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"To What Extent Should Students Learn Science Content Through Engaging in the Practice of Doing Science? Teacher Beliefs and NGSS Attitudes vs. Reported Classroom Practice"

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BACKGROUND

Following adoption of the Michigan Science Standards (MSS) last November, Michigan educators are beginning a transition toward teaching science according to the vision of ***A Framework for K-12 Science Education*** (NRC, 2013). This transition is substantial, because the new standards call for a 'three-dimensional' approach to education in which students consistently engage in science and engineering practices (SEPs) as they learn disciplinary content and concepts that cut across science and engineering disciplines (NGSS Lead States, 2013).

The ***Framework*** and Next Generation Science Standards (NGSS) provide a sense of how science classes should change as a result of adopting the MSS, which are closely aligned to NGSS. Nevertheless, the way in which science classes will actually change will largely be influenced by teachers' beliefs about, and attitudes toward, the standards (Davis, 2003; Czerniak, Lumpe, and Haney, 1999). Beliefs are often described as the personal convictions or ideas one holds, while groups of beliefs form attitudes or action agendas (Ajzen, 1985). Teachers' beliefs have a powerful impact on whether and how they adopt new curriculum and teaching strategies (Cornett, Yoetis, and Terwilliger, 1990; Crawley and Salyer, 1995; Haney, Czerniak and Lumpe, 1996; Hashweh, 1996; McDevitt, Heikkinen, Alcorn, Ambrosio, and Gardner, 1993; Czerniak et al., 1999).

One issue that will influence how teachers adopt NGSS-aligned standards is teachers' preexisting beliefs and attitudes about what constitute effective methods for science teaching and learning (Banilower, Trygstad, and Smith, 2015; Trygstad, Smith, Banilower, and Nelson, 2013). The ***Framework*** and NGSS describe a vision for science education in which students will primarily learn science concepts by engaging in SEPs. Students are to generate and interpret evidence and develop explanations through sustained investigations, all while increasing their capacity to direct all aspects of the process over time (National Research Council, 2012). This contrasts with the current state of science education in many classrooms, in which students primarily learn concepts through direct instruction with occasional reinforcement through engagement in SEPs (Banilower et al., 2015). According to results from the 2012 National Survey of Mathematics and Science Education (Banilower et al., 2013), around 60% of teachers believe that hands-on experimentation should reinforce concepts students have already learned, 40-50% of teachers believe that they should explain a concept to students before the students consider evidence related to the concept, and 90% of teachers believe that

vocabulary should come before conceptual understanding. Interventions to support teachers in adopting NGSS-aligned standards will need to take into account that many educators' beliefs may not align with the notion of consistently teaching science content through SEPs, as envisioned by authors of the ***Framework*** and NGSS.

The objectives of the present work are to describe what a sample of Michigan science teachers thought about NGSS while the state of Michigan was on the verge of adopting the new Michigan Science Standards, explore the extent to which the teachers believed that SEPs were important for the learning of science content, and explore the extent to which teachers mentioned the use of SEPs when describing instructional methods used in a typical week in their classroom. Our purpose was to understand and document teacher attitudes toward an essential attribute of teaching and learning under NGSS in order to inform efforts to support educators during the transition to the MSS in Michigan.

STUDY CONTEXT

This study was conducted in conjunction with the Mi-STAR project (www.Mi-STAR.mtu.edu). Mi-STAR is working with several partner districts and universities around Michigan to develop and implement curriculum for the middle grades that is aligned with NGSS and the new MSS. Twenty-one teachers from schools across eleven Michigan school districts were interviewed from February through April of 2015. Teachers were identified as potential participants in one of two ways: (1) they were invited to interview during a visit of the Mi-STAR team to their district, or (2) they signed up to interview at the 2015 Michigan Science Teachers' Association Annual Conference. None of the respondents had yet worked with Mi-STAR on curriculum development or curriculum implementation. Each respondent received a $10 gift card for their participation. Respondents had taught for an average of 16 years (range 9-23 years). Nine were from an urban district, eight from a suburban district, and four from a rural district. Eighteen of the teachers were female. At the time of interview, thirteen taught middle school science, five taught high school science, one taught high school science and math, one taught elementary science, and one was a teacher leader. In each interview, a respondent was asked 29 questions related to their instructional methods, beliefs about effective educational practices, and perspectives on reform-based education. Three questions were analyzed for this study (Table 1). Trained research assistants conducted all interviews. Interviews were transcribed and de-identified prior to analysis.

