through the coating” (3). One person who selected C explained the selection with “magnets stick to magnetic surfaces” (1). The possibility of the door being a magnet was not part of option C or any other options. Two participants (10%) selected E, perhaps confusing electrostatic and magnetic attractions. In fact explanations offered in support of their choices were:

Table 1

Multiple-choice Results for Tasks 1-5

Response Frequencies for Each Option, A-E

Task	A	B	C	D	E	Total
1	7*	0	8	3	2	20
2	4	0	15*	0	1	20
3	5	5	3	5*	2	20
4	3	12*	4	0	1	20
5	1	4	2	12*	1	20

Table 2

Confidence in Multiple-choice Selections and Explanations
Response Frequencies from 1, Highly Confident to 5, No Confidence

Task	Confidence Levels					
	1	2	3	4	5	Total
1	2	6	5	6	1	20
2	3	8	4	3	2	20
3	1	3	5	7	4	20
4	2	6	5	2	5	20
5	4	3	6	2	5	20
1-5	12	26	25	20	17	100

“magnets and electric charges are related” (4) and “the magnets’ electrons are attracted to the electrical charge” (4). Note the low confidence levels associated with these explanations.

Results for Task 1 are disappointing. Textbooks and teachers are frequently sources to inform students that magnets interact with iron, and a demonstration of iron fillings’ interaction with a magnet is not uncommon in schools. However, when students conduct investigations to determine what will interact with a magnet, they may fail to understand that the many metallic objects interacting with their magnets almost certainly contain iron, since nickel and cobalt are unlikely to be included in metallic objects in their environment. Do their teachers have this understanding? Results for Task 1 provide no reason for optimism.

Task 2 was used to probe participants’ understanding that the needle of a magnetic compass aligns to point approximately geographic north and south. The

task follows.

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.

As shown in Table 1, fifteen of the 20 participants (75%) selected the correct answer, C. Ten of those 15 gave an explanation that the compass needle always points north, and five of the ten added correct information about poles in their explanations. However, two of the remaining five gave no explanation (with confidence levels of 3 and 5), and responses consisting of “not sure” (4), “I think” (2) and “guess” (4) were provided by the other three persons. The confidence data generally were consistent with good explanations from participants who also selected the correct response. Nine of the ten who gave a satisfactory explanation, as previously described, selected one of the top two confidence levels and the other chose the neutral level. A low confidence level paired with no substantive explanation raises the suspicion of a scientific explanation that is not strongly held or, worse, guessing the correct response. Clearly a weakness of multiple-choice tasks is that they generate false positives (Trundle, Atwood & Christopher, 2002), correct responses that do not result from a scientific conceptual understanding.

As shown in Table 1, four persons selected option A for Task 2. We view

this to be a curious choice, but it is one not uncommon to encounter in our classes for preservice teachers. In the present study the explanations provided in support of this choice were: “compasses show you what direction you are traveling in” (4); “based on the north/south the needle will point the way you are facing” (3); “a compass tells you the direction you are facing” (2); “guess” (5). It would have been informative to be able to probe the understanding of these respondents in individual interviews and to judge how strongly their understandings were held, but it was not possible to do. Note the confidence level reported by one of the four persons was one step above the neutral level and two reported confidence below the neutral level.

The response of the person who selected Option E may represent a false negative. That is, the person may have a more scientific understanding than the selection of an incorrect response suggests. The person’s explanation, “the compass will move but the needle will stay the same” (3), provides a basis for optimism that is tempered by a neutral confidence selection.

Note in Table 2 participating teachers showed more confidence in their responses to Task 2 than for any of the other tasks. Even so, considering the responses to the multiple-choice tasks, the supporting explanations and the levels of confidence expressed, the conceptual understanding of this sample falls short of what is needed.

Bar magnets are frequently used in elementary classrooms. Task 3, which follows, provided an opportunity for the teachers to consider the validity of five statements about bar magnets and the behavior of bar magnets.

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.

From an examination of the data in Table 1 it appears performance on Task 3 was weakest of the set as only five participants (25%) selected the correct answer, D.

The confidence data in Table 2 for Task 3, consistent with the multiple-choice results, are the lowest of the set. For the five teachers who selected the correct answer the explanations provided were: “process of elimination” (4); “guess” (3); “guess” (4); “has plus and minus charged ends” (4); “they will repel if turned correctly” (4). The first of these five responses provides small cause for celebration, if one infers it means the respondent knew the other four options were incorrect. Sadly, the next three of the five responses suggest the correct responses on the multiple-choice task were false positives. Note also that one confidence level was neutral and the other four were below the neutral level.

