Inquiry Instruction: The More You Know the Less You Think You Know

Samantha Haugen[1], Sherri Newenhouse[1], Deborah Herrington[1], and Ellen Yezierski[2]

[1]Grand Valley State University, Department of Chemistry, Allendale, MI

[2]Miami University, Department of Chemistry and Biochemistry, Oxford, OH

Background

Reformed Teaching Observation Protocol (RTOP)[1]:
- 25 item classroom observation protocol
- Standards-based (*National Science Education Standards*[2] and *Benchmarks for Science Literacy*[3])
- Student-centered and inquiry-focused

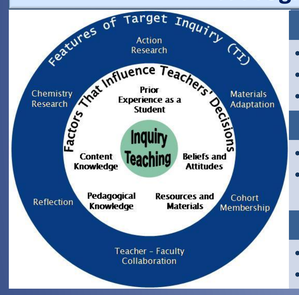
Teaching Science with Inquiry (TSI) Instrument[4]:
- Designed to measure pre-service teachers' self-efficacy in regards to teaching science as inquiry
- Based on Bandura's work indicating that self-efficacy and beliefs strongly influence teaching practices[5-7] and the 5 essential features of inquiry-based instruction as defined in *NSES*[2]
- Has also been used with in-service teachers participating in a Research Experiences for Teachers (RET)[8] program

Initial Predictions:
- Teachers participating in the Target Inquiry (TI) program will reform their teaching to be more aligned with *NSES* teaching standards, thus increasing their RTOP scores
- Teachers implementing inquiry-based practices will have higher TSI scores, so as teachers RTOP scores go up so will their TSI scores

Initial Findings:
- RTOP scores increased, but TSI scores decreased

Research Questions:
- Why do we find that as teachers' RTOP scores increase, their TSI scores decrease?
- Can teacher interviews provide insight into the RTOP and TSI findings?

TI Program



RET – Yr. 1
- CHM 610: Prep for research
- CHM 611: RET
- CHM 612: Applic. to teaching

Materials Adaptation – Yr. 2
- CHM 621: Ed. res. in chem.
- CHM 631: Inquiry materials development

Action Research – Yr. 3
- CHM 632: Inquiry colloquium
- CHM 633: Applic. of chem ed

Methods

Reformed Teaching Observation Protocol (RTOP)[1]:
- Administered pre-program and annually for the next 2 years
- Teachers chose a class that they felt was their "best" inquiry lesson
- Videotaped class was rated independently by 3 trained raters and scores were negotiated if overall score differed by 5+ points

Teaching Science with Inquiry (TSI) Instrument[4]:
- Administered pre-program and each subsequent June for next 2 years

Interviews:
- Teachers were interviewed pre-program and each subsequent summer regarding teaching methods they used, student behavior and attributes, and perceived changes in themselves, their teaching, or their students.
- Interviews were coded under two main themes: Confidence and Inquiry
  - Confidence statements were defined as anything teachers indicated they understood/did better or worse, things they needed to work on, or any indication of student confidence
  - Inquiry statements were coded using the RTOP instrument as a framework

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Data and Results

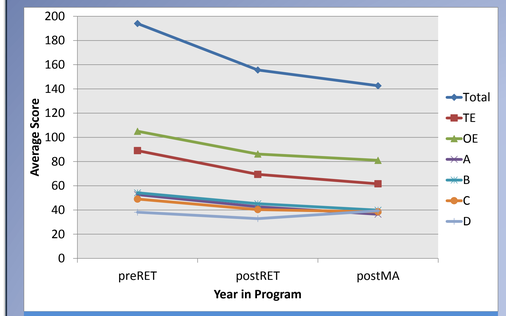

Figure 1: Average TSI scores for each year in the TI program. TE = Teacher Self-Efficacy; OE = Outcome Expectancy; A, B, C, D = level of student self-direction with, A being the most, based on NRC essential features of classroom inquiry.

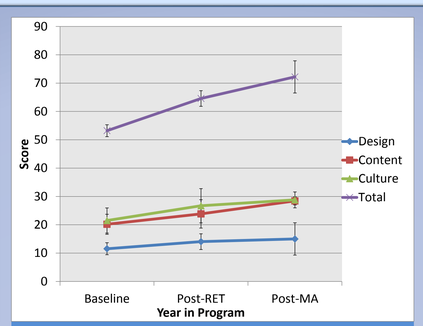

Figure 2: Average RTOP total and sub-scale scores for each year in the program. ANOVA followed by pair-wise comparisons shows significant increases from baseline to post-MA.

