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# Measuring Teacher Beliefs About Inquiry: The Development of a Blended Qualitative/Quantitative Instrument

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A major trend in science education reform is an emphasis toward inquiry-based learning over transmission-based instruction. The effort to reform science teaching is not a simple effort however. Teacher beliefs have been demonstrated to have a strong influence on teacher practice. Current methods to describe teacher beliefs are often interpretative. We describe the development of an instrument that captures qualitative and quantitative information regarding teachers' beliefs inquiry teaching. The instrument provides data that can be tracked over time to measure changing beliefs, a necessary precondition for changing practice. Change in belief can be monitored for individuals or for groups of subjects. We discuss several types of studies that can be accomplished using the Inquiry Teaching Belief (ITB) instrument. We also discuss several ways to analyze the data from this instrument. The instrument may be combined with observation protocols to elucidate barriers to changing practice.

**KEY WORDS:** inquiry teaching; teacher beliefs; blended measurement.

## INTRODUCTION

A major trend in science education reform is an emphasis toward inquiry-based learning over transmission-based instruction. For example, the National Science Education Standards proposed by the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996) recommend that science education be restructured around inquiry. At the heart of this reform is the notion that students need to be engaged in activities that develop their understanding of the investigation processes including the ability to ask and answer useful questions (Blumenfeld *et al.*, 1991; Krajcik *et al.*, 1998). However, to engage in scientific inquiry students need teachers who not only believe that inquiry-based teaching is the best instructional approach to support their students' learning, but also, students need teachers who are confident in their ability to teach using inquiry-based approaches (Damnjanovic, 1999; NRC, 1996). Many teachers however, either do not fully understand the inquiry process or do not have confidence or the time to develop new teaching strategies geared to develop students' understanding and use of the inquiry process (Schauble *et al.*, 1991; White and Frederiksen, 1998).

Factors that influence teachers' practice are complex and numerous. In working toward the improvement of teaching, one has to consider teaching from a number of interrelated perspectives (Cochran-Smith and Lytle, 1999; Kagan, 1992). One factor that has recently emerged as a central feature in understanding teacher practice is that of teacher beliefs (Richardson, 1996; Simmons *et al.*, 1999). Research evidence indicates that teachers' beliefs color and influence their teaching practices, how they believe content should be taught, and how they think students learn (Cochran-Smith and Lytle, 1999; Mellado, 1998; Pajares, 1992). In fact, a number of researchers have argued that any efforts to change

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teacher practices must consider teacher beliefs from the beginning (Simmons *et al.*, 1999; Wideen *et al.*, 1998). These beliefs are considered to be inherited from their own years in school and their epistemological commitments to how a content domain should be taught (Pajares, 1992). Hence, when prospective teachers start their university education, they bring to it ideas, conceptions, and attitudes about the nature of science, science teaching, and how students learn (Brookhart and Freeman, 1992; Loucks-Horsley and Matsumoto, 1999). Further, these beliefs have been steadily forming since their beginning school years through a process of apprenticeship by observation that makes it difficult for prospective teachers to consider alternative approaches to teaching and learning that are different from how they were taught (Grossman, 1991; Lortie, 1975).

The problem of teaching preservice teachers science, technology, engineering, and mathematics (STEM), within an inquiry framework is further exacerbated by the lack of constructive evaluation of and feedback for the university science and science education faculty who teach the teachers. In a report by the American Association for Higher Education, Rice *et al.* (2000) found that new faculty are greatly concerned that meaningful feedback and evaluation of their performance is insufficient, unfocused, and unclear. Meeting these goals in science education reform requires new efforts on two fronts. First, because teachers tend to teach the way they were taught (Shumba and Glass, 1994), we must develop a deeper understanding regarding how preservice teachers' beliefs can change with STEM coursework that is grounded in scientific inquiry. Second, we must develop new mechanisms to provide meaningful feedback and evaluation of our university STEM courses that can guide individual faculty members in making improvements to their courses that are informed by student outcomes.

Currently, methods to describe or determine teacher beliefs involve mostly qualitative methods (Kagan, 1992). In this paper, we describe the development of the Inquiry Teaching Belief instrument (ITB) along with examples of several methods of analysis and interpretation of the resulting data. The ITB is an instrument that simultaneously captures qualitative and quantitative information regarding teachers' beliefs of inquiry science teaching.

## THEORETICAL FRAMEWORK

Our work on the ITB is grounded in a phenomenographical perspective as described by Marton (1981). That is, that people have internal models of the world and base their actions on these models. Ryder *et al.* (1999) describe this research as providing descriptions of people's conceptions of the world rather than providing descriptions of the world itself. Fetterman (1988), used the term *phenomenology* and describes the goal of phenomenological research as seeking "to understand human behavior from the 'insider's' perspective. Their most significant reality or set of realities is found in the subject realities of human perception," (p. 18). He further suggests that "what people believe to be true is more important than any objective reality; people act on what they believe," (p. 18). Fetterman's description, however, is much more consistent with *phenomenography* as clarified and defined by Marton (pp. 180–181).

The ITB instrument, then, seeks to provide information about how teachers' describe their conception of inquiry teaching. If teachers are to enact inquiry methods of instruction, they must have an internal model of good inquiry teaching practice that is consistent with sound external models. In addition they should believe in the efficacy of their model. Both the model and their sense of its ability to be implemented are beliefs held by the teacher. The ITB is designed to elicit the subject's current beliefs about inquiry teaching in a science classroom.