Each distracter option was attractive to 10-25% of the sample. Five participants selected option A, the idea that a bar magnet has the strongest magnetic effect in the middle of the bar. Since the explanations include one idea the investigators had not encountered previously, they are included as follows: “strongest where the N/S come together” (3); “a process of elimination, I think” (3); “guess” (5); “I am not sure. I used an educated guess” (5); “more area equals

stronger hold” (1). None of these explanations reflects a good understanding of a magnetic pole. Note the confidence levels associated with the first four explanations in the sequence of five were neutral or the lowest. Interestingly the teacher who provided the last explanation and selected an incorrect response for Task 3 indicated he/she was highly confident of the responses provided. If one sticks a large magnet and small magnet of equal strength into a pile of steel paperclips, more paperclips likely will cling to the larger magnet because of the greater surface area. Perhaps the teacher who provided the last explanation was thinking of this procedure as a valid test of relative strength.

Looking at results for other distracters, five teachers selected option B, which indicates a bar magnet interacts with all metallic objects. The explanations provided were: “B seemed like the only one that could be true” (4); “A magnet interacts with metal no matter what shape” (2); “A bar magnet has no charges,?? Plus and minus” (2); “?B” (4); “because its magnetic” (3). The confidence ratings provided show only the second and third responses in the sequence were associated with above average confidence. Two of the three persons who selected option C apparently were clueless. One of the two did not provide an explanation (confidence level 4) and the other wrote “I guessed” (5). The third person who selected C was somewhat confident and explained the selection with “The opposite poles will react and similar poles will not” (2) The two persons selecting option E wrote “attracts to all metals” (3) and “guess” (5) as explanations. Note that the former respondent expressed neutral confidence while the latter expressed no confidence. Both Tasks 1 and 3 reveal the attractiveness of the non-scientific

conception that magnets attract many different metals.

Task 4 has three important concepts embedded in the options. Option A of Task 4 taps understanding of whether the size of a magnet is a reliable predictor of magnetic strength. Options C and E tap understanding of whether the shape of a magnet is a reliable predictor of magnetic strength. Options B and D tap understanding that magnets have two poles, N and S. The extent to which the 12 teachers who selected the correct answer, B, understood that neither size nor shape is a predictor of magnetic strength is unknown. Still, it is comforting that 60% of the sample provided evidence of understanding that magnets have two poles, N and S, and that option D was not selected by anyone. Seven of the 12 respondents specifically mentioned in their explanations that magnets have an N and S pole. It was encouraging that one of the seven stated this was true regardless of size and another stated it was true regardless of shape. Five persons provided no substantive explanation. In fact one of the five provided no explanation at all and another confessed to guessing and reported no confidence in the response. The average confidence level for the twelve persons responding correctly was 2.7, essentially a neutral confidence reading on the five-point scale with 1 being the highest confidence level and 5 the lowest.

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.

The three persons who selected option A explained: “a larger magnet should pick up more regardless of shape” (4); “more magnetism” (1); and “guess” (2). Two of the four persons who selected option C indicated they guessed and expressed no confidence in the guess. A third perhaps was relying on a specific previous experience in explaining “it just seems stronger” (3). The fourth person explained “has 2x force on object” (5), perhaps thinking both ends of a horseshoe magnet could more easily be brought into contact with a ferromagnetic object than both ends of a bar magnet. However, the lack of confidence in the selection of option C and accompanying explanation does not support the suggestion that it was a highly reasoned selection. The one person who selected option E explained “this one seems to be most accurate” (5) and recorded no confidence in making the selection and providing an explanation.

Collectively the results for Task 4 suggest several teachers had learned magnets have two poles, N and S. This could have been memory-level learning or learning based on investigative activities. The medium level of confidence expressed on average by those who responded correctly is not what one would expect from a firm understanding based on tests of magnets varying in shape and size to determine that each had two poles, N and S.