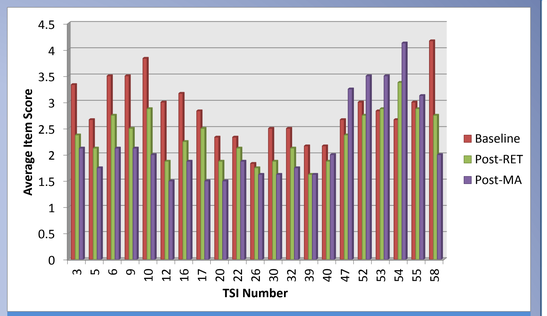

Figure 3: Average TSI score for select items.

Table 1. Teachers Post-MA Interview Statements Regarding Inquiry Teaching

Category	Sample Comments from Teacher Interviews	Sample RTOP Items
Teacher Questioning/ Facilitation	Not telling them what to do. I'm helping them to see where they're stuck and where the resources might be. -HC I think it's because the questions guiding along through the lab, it keeps the kids focused on what they should be looking at, and I think it also provides for more interaction with the students. -WO	17. The teacher's questions triggered divergent modes of thinking. 23. In general the teacher was patient with students. 24. The teacher acted as a resource person, working to support and enhance student investigation.
Communication – sharing in groups, student-to-student, teacher-to-student	Having students collaborate is absolutely something that has increased since this program. I have the tables in groups now instead of separate, and so you can see that change when you walk in. - WH The collaboration is that they either need to share results with someone or talk with other people who have the same problem, then share that information with others. -HC	16. Students were involved in the communication of their ideas to others using a variety of means and media. 18. High proportion of student talk & a significant amount of it occurred between & among students. 25. The metaphor "teacher as listener" was very characteristic of this classroom.
Conceptual Understanding	Well I think I definitely moved away from memorized processes… towards a conceptual understanding. -GV …Concrete thought about things versus just raw memorization experience. -WO	7. The lesson promoted strongly coherent conceptual understanding.
Student Reflection & Justification	Get students to evaluate what they've done while they are writing, asking what your data means, and being able to be thoughtful. –PN I spend a lot of time having the kids think about what they thought… students using evidence to defend their conclusions. – GV	14. Students were reflective about their learning. 22. Students were encouraged to generate conjectures, alternative solution strategies, & ways of interpreting evidence.
Student Engagement	As far as my students doing labs and experimenting, I do give them a lot more ownership and I feel a lot more comfortable stepping back - MH It does help get a much higher percentage of the students involved… to what they are actually doing, and it's not just "what do I write here?" or "just give me the answer." –CH	2. The lesson was designed to engage students as members of a learning community. 13. Students were actively engaged in thought-provoking activity that often involved critical assessment of procedures. 21. Active participation of students was encouraged & valued.

Table 2. Teachers Post-MA Interview Statements Regarding Confidence in Inquiry Teaching

Category	Sample Comments from Teacher Interviews
Facilitation (teachers role in planning and during the activity)	…there are a variety of resources and they are expected to use more than just me, … [before] we were all moving at the same pace, because they needed me to provide the next steps. - HC I view myself as more of a facilitator for my students to learn on their own and figure out things on their own…I question my students a lot, kind of leading questions to have them think through where I want them to get. – MH How do I interact with the class as a whole, when things aren't working or when they are, how do I interact with groups… and how do I interact with individuals when they don't, or when they do get it, how do I push them to the next level? I don't think I've gained a complete understanding of how to do that, but that is very important that I don't think in the past that I felt. - GV
Understanding of Inquiry Instruction (& confidence with inquiry teaching)	Almost all of these things I feel like I can relate to inquiry now. Like before I had reading assignments from a textbook, completing worksheets, and listening to the teacher lecture [as non-supportive of inquiry]. I guess I still feel like lecturing is [non-supportive], but completing worksheets or reading an assignment from the textbook, it just totally depends on what that worksheet is. [It] might be a series of questions that helps them build on their prior knowledge. – MH
Student Ability (increased student confidence, independence, & understanding of investigations)	And my job isn't to put them over the hurdle and carry them to the finish line, but to simply get them over that hurdle and then see how far they can run after that … students start coming to me less with what do I do and more with a question of here's what I want to do, what do you think about that, and I might be able to think through some things with them … but it's much more of them thinking it through before they do it… I ask lots of questions that they answer and … some of the most fun ones are where the kid goes, Oh, I know what to do, and I never really say goodbye. They just take off to do it. – HC
Teaching Methods (teaching ability & student outcomes)	I think maybe more willing to do more things that are different, or … to be able to do that more versatile in that way. I can better understand how to write the questions that make them do what I want to do, rather than just write some questions and see what happens…I think I know how to make them do what I want to do quicker. – PN
Sharing Knowledge (teacher confidence to share knowledge)	There are three of us in my department and one of the teachers taught intro to chemistry this year, so he used a few [TI] activities and I think he was a little more open to teaching through inquiry… We were teaching a few of the same things, so we were able to collaborate a little bit and he was able to use some of the activities. – MH