## THE ITB INSTRUMENT AND ITS DEVELOPMENT

The ITB is a card-sorting activity where subjects are asked to place cards either close to or further from a "classroom" card depending on how important the subject felt the activity was in supporting an inquiry-based science classroom. In each version of the ITB, there are a number of cards indicating an activity that students might be engaged in with in a classroom. Subjects are instructed to place activity cards that represent or support an inquiry-based science classroom close to the classroom card. Activity cards that are less representative or that do not support an inquiry-based classroom are placed farther from the classroom card (see Fig. 1).

After completing the exercise, subjects are asked to explain their model. This information

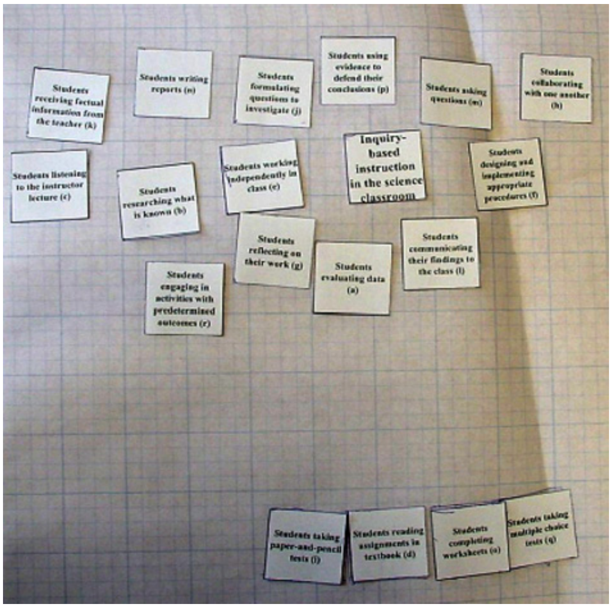


**Fig. 1.** ITB model (gamma version) for a science faculty member.

provides an internal validity check and assures that the researchers correctly interpret a subject's understanding of each item and their intent regarding placement. This open-ended request differs from the very focused interview protocol required by the Teachers' Pedagogical Philosophy Interview (TPPI, see Simmons *et al.*, 1999, for an excellent study that used this instrument). The TPPI is a 49-question protocol that provides researchers with an understanding of subjects' views of "epistemology, nature of science, nature of teaching and learning, view of self as a teacher, and educational environment" (Simmons, p. 934). As such, it is a broad-based instrument and may be helpful in combination with the ITB. The ITB is more similar to a card-sorting task. The task requested of subjects using the ITB differs from typical card-sorting tasks, however, because the subjects are not required to rank items in a linear list or sort the cards into categories (Jonassen *et al.*, 1993). Nor are they responding to specific scenarios that they accept or reject (Friedrichsen and Dana, 2003).

The ITB is more dynamic than simple sorting because it allows subjects to invent their own relationship and equivalence patterns between the activities represented on the cards. Subjects make fine distinctions amongst the activity cards based on position. We commonly observe, for example, that subjects make many small adjustments of the position of items relative to other items as well as relative to the classroom card. This suggests that subjects are using complex criteria to determine not only position relative to the classroom but also making value judgments regarding position relative to other items. We suggest this behavior reflects their attempts to map their internal belief structure within this external context.

The initial version of the ITB was used in a study of an innovative science teaching methods class for elementary teachers (Barnett *et al.*, 2002; Harwood *et al.*, in press). This version ($\alpha$-ITB) used 14 activity cards (see Table I) and the researchers did not impose an "expert" perspective onto the card items as is typically the case for card sorts (Stein *et al.*, 1990). After this initial use, several limitations of the alpha version were discovered. Some subjects misunderstood the meaning of some cards or conflated two activities into one. More critically, the $\alpha$-ITB activity cards were researcher generated and not linked directly to the literature regarding inquiry teaching. This limited the initial study to examining only qualitative interpretations by the subjects and looking for quantitative significance in the variance of the subjects' responses (indicating group consensus development or its lack). Nevertheless, we were able to identify the activities in the $\alpha$-ITB that our subjects felt most supported inquiry teaching and those that least supported inquiry teaching. Moreover, subjects' identifications were in good agreement with that found in the literature (Anderson, 2002; NRC, 1996, 2000; Sawada *et al.*, 2002).

Building on this beginning subsequent versions of the ITB, the beta and gamma versions, had activities that were identified by the researchers as "inquiry," "neutral," or "noninquiry" by linking to the research and policy literature. Subjects were not aware of these designations. Classification of activities was based on the literature for inquiry and reformed teaching (Anderson, 2002; NRC, 1996, 2000; Sawada *et al.*, 2002).