TABLE 1: SURVEY QUESTIONS INCLUDED IN ANALYSIS

"What kind of instructional methods do you use in a typical week in your classroom?"
"What do you think about the new science standards that are being considered for Michigan, which align with the new Next Generation Science Standards (NGSS)?"
"What educational practices best support student learning of science ideas (content)?"

Responses to the three questions were analyzed using latent content analysis (Downe Wamboldt, 1992). Themes or patterns within data were identified inductively, such that detailed readings of the raw data was used to derive themes (e.g., Frith and Gleeson, 2004; Braun and Clark, 2006). Coders identified underlying ideas that shape the semantic content of the respondents' words (Braun and Clark, 2006). For example, if a respondent answered the question "What educational practices best support learning of science ideas?" by describing the importance of students engaging in activities such as asking questions, collecting data,

articulating their own explanations for observations, or defending their findings to other students, this was coded as engagement with the SEPs even if the respondent did not mention NGSS terminology.

One coder identified and defined an initial set of codes that summarize the data, and provided these to the second coder who analyzed the data against these categories (Mayring, 2014). The second coder used the definitions and codes, without presuming correctness of the descriptions or categories (Krippendorff, 2004). Any disagreements about codes and definitions were addressed through discussion (Lombard, Snyder-Duch, and Bracken, 2002). Each coder then independently refined coding of the full data set. The full data set was coded to minimize error associated with estimating disagreement based on only a subsample of the data (Krippendorff, 2004). Any disagreements were addressed through the method of discussion and resolution among the coders (Mayring, 2014; Lombard et al., 2002). For the question on NGSS attitudes, responses were coded both to identify respondents' attitudes toward NGSS and to identify justifications respondents gave for their attitudes.

FINDINGS

In order to facilitate comparison between beliefs about effective science teaching and actual classroom practices, we present these together after findings on educators' general attitudes toward NGSS.

EDUCATOR ATTITUDES TOWARDS NGSS

As shown in Table 2, more than half of the teacher respondents were supportive of the Michigan Science Standards (n=12), with most being supportive without qualification (n=7) and some being supportive with qualification (n=5). Of the non-supportive respondents, some were unfamiliar with the standards (n=5), while smaller numbers had a mixed opinion (n=2), or were concerned about their adoption (n=2).

TABLE 2: GENERAL ATTITUDES OF TEACHERS (N=21) TOWARD NGSS

Theme	No. of respondents (n=21)
Supportive	**7**
Supportive, with qualification or uncertainty	**5**
Unfamiliar	**5**
Mixed attitude	**2**
Concerned	**2**

Justifications for support. Among those teachers that indicated any degree of support, five respondents expressed the opinion that NGSS-aligned standards would work better in general than the current standards. Some respondents provided more specific reasoning for their support, including that the MSS would improve the way students learn science and that students would gain needed skills such as problem solving and the ability to think critically (Table 3). One respondent explained, "***Why do we need to remember facts? That's not our century. You can find out this stuff by doing a quick google search. Why are we having the kids remember it? We need to teach them, have more of a focus on problem solving.***" Three teachers expressed that the new standards would benefit teachers because, for example, they would motivate teachers to

improve and are better organized for teachers. Three respondents mentioned that they felt the standards would not require much change and that this was a positive thing.

Justifications for concern. Of the respondents who expressed any degree of concern, the most common concern was that NGSS would be challenging for teachers because it requires pedagogy that is unfamiliar, intimidating, or difficult (n=3, Table 3). One participant expressed strong concern that other teachers would be unable to implement the standards, saying, "*[To teachers] it sounds like the same thing because it's the same content but the problem is, nothing is really done to change teachers in 20 years of how they teach. I think the content is less important than how you teach. So the problem is, does the NGSS actually address how you teach? Yes, but it doesn't show guiding light to teachers on how to do it.*"

Other concerns related to issues teachers envisioned with implementation in their own classroom. Two respondents mentioned that they worried there would not be time to teach everything in depth. One respondent explained, "*I'm just hoping we can do it in the time that we have within the school year and the school day. You know, be able to fit all of that into the time that we have with them. And cover that sufficiently. In a practical way that, where the kids get something out of it.*" Another teacher was frustrated with the ambiguity surrounding state assessment of the potential Michigan Science Standards.