Sample TSI Items
3. I am able to encourage students to independently examine resources in an attempt to connect their explanations to scientific knowledge.
5. I have the necessary skills to determine the best matter through which students can obtain scientific evidence.
6. I require students to defend their newly acquired knowledge during large and/or small group discussions.
9. I expect my students to make the results of their investigations public.
10. I am able to provide opportunities for students to become the critical decision makers when evaluating the validity of scientific explanations.
12. I am able to provide opportunities for my students to describe their investigations and findings to others using their evidence to justify explanations and how data was collected.
13. I create investigations through which students will be expected to gather particular evidence.
16. I am able to encourage students to review & ask questions about the results of others' work.
17. I am able to guide students toward appropriate investigations depending on the question they are attempting to answer.
20. My students will make use of data to develop explanations as a result of teacher guidance.
22. I am able to guide students toward scientifically accepted ideas upon which they can develop more meaningful understandings of science.
26. I possess the skills necessary for guiding my students toward explanations that are consistent with experimental & observational evidence.
30. I am able to encourage students to gather the appropriate data necessary to answer their questions.
32. I am able to coach students in the clear articulation of explanations.
39. Students develop explanations using evidence.
40. I am able to use worksheets as an instructional tool for providing data & walking students through the analysis process.
47. Students analyze data that has been provided following teacher instructions.
52. Students analyze teacher provided data in a particular manner.
53. Students form explanations using evidence provided.
54. I am able to provide students with all evidence required to form explanations from lecture and textbook.
55. My students construct explanations from evidence using a framework I have provided.
58. My students design their own investigations & gather evidence necessary to answer a question.

Discussion

RTOP Results
- RTOP data indicates, as teachers progress through the TI program, their classroom instruction has become more inquiry-based.
- Teacher post-MA interview statements describing how their teaching had changed cited the following changes, which support higher RTOP scores:
  - Less teacher direction, more teacher questioning and guidance
  - Greater requirement for students to use evidence to justify answers
  - Increased focus on conceptual understanding
  - More student independence and ownership of activities
  - More collaboration and communication between students

TSI Results
- Decreasing TSI scores, for the instrument as a whole as well as the Teacher Self-Efficacy (TE) and Outcome Expectancy (OE) sub-scales , suggests that the teachers are less confident in their ability to use inquiry-based methods.
- Analysis of TSI items grouped by level of student self-direction (A-D) showed decreases in all but the least self-directed items (D).
- Teacher interview statements, in general, indicated a greater confidence in abilities to design and facilitate inquiry , use of more inquiry-based instruction, and increased student independence.

TSI Reliability
- TSI instrument developers found increase in TSI scores for pre-service teachers after an inquiry science methods course, attributed to the inquiry experiences in the course.[9]
- Developers also indicated that reliability decreased from pre to post administration, attributed to pre-service teachers' realizations that inquiry instruction is more complex than they originally thought.[4]
- Our data suggests that the TSI instrument may not provide valid and reliable data for in-service teachers in a long term professional development program that results in substantial changes to inquiry teaching practices.

Conclusion

TI Teachers' TSI scores decrease because as they implement more inquiry instruction, they gain a better understanding of what inquiry instruction involves and what they need to work on. Thus, the TSI cannot be used to accurately detect changes in teachers' use of inquiry-based instruction.

Future Work

- Presenting teachers with the TSI instrument and asking them why they think their scores have gone down each year they have participated in the TI program.
- Using a pre, post, post model where teachers complete the TSI before entering the program, after their first summer experience, but before trying to implement anything new in their classroom, and then after teaching for a year in the program.
- Design a student questionnaire based on the TSI instrument items to compare student and teacher perceptions of instructional practices.

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