The evolution of ITB activity cards is outlined in Table I. The beta version used the transcript data and field notes from the first study to develop activity cards whose meaning was clearer to the subjects and that were also grounded in the literature. The result was a 20-activity card set. After using this version for 1 year in several studies, the researchers felt that some activities could be refined and others dropped. Having 20 activities seemed to be too many for some subjects and we felt that fewer would be better. We

**Table I.** Development of Activity Cards

| $\alpha$-ITB activities ($N = 14$) | $\beta$-ITB activities ($N = 20$) | $\gamma$-ITB activities ($N = 18$) |
|---|---|---|
| **Evaluating evidence** | **Students evaluating data** | **Students evaluating data** |
| **Reflecting on their work** | **Students reflecting on their work** | **Students reflecting on their work** |
| **Working together** | **Students working together** | **Students collaborating with one another** |
| | **Students developing procedures** | **Students designing and implementing appropriate procedures** |
| **Collecting data** | Students collecting data | |
| **Communicating findings** | **Students communicating their findings** | **Students communicating their findings to the class** |
| | Students writing reports | Students writing reports |
| | **Students drawing conclusions from evidence** | **Students using evidence to defend their conclusions** |
| | **Students debating with each other** | |
| **Formulating questions** | Students asking questions | Students asking questions |
| | **Students formulating questions to investigate** | **Students formulating questions to investigate** |
| Following procedures | *Students following explicit procedures* | **Students researching what is known** |
| | *Students verifying known phenomena* | *Students engaging in activities with predetermined outcomes* |
| Continuously assessed | Students performing assessment activities | |
| Responding to teacher questions | Students responding to teacher questions | *Students receiving factual information from their teacher* |
| *Listening to teacher lecture* | *Students listening to the instructor lecture* | *Students listening to instructor lecture* |
| *Reading textbooks* | *Students reading assignments in textbooks* | Students reading assignments in textbooks |
| *Filling out worksheets* | *Students filling out worksheets* | *Students completing worksheets* |
| *Working quietly in seats* | *Students solving assigned problems independently* | *Students working independently in class* |
| *Taking tests to measure learning* | *Students taking paper-and-pencil tests to measure their learning* | Students taking paper-and-pencil tests |
| | | *Students taking multiple choice tests* |

*Note*. Activity cards from the several ITB versions. Inquiry oriented activities are in bold, neutral activities are in regular type, and noninquiry activities are in italic.

also recognized that some activities from the $\beta$-ITB were not effective in discerning subjects' relative understanding of inquiry and noninquiry activities. For example, because science students often collect data regardless of whether a classroom is inquiry based or using traditional verification labs, this activity was dropped for the gamma version.

Another activity that was dropped when making the $\gamma$-ITB was *students debating with each other*. This was linked to the activity *students drawing conclusions from evidence* in the $\beta$-ITB to give the $\gamma$-ITB version: students using evidence to defend their conclusions. The gamma version more aptly captures a key aspect of the nature of science and scientific inquiry. Science requires evidence-based conclusions that are articulated to a public (NRC, 2000). The latest version avoids issues surrounding subjects' understanding of and/or value of "debate," while preserving a key activity associated with the process of scientific inquiry (Harwood, 2004a,b; Reiff *et al.*, 2002).

Finally, in the $\gamma$-ITB we changed the context slightly by making the activity cards square, rather than rectangular as in the alpha and beta versions. The paper used to position the cards was also made into a $17'' \times 17''$ square sheet. This change reduced measurement error and also helped subjects to more easily show which activities were equivalent in value.

## QUALITATIVE ASPECTS OF THE ITB

In our hands, the ITB has been used as the last item in a semi-structured interview protocol. The interview protocol provides information that can be triangulated with the subject's description of their ITB model. This provides the opportunity to look for consistencies and inconsistencies across a range of beliefs. For example, typical items in many of the semi-structured protocols we have used include asking subjects "how do students best learn science?" and "how do you know if someone has learned something?" These and other questions help us to elucidate the underlying belief structures of the subject. As mentioned earlier, the TPPI may be a good protocol for some studies and will capture a broad range of detail regarding subjects' beliefs (Simmons *et al.*, 1999). Our interview protocols were researcher created to fit specific needs of the several different studies we are engaged in. The ITB provides additional information regarding participants' beliefs regarding typical classroom activities and how they fit into an inquiry-based science classroom.

The $\gamma$-ITB entails the ordering of eight inquiry activities, six noninquiry activities, and four neutral activities. The activity cards are shuffled and subjects are instructed to put activities that support an inquiry-based science classroom close to the classroom card and those activities less supportive of an inquiry-based science classroom should be placed farther from the classroom card. Blank cards are available should a subject feel there is some missing activity of importance. Once the subject has completed the placement of the activities, they are asked to explain their model. Subjects may be asked specific questions regarding their interpretation of activities or their placement relative to other activities the researcher identifies as of interest. Alternatively, subjects may be asked for additional details of their own teaching experiences and if they have examples that contrast or reinforce their placement of the activities. The use of the ITB as a qualitative probe has been effective for a case study (Lotter, 2004) and small group study (MaKinster, 2004, private communication).

The $\alpha$-ITB was used as a purely qualitative instrument where the activities that are listed in Table I as inquiry activities emerged from the subjects' interviews. As a qualitative instrument, the ITB can be an effective way to lead a subject into substantive conversation regarding their choices for the placement of teaching activities and to elucidate the subject's perceived difference between an ideal teaching circumstance and their own "real" circumstance. For example, after completing the ITB exercise and explaining their model of inquiry teaching, a subject could be asked to show which activities they most commonly use in their classroom. This is often a stark contrast to the model of inquiry teaching that the subject put forward and provides an opportunity to discuss real and perceived constraints to implementing inquiry teaching.

In the interpretative analysis of the ITB models, the central data is in the interview transcript. This can be coded and a constant comparison method used to develop an interpretation of an individual's perspective or a small groups' perspective. Individual results can be compared and contrasted to present a picture of the changing conceptions (or fixed conceptions) of a group. Figure 1 depicts the ITB (gamma version) for a science faculty member who is engaged in reforming a first year course for science majors.