TABLE 3: TEACHERS' MOST FREQUENT REASONS FOR THEIR ATTITUDE TOWARD NGSS-ALIGNED STANDARDS

Reasons for support	**N (of 12 total)[1]**
Will work better than current standards (general)	**5**
Students will gain important skills	**3**
Will improve the way students learn science	**3**
Similar to old standards (not much of a change)	**3**
Allows for greater depth of teaching	**2**
Incorporates engineering	**2**
Necessary for students and society	**1**
Will motivate teachers to improve	**1**
Three-dimensional approach is good	**1**
More teacher-friendly organization	**1**
Michigan teachers had a lot of voice in the standards	**1**
Reasons for concern	**N(of 9 total)[2]**
Difficult for teachers	**3**
May not have enough time to teach everything meaningfully	**2**
The transition will take work	**1**
State assessment is uncertain	**1**
Teachers will not be able to implement	**1**
The standards may easily be misinterpreted scientifically	**1**
Notes: [1.] **From 12 respondents who expressed any degree of support.** [2.] **From nine respondents who expressed any degree of concern.**	

BELIEFS ABOUT LEARNING SCIENCE CONTENT THROUGH PRACTICES

Teachers varied in their beliefs about the educational practices that are most supportive of student learning (Table 4). Their responses to the question "What educational practices best support student learning of science ideas (also known as content)?" were divided almost evenly between the following themes: students learn best through science practices, through experiences (no clear mention of science practices), through a mix of science practices and direct instruction , through a mixture of experiences (no clear mention of practices) and direct instruction, and when they are engaged (regardless of how they learn concepts).

TABLE 4. TEACHERS' BELIEFS ABOUT WHICH EDUCATIONAL PRACTICES BEST SUPPORT STUDENT LEARNING OF SCIENCE CONCEPTS (N=21)

Theme (number of respondents)	*Example statement*
Students best learn concepts by using science practices (i.e. questioning, investigation/ experimentation, explanation, argumentation) **(4)**	*"...They need to be able to experiment and touch and feel and question. Then once they've done that, to ask some questions that encourage them to continue their thinking or investigations."*
Students best learn concepts through a mix of science practices and direct instruction (e.g. teacher, textbook, video) **(4**)	*"… That's the big kick: get people moving with their hands. But you still have to tie it back to ideas and if we don't have teachers that are trained in conceptual understanding, we're never going to get concept across to kids. We're going to do science and act them out but we're still going to miss that connection to, why are we doing this in the first place? Doing science is great. There are times in which it's ok to listen to a lecture and to absorb information, it's just knowledge-based."*
Students best learn concepts through experiences (no clear mention of science practices) **(5)**	*"Hands-on. Because they're actually manipulating it and for me, that's how I learned. I think back to when I was learning … I remember thinking, I have no idea what they're talking about because I never saw it. I never got to do it. I really, I know myself as a learner and I need to put my hands on it. I need to see it."*
Students best learn concepts through a mix of experiential learning(no clear mention of practices) and direct instruction (e.g. teacher, textbook, video) **(4)**	*"I think them being hands on learning instead of direct instruction, there will be a little bit of it just to give them some sort of direction and, you know, what they're doing. But for them to experience things themselves, you know, hands on developing things... you're always going to have some kids that prefer the reading, taking notes sort of portion. But I think the good majority of kids these days, they need to get in there with their hands and kind of experience all of that stuff."*
Students best learn concepts when they're engaged, regardless of how they learn (**4)**	*"You have to catch their interest. If they're not interested they don't care. I would think that would be the first, they have to be interested in the idea and they have to see how it relates to them."*

INSTRUCTIONAL METHODS USED IN CLASSROOMS

Teacher responses about their typical classroom instructional methods reveal that, at the time of response, students did not primarily learn through science practices in most respondents' classrooms (Table 5). Only three teachers described the majority of instruction occurring through science practices in their classroom in a typical week, while four described students learning some content through practices. Two-thirds of respondents described their students as learning content through science practices rarely, or only through periodic labs.

TABLE 5. TEACHERS' BELIEFS ABOUT WHICH EDUCATIONAL PRACTICES BEST SUPPORT STUDENT LEARNING OF SCIENCE CONCEPTS (N=21)

Theme (number of respondents)	*Example statement*
Students usually learn science content through engaging in science practices (i.e. questioning, investigation/ experimentation, explanation, argumentation) **(3)**	*"My role in this, it's more of a facilitator rather than a teacher. If kids ask me questions, I answer them with questions…. I'll give you an example: they have to test the pH of some water samples… and they'll come and say to me, what should it be? I'll ask them what do you think it should be? I don't give them an answer. They have to come up with it on their own. Then they have to explain why they came up with an answer and then based on their findings, is that water safe for drinking or not?"*
Students learn some but not all content through practices **(4)**	*"I do have some lecture, for content, to front-load them …. Sometimes they research it beforehand so they have a general knowledge beforehand so they have knowledge when I'm teaching the vocabulary, and other content. Then we do some type of hands-on project depending on the unit."*
Students usually do not learn content through practices, generally only during periodic labs **(7)**	*"In a typical week I do anything from directing instruction, like giving notes, to answering questions on a worksheet. Generally I incorporate at least one lab activity every week in my classroom and we also spent some time every week doing some kind of silent sustained reading"*
Students infrequently or never learn content through using practices experiences **(7)**	*"I always talk. I probably do more teacher leading than is recommended."*