In Task 5 participants can show their understanding that the N pole of a bar magnet attracts not only the S pole of another magnet, but also attracts objects containing a ferromagnetic material, such as iron. Option D offers this response, and twelve of the 20 participants (60%) selected D. This is a sizeable fraction of the group. However, of the 12 participants selecting the correct option, only three gave an explanation which included both possible causes for the attraction. Of these three, two made the brief comments, “Opposite ends attract or it has to be a material that attracts as a magnet” (3) and “Opposites attract and iron attracts to magnets” (1). A third wrote that “Metal will stick to the bar magnet and so will the S pole of another magnet” (1), where the non-scientific conception that all metals attract to magnets appears again. Note that the second and third respondents were highly confident, while the third was neutral in confidence. Of the other nine participants choosing the correct multiple-choice option, six offered very brief explanatory statements like “N attracts S” (3). One stated that “The bar magnet should attract to the other magnet” (4) and two offered no explanation. None of the other nine explanations included that the magnet is attracted to an object containing iron, although their multiple-choice selection included this information. Perhaps they had seen during experiments that magnets attract ferromagnetic materials but their understanding was inadequate to construct an explanation. Surprisingly, the confidence of these nine teachers ranged equally from top to bottom. Three were highly or somewhat confident, three were neutral in confidence and three were somewhat lacking confidence or expressed no confidence.

5. Consider the diagram below



The N-pole of a bar magnet is brought near end A of an object that 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. not make any of the conclusions in A. – D.

Four participants (20%) chose the selection which offers opposite magnetic poles attracting as the only reason for a magnet to be attracted to an object. Of these participants one explained “Opposites attract” (2) while two others “guessed” (5,5) and one stated “Opposite poles attract as the electrons will align/bond” (2). For the total of 20 participants 16 (12 selecting D and 4 selecting B) indicated via multiple-choice selections that opposite magnetic poles attract. However, as noted only a few explanations address the issue correctly and none fully address the issue or invoke evidence such as might be gained through simple experiments.

Finally, of the four participants choosing incorrect responses A, C or E, only one, with option C as the choice, wrote an explanation, “Opposite poles repel each other” (4). Perhaps this teacher misread the problem, had no experience with magnets, or remembered poorly. All four participants who chose A, C or E were either neutral or low in confidence with their selection.

The multiple-choice results for Task 5 are encouraging in that on an unannounced test on magnetism, 80% of the practicing teachers indicated that opposite magnetic poles attract. However, only 60% selected the best multiple-choice response that the pole of a magnet is attracted not only to the opposite type pole of another magnet but also is attracted to a ferromagnetic object. The outcome desired by most science teacher educators is probably for 100% correct responses for both conditions. The frequency of explanations that were incorrect, incomplete, or were not evidence-based appears to be unacceptable.

Conclusions and Implications

Based on the results of this study, it is concluded that the inservice elementary teachers in this group were not adequately prepared to teach a rich unit on fundamental concepts of magnets and the behavior of magnets. Results for the five multiple-choice tasks combined reveal only 51 of 100 responses were correct. Further, the explanations associated with those 51 responses often were incomplete, not evidence-based or indicative of guessing to produce false positives. Also, low confidence was frequently reported by teachers in selecting a correct answer.

If teachers are not adequately prepared to teach fundamental concepts about magnets and the behavior of magnets, there are important implications for both preservice and inservice teacher education. First, the topic likely is not being adequately addressed in preservice teacher education programs. If not, is it because the topic is viewed as easier than other physical science topics, which then are given higher priority? Or, is this just part of the more general problem of

inadequate coursework in science for prospective elementary teachers

(McDermott, 1991; Authors, 2002)? Second, any assumption that inservice elementary teachers are relatively well prepared to teach fundamental concepts about magnets and the behavior of magnets should be questioned. It seems likely that the popular task of having children use magnets to test several objects in a classroom is not a highly productive activity in terms of concept development. The teachers involved may not understand that all of the objects interacting with a magnet likely do so because of iron in them. If this is the case, these teachers are unlikely to help their students develop that understanding by making sure a variety of non-ferromagnetic metals are identified and tested, followed by appropriate, sense-making discussions and explanations.

In addition, these results suggest that teachers need experience in determining where several magnets, varying in shape and size, are strongest (where the poles are located). In the process it should be determined that all magnets tested have two and only two magnetic poles, and like poles repel and unlike attract. Further, experience with large and small magnets of the same shape should be structured so it becomes clear the strength of a magnet can't be reliably predicted by size. Controlling size to the extent possible, while varying shape of magnets in appropriate investigations also seems needed, if teachers are to understand that the strength of a magnet can't be reliably predicted by shape. Finally more direct experiences and sense-making discussions involving the earth's magnetic effects interacting with compass needles and other magnets seem needed for teachers.

Thus, results of the present study could be useful to help establish professional

development priorities for inservice teachers and inform professional development plans that target magnets and the behavior of magnets with instruction designed to promote conceptual change (Vosniadou, 1991, 2003). The results could also be useful for formative purposes by higher education faculty who are involved in providing science programming for preservice elementary teachers.

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