The subject whose ITB is in Fig. 1 identified four activities as not supportive of an inquiry-based science classroom and placed them as a tier of cards that were intended to be equidistant from the classroom card. There are eight activities that the subject valued equally and these are placed in a circle around the classroom card. The remaining six activities are in arcs around the central classroom card, indicating relative importance of these activities to inquiry teaching. As it happens, this subject has a strong clarity consistent with the national standards. A careful examination of the activity cards and their relative placement indicate this and clarity via distance comparisons, the ITB allows for a quantification of the subject's conception of inquiry teaching.

## QUANTITATIVE ASPECTS OF THE ITB

As described earlier, subjects place activity cards using distance from the classroom card as a means to represent the degree of importance they feel the activity cards play in their mental model of inquiry-based science teaching. These relative distances from the activity cards to the central classroom card provide the opportunity to make quantitative measures regarding the importance that subjects place on inquiry, noninquiry, and neutral activities. Changes in individuals' or a groups' concept of inquiry-based science instruction can then be computed with a pre/post treatment comparison of the relative distances. Thus, if the intervening event, such as an inquiry-based science course, a methods course, an authentic research experience, or other professional development program has an impact on the subject, the change in their value of the relative distances and variation of these distances can provide a quantitative insight into the effectiveness, or perceived effectiveness, of the intervention.

Distances were initially measured using a ruler to the nearest 0.1 cm from the center of the "classroom" card to the center of each activity card. In recording distances, however, it is important to be mindful of the intent of the subject. Thus, subjects often indicated that a set of activities were of equal importance. This indication may occur while they are manipulating the cards or afterwards in response to the prompt, "tell me about your model." In Fig. 1, for example, this subject indicated that the activities immediately circling the classroom card were of equal importance. The four activities in a tier at the farthest distance from the classroom card (cards d, i, o, and q) were also indicated as equal to each other. Thus, we found the distances as described, but for each of a grouped set of items we recorded the official distances as an average across the group (see Table II, "averages" column versus the "raw cm" column).

In order to compare these data both pre/post as well as across subjects, the distances were placed on a relative scale from 0.0 to 1.0 by dividing all distances by the distance to the activity farthest from the "classroom" card. In the case of the example in Table II, all values in the "averages" column were then divided by 16.6 to give the values in the "*R*-value" column. Thus, the activity a subject views as least important in supporting an inquiry-based classroom will have a value of 1.00. The resulting measures can then be represented in a table of relative scale distances that can be examined to provide information about the individual regarding their conceptions of inquiry-based teaching and how it changes at different points in time that may be separated by key events.

There are several concerns regarding the measurement itself that we have addressed in the development of the ITB from alpha to beta to gamma versions. In the beta version, we made the activity cards more uniform in size than they had been in the alpha version. However, they were rectangular. This presented the opportunity for subjects to misjudge the distance of activity cards from the classroom card. Placing cards in a circle, for example, would give noticeably different distances to the center of each rectangle as one goes around the circle. The averaging helps avoid interpretive challenges this could present. In the gamma version, however, we minimize the problem by having all cards as same size squares. The result is a more compact card that is easier for subjects to place and gives the researchers a measurement in which they can have more confidence.

After a subject has left the interview, the researcher traces the outline of each card and labels the traced outline. Center is determined as the intersection of the two lines made by connecting opposite corners of the rectangular or square outline. Then the measurement is made from the center of the classroom card to the center of each activity card using a ruler. A quicker means of accomplishing this task is to take a digital picture of the ITB after it is completed by the subject. Using the freely available software ImageJ (http://rsb.info.nih.gov/ij/) one can measure the distances in pixels. The same averaging and relative scaling steps are followed as with the low-tech ruler-based measurement. Both methods provide results within 0.02 units of one another for *R*-values. The advantages to the digital method are that there is a digital record of a subject's ITB, the measuring process is quicker and easier, and there is no opportunity for a researcher to accidentally move a card during tracing.

## QUANTITATIVE ANALYSES WITH THE ITB

Analysis of the quantitative information from the ITB can be accomplished at a coarse general level down to a fine-grained level. We have developed the Inquiry Ratio (IR) as a quick means to determine the clarity of subjects' understanding of inquiry as opposed to noninquiry items. The IR is computed by dividing the mean distances of the noninquiry items by the mean distances of the inquiry items (Table III). The larger this ratio, the greater the separation between the subjects' understanding of inquiry activities as opposed to noninquiry activities. That is, the more consistent their concept of inquiry teaching is with the emergent national standard.

The subject shown in Table III was an in-service teacher, Beatrice (a pseudonym), evaluated using the $\beta$-ITB before and after a professional development workshop. The pre/postworkshop IRs shown in Table III indicate an increase in her understanding of inquiry teaching of science pre to postcourse. For this teacher the professional development workshop appears to have helped improve her understanding of inquiry-based science teaching. A finer grain of detail, however, reveals some interesting patterns.

First, notice the standard deviation columns. The size of the standard deviation provides an indication of whether the subject valued the set of items (inquiry or noninquiry) equally or if there was wide variation in value among the set. In other words, did the subject see the activities associated with inquiry (or noninquiry) as a set of equally valued activities? In Beatrice's case, she became remarkably clear about the inquiry items, moving from a standard deviation of 0.16 to 0.00. In other words, postworkshop, Beatrice valued all the inquiry items equally. Her valuation of the noninquiry items, however, became more diffuse, moving from 0.21 to 0.34.