BELIEFS ABOUT TEACHING COMPARED WITH INSTRUCTIONAL METHODS USED IN CLASSROOMS

Some respondents' beliefs about the educational methods that are most supportive of student learning were not always consistent with the actual instructional methods they used in the classroom. Of the four respondents who expressed that the best way for students to learn content was through science practices, one reported that their students infrequently or never learned through science practices. Of the four respondents who expressed that students best learned through a mixture of science practices and direct instruction, three infrequently or never taught using science practices.

DISCUSSION

These findings must be understood as a snapshot of a sample of Michigan teachers' beliefs, attitudes, and practices prior to incorporation of the new MSS into their schools. This sample is not as a representation of Michigan science teachers as a whole. Limitations to the generalizability of the results include the fact that the sample is small and some participants in the study were self-selected. Recruitment methods were biased toward teachers with an interest in learning more about NGSS and a positive attitude toward standards reform and innovation.

Despite this study's limitations, the findings imply that there is not always a clear link between teacher attitudes about NGSS, beliefs about effective instruction, and teaching methods employed in the classroom. More than half of the teachers were supportive of NGSS. At the time of interview, however, one third of the teachers interviewed only occasionally had their students learn through SEPs, which took place during periodic labs. Another third infrequently or never had their students learn through science practices. Some teachers appear to engage students in science practices less frequently than they believe is ideal for student learning of science content. A disconnect between beliefs and practices could be the result of both internal and external constraints (***e.g.***, Cross and Hong, 2009). While professional development programs are essential to supporting teachers in overcoming internal constraints, there is also a need to understand and address external constraints, such as teaching time or budgets, that may affect teachers' classroom practices (Doyle and Ponder, 1977; Sparks 1983).

The results of this study support the value of a differentiated approach to supporting teachers during the transition to the newly adopted MSS. The needs of the smaller group of teachers who are supportive of the transition and often teach using SEPs will differ from those of teachers who are supportive but do not often teach through the SEPs. Likewise, the needs of those groups will differ from those who are intimidated by the standards or feel the transition is impractical or not worthwhile. Teachers who are supportive of the standards may be more likely to invest energy in the transition by actively educating themselves and seeking professional development opportunities and new curricula. Many of these teachers can be strong leaders and role models who are likely to have a positive influence on their peers (Jackson and Bruegmann, 2009).

Overall, the adoption of these new standards is more likely to be successful if as many teachers as possible perceive the transition as self-directed (Hargreaves 2007). Intimidated or skeptical teachers will need to have their voices heard. Approaches to engaging these teachers must recognize that in the context of reform, teachers' emotional responses can influence their instructional practices (Cross and Hong, 2009). If the reform goal is not aligned with the teachers' existing beliefs or identities, the call for reform can elicit negative emotions and ultimately rejection of reform-based practices (Cross and Hong, 2009). Skeptical teachers must therefore be engaged in experiences that are likely to increase the receptivity for the reform-based practices. Intensive and sustained professional development programs are more likely to yield positive outcomes. According to an analysis of 24 reform-based projects, professional development programs that are sustained for more than two weeks can have a positive influence on teacher practices, but programs sustained for four or more weeks are more likely to have positive influence on classroom culture (Supovitz and Turner, 2000).

CONCLUSION

Michigan teachers in this sample had varied attitudes toward NGSS. The majority of teachers who were familiar with the new standards were supportive of them, although several expressed qualifications of their support. A minority of teachers was strongly concerned about the new standards. Although most of the teachers interviewed supported NGSS, less than 20% of them believed that students best learn concepts primarily through SEPs, and only three of them instructed primarily through the SEPs in a typical week. Several teachers did not appear to teach content through SEPs to the extent that they believed was ideal for student learning. These results highlight that teacher beliefs about instruction are not always consistent with actual practices. Professional development initiatives will likely need to be differentiated and sustained in order to provide effective support to teachers. Sensitivity to teachers' preexisting beliefs and attention to both internal and external constraints faced by teachers will be essential to the successful transition to the MSS.

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