**Table II.** Raw and Relative Distances (*R*-value) for Subject with $\gamma$-ITB in Fig. 1

| Item | *R*-value | Averages | Raw cm |
|---|---|---|---|
| **Students evaluating data (a)** | **0.31** | 5.1 | 5.0 |
| **Students researching what is known (b)** | **0.55** | 9.2 | 9.2 |
| *Students listening to instructor lecture (c)* | **0.80** | 13.2 | 13.6 |
| Students reading assignments in textbooks (d) | **1.00** | 16.6 | 16.35 |
| *Students working independently in class (e)* | **0.31** | 5.1 | 4.9 |
| **Students designing and implementing appropriate procedures (f)** | **0.31** | 5.1 | 5.65 |
| **Students reflecting on their work (g)** | **0.31** | 5.1 | 5.7 |
| **Students collaborating with one another (h)** | **0.52** | 8.6 | 8.6 |
| Students taking paper-and-pencil tests (i) | **1.00** | 16.6 | 16.6 |
| **Students formulating questions to investigate (j)** | **0.31** | 5.1 | 5.7 |
| *Students receiving factual information from their teacher (k)* | **0.80** | 13.2 | 13.2 |
| **Students communicating their findings to the class (l)** | **0.31** | 5.1 | 4.4 |
| Students asking questions (m) | **0.31** | 5.1 | 4.9 |
| Students writing reports (n) | **0.57** | 9.5 | 9.5 |
| *Students completing worksheets (o)* | **1.00** | 16.6 | 16.6 |
| **Students using evidence to defend their conclusions (p)** | **0.31** | 5.1 | 4.55 |
| *Students taking multiple choice tests (q)* | **1.00** | 16.6 | 17 |
| *Students engaging in activities with predetermined outcomes (r)* | **0.59** | 9.75 | 9.75 |

*Note*. Inquiry oriented activities are in bold, neutral activities are in regular type, and noninquiry activities are in italic.

In order to get a clearer picture of what was going on with Beatrice, a frequency table is helpful. The table is constructed by dividing *R*-values into tenths. The number of inquiry items or noninquiry items that falls into each tenth is indicated as a frequency (see Table IV). This provides a finer grained way to understand Beatrice's changing perception of inquiry teaching.

Beatrice came away from the professional development workshop with a great clarity regarding what constitutes inquiry and a high value on these items as indicated by the low *R*-value for the inquiry activities. One might conclude that this demonstrates the success of the workshop in the case of Beatrice, at least. That conclusion, however, is premature based on an examination of Table IV with respect to the noninquiry items. As clear as Beatrice became in understanding what classroom activities support inquiry teaching, she became less clear about what activities are not supportive of inquiry in the classroom. Several noninquiry activities were valued as highly as inquiry activities as shown by her *R*-values for these activities which were identical or nearly identical to the *R*-values for the inquiry activities. Nevertheless, her great clarity and *R*-value set on the inquiry activities gave her an overall IR increase. This finer grained frequency table suggests more is going on regarding Beatrice's belief structure.

Having identified this interesting pattern, one can look at the specific noninquiry activities that Beatrice valued highly (Lotter *et al.*, in preparation). Is there evidence from the qualitative data (interview transcripts, journals, etc.) that help us to understand why she made these valuations? Is her interpretation of the activities different from the literature and, if so, in what ways? Is her result typical for the group or unique to her? Thus, the quantitative results lead us back to our qualitative data. The reverse can also occur. Patterns in the qualitative data can lead us to examine the quantitative data more closely for evidence supporting or refuting assertions that arise from the qualitative data set.

Groups can also be treated as single entities, if desired. For example, the *R*-values for each item can be averaged across a group. The result is a set of group averages that provide similar information

**Table III.** Data from Beta Version of ITB Showing the Inquiry Ratio Calculation

| | IR-pre | Standard deviation | Mean Rpre | IR-post | Mean Rpost | Standard deviation |
|---|---|---|---|---|---|---|
| Inquiry | 1.62 | 0.16 | 0.41 | 2.34 | 0.20 | 0.00 |
| Noninquiry | | 0.21 | 0.66 | | 0.48 | 0.34 |
| Neutral | | 0.26 | 0.61 | | 0.29 | 0.15 |

*Note*. Mean values for each category are shown.

**Table IV.** Frequency Table for Inquiry and NonInquiry Items for Beatrice

| *R*-value by tenths | Preinquiry | Noninquiry | Postinquiry | Noninquiry |
|---|---|---|---|---|
| 0.00–0.10 | | | | |
| 0.11–0.20 | | | 8 | 2 |
| 0.21–0.30 | 5 | | | 1 |
| 0.31–0.40 | | | | |
| 0.41–0.50 | | 1 | | 1 |
| 0.51–0.60 | 3 | 3 | | |
| 0.61–0.70 | | | | |
| 0.71–0.80 | | | | 1 |
| 0.81–0.90 | | 1 | | |
| 0.91–1.00 | | 1 | | 1 |

as individual data. Does the group improve its understanding? In what ways and to what extent? One convenient way to look at group data is to rank the items from most valued to least valued using average *R*-values for the items.

A side-to-side comparison of a group of teachers from pre/postworkshop data shows how items moved and in what directions. Generally, the group valued inquiry items more highly than they did noninquiry items (Table V). However, the gap between the least valued inquiry item (card q in both pre- and post-test) and the most valued noninquiry item (pre-test = card e and post-test = card t) shrank slightly (0.15–0.12) pre- to postworkshop. It is also clear that the inquiry items did not change much in value, while a change in value was seen for some noninquiry items. This suggests that, like Beatrice's individual case, the group as a whole became less clear about how noninquiry items support the inquiry classroom. The side-to-side format allows one to see that most noninquiry items had values that also changed little pre to post for the group as a whole. Two items, however, stand out as having the greatest change in value for the group. "Students following explicit procedures" became much more valued ($0.74 - 0.60 = +0.14$). "Students verifying known phenomena" also increased in value ($0.64 - 0.57 = +0.07$). Only "students filling out worksheets" decreased in value ($0.80 - 0.89 =$

**Table V.** Ranking of Item *R*-Value Averages Across a Group of In-Service Teachers Participating in a Workshop

| Item | Average Pre | Item | Average Post |
|---|---|---|---|
| Students taking paper-and-pencil tests to measure their learning (i) | 0.82 | *Students filling out worksheets (p)* | 0.89 |
| *Students filling out worksheets (p)* | 0.80 | Students taking paper-and-pencil tests to measure their learning (i) | 0.81 |
| *Students listening to the instructor lecture (c)* | 0.76 | *Students listening to the instructor lecture (c)* | 0.74 |
| *Students reading assignments in textbooks (d)* | 0.76 | *Students reading assignments in textbooks (d)* | 0.63 |
| *Students following explicit procedures (b)* | 0.74 | *Students following explicit procedures (b)* | 0.60 |
| *Students verifying known phenomena (t)* | 0.64 | Students writing reports (o) | 0.60 |
| Students writing reports (o) | 0.64 | *Students solving assigned problems independently (e)* | 0.59 |
| *Students solving assigned problems independently (e)* | 0.62 | *Students verifying known phenomena (t)* | 0.57 |
| Students performing assessment activities (s) | 0.54 | Students responding to teacher questions (l) | 0.45 |
| Students responding to teacher questions (l) | 0.53 | **Students debating with each other (q)** | 0.45 |
| **Students debating with each other (q)** | 0.47 | Students performing assessment activities (s) | 0.41 |
| **Students communicating their findings (m)** | 0.37 | Students collecting data (k) | 0.37 |
| Students collecting data (k) | 0.37 | **Students reflecting on their work (g)** | 0.36 |
| **Students evaluating data (a)** | 0.37 | **Students evaluating data (a)** | 0.35 |
| **Students reflecting on their work (g)** | 0.36 | **Students communicating their findings (m)** | 0.35 |
| **Students drawing conclusions from evidence (r)** | 0.34 | **Students developing procedures (f)** | 0.35 |
| Students asking questions (n) | 0.32 | **Students drawing conclusions from evidence (r)** | 0.34 |
| **Students working together (h)** | 0.31 | **Students working together (h)** | 0.34 |
| **Students developing procedures (f)** | 0.28 | **Students formulating questions to investigate (j)** | 0.33 |
| **Students formulating questions to investigate (j)** | 0.27 | Students asking questions (n) | 0.32 |

*Note*. Inquiry oriented activities are in bold, neutral activities are in regular type, and noninquiry activities are in italic.

**Table VI.** Summary of Teachers' Average Placement of the Inquiry, Neutral, and NonInquiry Items from the Central Label "Inquiry in a Secondary Classroom" at Three Points in Time

| Number | ITB item | Time 1 | Time 2 | Time 3 |
|---|---|---|---|---|
| **1** | **Students evaluating data** | 0.37 | 0.36 | 0.32 |
| **2** | **Students developing procedures** | 0.28 | 0.35 | 0.31 |
| **3** | **Students reflecting on their work** | 0.36 | 0.36 | 0.32 |
| **4** | **Students working together** | 0.31 | 0.34 | 0.36 |
| **5** | **Students formulating questions to investigate** | 0.27 | 0.34 | 0.29 |
| **6** | **Students communicating their findings** | 0.37 | 0.36 | 0.36 |
| **7** | **Students debating with each other** | 0.47 | 0.44 | 0.39 |
| **8** | **Students drawing conclusions from evidence** | 0.34 | 0.33 | 0.34 |
| 9 | Students collecting data | 0.37 | 0.36 | 0.31 |
| 10 | Students responding to teacher questions | 0.53 | 0.45 | 0.52 |
| 11 | Students asking questions | 0.32 | 0.33 | 0.28 |
| 12 | Students performing assessment activities | 0.54 | 0.42 | 0.53 |
| 13 | Students writing reports | 0.64 | 0.60 | 0.70 |
| 14 | Students taking paper-and-pencil tests to measure their learning | 0.82 | 0.81 | 0.75 |
| *15* | *Students following explicit procedures* | 0.74 | 0.60 | 0.86 |
| *16* | *Students listening to the instructor lecture* | 0.76 | 0.74 | 0.74 |
| *17* | *Students reading assignments in textbooks* | 0.76 | 0.63 | 0.84 |
| *18* | *Students solving assigned problems independently* | 0.62 | 0.58 | 0.68 |
| *19* | *Students filling out worksheets* | 0.80 | 0.89 | 0.89 |
| *20* | *Students verifying known phenomena* | 0.64 | 0.56 | 0.55 |

*Note*. Inquiry items are in bold, neutral items are in regular type, and noninquiry items are in italic.

−0.09) and the position of this item as one of the lowest valued items did not change.

Again, the interpretation of these quantitative results requires an examination of the qualitative data set (Harwood and Lotter, 2004; Lotter *et al.*, in preparation). Our purpose in this paper, however, is only to show how the data can be analyzed for a group. Standard deviations of the items can provide insight regarding how consistent the valuation is across the group or whether there are strong differences among group members that would result in larger standard deviations for the $R$-value item averages.

Another way to look at group ITB data, especially for changes (or lack of change) over time is to reorder the items and plot value (distance) on the $y$-axis against item on the $x$-axis. If, using the $\beta$-ITB as an example, the inquiry items are labeled 1–8, followed by the six neutral items labeled 9–14, and the six noninquiry items labeled 15–20 we obtain Table VI (Lotter, 2005; Lotter *et al.*, in preparation). This information can be used to produce Fig. 2. The graph in Fig. 2 shows that the group studied had a good understanding of inquiry and that their understanding remained constant at several points in time over a year. However, their value for noninquiry activities tended to change across the several points in time.

## LIMITATIONS

We have improved the construct validity of successive iterations of the ITB instrument by connecting the activities to the literature on inquiry teaching. We generally find that subjects using the $\gamma$-ITB understand the activities as we intended, however, we caution researchers to be mindful that subjects may still have unique interpretations of the activity cards. This random variation in interpretation threatens the reliability and validity of inferences drawn from the instrument. By combining these quantitative data with the captured qualitative interview data, however, the variance can be managed resulting in a

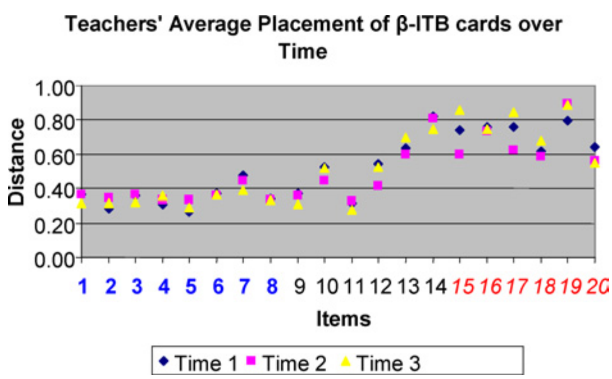


**Fig. 2.** Teachers' average placement of ITB activities at three points in time over the study period.

stable indicator of participant beliefs. For example, in a recent study (Harwood and Lotter, 2004) we learned that teachers in a professional development program developed a unique understanding of "following explicit procedures." This change was noted in the quantitative analysis of the ITB, but could only be fully understood based on the qualitative data provided from teachers' interviews and journal reflections.

## FUTURE WORK

We are actively working with the validation of the ITB instrument to make it a strong quantitative instrument. Current efforts are focused on using a variety of analytical techniques to model these data. Additionally, we would also like to make the instrument available on-line. The convenience for both researchers and subjects would be a tremendous help with respect to collecting and aggregating data. Moreover, an on-line version would allow for a larger number of subjects to be analyzed—a desired goal for a quantitative instrument.

Understanding how the subject interacts with the instrument is also being investigated. We need to continue to address questions regarding how subjects interpret the activity cards and stimulus prompt of the instrument. Also, at present, the subject has relatively little constraints regarding their placement of the classroom and activity cards on the map, they can place the classroom card where they choose and arrange the activity cards as they desire. What if we impose some constraints? For example, we would like to test a cohort with the classroom card fixed to the center of the page ringed by concentric "target" circles. This we feel may reduce some of the error variation that appears to be captured when subjects model linear or square relationships with the activity cards about the classroom card.

Finally, the instrument provides insight into a subject's clarity regarding teaching practices (that is, inquiry teaching). By sharing this information back with subjects, the ITB could be a tool that is used more actively in the professional development of teachers. Also, in combination with other instruments, such as the Reformed Teaching Observation Protocol (Sawada *et al.*, 2002), the ITB can provide one means to help identify barriers that affect teachers' ability to enact their beliefs as practice.

## APPENDIX 1

ITB Cards for Gamma Version

| | | |
|---|---|---|
| Students evaluating data (a) | Students researching what is known (b) | Students listening to the instructor lecture (c) |
| Students reading assignments in textbook (d) | Students working independently in class (e) | Students designing and implementing appropriate procedures (f) |
| Students reflecting on their work (g) | Students collaborating with one another (h) | Students taking paper-and-pencil tests (i) |
| Students formulating questions to investigate (j) | Students receiving factual information from the teacher (k) | Students communicating their findings to the class (l) |
| Students asking questions (m) | Students writing reports (n) | Students completing worksheets (o) |
| Students using evidence to defend their conclusions (p) | Students taking multiple choice tests (q) | Students engaging in activities with predetermined outcomes (r) |
| | | Inquiry-based instruction in the science classroom |

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## REFERENCES

AAAS (1993). *Benchmarks for Scientific Literacy*, Oxford University Press, New York.

Anderson, R. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education* 13: 1–12.

Barnett, M., Harwood, W., Keating, T., and Saam, J. (2002). Using emerging technologies to help bridge the gap between university theory and classroom practice: Challenges and successes. *School Science and Mathematics* 102: 299–313.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M., and Palincsar, A. (1991). Motivating project-based learning:

Sustaining the doing, supporting the learning. *Educational Psychologist* 26: 369–398.

Brookhart, S. M., and Freeman, D. J. (1992). Characteristics of entering teacher candidates. *Review of Educational Research* 62: 37–60.

Cochran-Smith, M., and Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. *Review of Research in Education* 24: 249–305.

Damnjanovic, A. (1999). Attitudes toward inquiry-based teaching: Differences between preservice and in-service teachers. *School Science and Mathematics* 99: 71–76.

Fetterman, D. M. (1988). Qualitative approaches to evaluating education. *Educational Researcher* 17: 17–23.

Friedrichsen, P. M., and Dana, T. M. (2003). Using a card-sorting task to elicit and clarify science-teaching orientations. *Journal of Science Teacher Education* 14: 291–309.

Grossman, P. L. (1991). Overcoming the apprenticeship of observation in teacher-education coursework. *Teaching and Teacher Education* 7: 345–357.

Harwood, W. S. (2004a). An activity model for scientific inquiry. *The Science Teacher*, January, 44–46.

Harwood, W. S. (2004b). A model for inquiry: Is the scientific method dead? *Journal of College Science Teaching* 34: 29–33.

Harwood, W. S., Barnett, G. M., and Hansen, J. (in press). Coming to terms with inquiry-based teaching through collaborative discussion, participation, and reflection. *Journal of Research in Science Teching.*

Harwood, W. S., and Lotter, C. (2004). *Secondary Teachers' Conceptions of Scientific Inquiry: Impact of a Summer Research Institute*, Paper presented at National Association for Research in Science Teaching National Meeting, April 2004, Vancouver, BC.

Jonassen, D. H., Beissner, K., and Yacci, M. (1993). *Structural knowledge Techniques for Representing, Conveying, and Acquiring Structural Knowledge*, Lawrence Erlbaum Associates, Hillsdale, NJ.

Kagan, D. M. (1992). Implications of research on teacher belief. *Educational Psychologist* 27: 65–90.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., and Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences* 7: 313–350.

Lortie, D. (1975). *Schoolteacher*, University Press, Chicago.

Lotter, C. (2004). *Nature of Inquiry Teaching and Learning in a High School Biology Class*, Paper presented at the annual meeting of the Association for the Education of Teaching of Science, Nashville, TN.

Lotter, C. (2005). *The Influence of an Inquiry Professional Development Program on Secondary Science Teachers' Conceptions and Use of Inquiry Teaching*, Doctoral Dissertation defended June 10, 2005.

Lotter, C., Harwood, W. S., and Bonner, J. J. (in preparation). The impact of an inquiry professional development program on secondary science teachers' conceptions of inquiry teaching.

Loucks-Horsley, S., and Matsumoto, C. (1999). Research on professional development of teachers of mathematics and science: The state of the scene. *School Science and Mathematics* 99: 258–271.

Marton, F. (1981). Phenomenography—Describing conceptions of the world around us. *Instructional Science* 10: 177–200.

Mellado, V. (1998). The classroom practice of preservice teachers and their conceptions of teaching and learning science. *Science Education* 82: 197–214.

NRC (1996). *National Science Education Standards*, National Academy Press, Washington, DC.

NRC (2000). *Inquiry and the National Science Education Standards*, National Academy Press, Washington, DC.

Pajares, M. F. (1992). Teachers beliefs and educational-research—Cleaning up a messy construct. *Review of Educational Research* 62: 307–332.

Reiff, R., Harwood, W. S., and Phillipson, T. (2002). *A Scientific Method Based upon Research Scientists' Conceptions of Scientific Inquiry*, Paper presented at the 2002 AETS Convention. Available online at http://www.ed.psu.edu/CI/Journals/2002aets/f3_reiff_harwood_p.rtf accessed July 6, 2005

Rice, R. E., Sorcinelli, M. D., and Austin, A. E. (2000). *Heeding New Voices: Academic Careers for a New Generation*, American Association for Higher Education, Washington, DC.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In Sikula, J., Buttery, T., and Guyton, E. (Eds.), *Handbook of Research on Teacher Education*, MacMillan, New York, pp. 102–119.

Ryder, J., Leach, J., and Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching* 36: 201–219.

Sawada, D., Piburn, M., Judson, E., Turley, J., Falconer, K., Russell, B., and Bloom, I. (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. *School Science and Mathematics* 102: 245–253.

Schauble, L., Klopfer, L. E., and Raghavan, K. (1991). Students' transition from an engineering model to a science model of experimentation. *Journal of Research in Science Teaching* 28: 859–882.

Shumba, O., and Glass, L. W. (1994). Perceptions of coordinators of college freshman chemistry regarding selected goals and outcomes of high-school chemistry. *Journal of Research in Science Teaching* 31: 381–392.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., Richardson, L., Yager, R., Craven, J., Tillotson, J., Brunkhorst, H., Twiest, M., Hossain, K., Gallagher, J., Duggan-Haas, D., Parker, J., Cajas, F., Alshannag, Q., McGlamery, S., Krockover, J., Adams, P., Spector, B., LaPorta, T., James, B., Rearden, K., and Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching* 36: 930–954.

Stein, M. K., Baxter, J. A., and Leinhardt, G. (1990). Subject-matter knowledge and elementary instruction: A case from functions and graphing. *American Educational Research Journal* 27: 639–663.

White, B. Y., and Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction* 16: 3–118.

Wideen, M., Mayer-Smith, J., and Moon, B. (1998). A critical analysis of research on learning to teach: Making the case for an ecological perspective on inquiry. *Review of Educational Research* 68: 130–178.