ADDRESSING PRESERVICE TEACHER'S DISJUNCTIVE KNOWLEDGE AND CORRESPONDING BELIEFS REGARDING GUIDED-DISCOVERY BASED PEDAGOGICAL PRACTICES

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ABSTRACT
This study assesses pre-service teachers' understanding of Piagetian theory, how these teachers-in-training would implement and execute discovery-based and guided-discovery based lessons, as well as their preferred pedagogical practices, before and after having participated in both didactic and an immersive guided-discovery based lesson. Within both, linkages between theory and practice were explicitly made in reference to disequilibration, assimilation, accommodation, schema development, re-equilibration, and related topics. Results indicate that by the end of the course, pre-service teachers' were reliably able to discern whether a task was more assimilative versus accommodative; they also demonstrated accuracy in their conceptions of what constituted disequilibrating events. Students' descriptions of how they would "facilitate" their students' active construction of knowledge however, revealed several misconceptions and a superficial understanding of how these theories intersect with practice. Additional data that were culled pertaining to students' theories about science teaching revealed a marked stability in beliefs regarding preferred pedagogical practices. Discussion, implications, and suggested future research are provided so this immersive experience can be replicated, and augmented by concept teaching, to foster positive outcomes for pre-service instructors and the students they will serve.
Keywords: pre-service teacher preparation, Piagetian theory, reconciling theory with practice

Introduction

Teachers are now required to educate K-12 learners in rapidly changing knowledge-based era with increasingly challenging academic standards (Darling-Hammond, 1998). To meet these goals, and do so for an increasingly diverse student population, educators must cultivate a complex array of skills. These include facilitating their students' ability to detect discrepancies in the material they are learning, gather evidence that enables them to reconcile these disparities, and formulate increasingly accurate – and more elaborate – knowledge schemes. These facets of – what Shulman (1987) operationalized to be -- pedagogical content knowledge are, in part, cultivated and informed by tenets of Piagetian theories (Karplus, 1977; Hancock & Gallard, 2004; Korthagen & Kessels, 1999; Tobin, Tippins, & Gallard, 1994). However, data indicate that preservice teachers struggle to "transfer" these theoretical understandings into practice, thereby diminishing their capacity to facilitate their students' mastery of higher-order learning objectives. This is significant, given research indicating both the need for more effective, student-directed K-12 STEAM instruction, as well as the resource limitations affecting lower income districts (Thorley & Stofflett, 1996; Tessier, 2010).

Specifically, data derived by the authors indicated that preservice teachers taking an introductory course, on theories of learning and teaching and their application to serving learners whose families are economically disadvantaged, had – in the best circumstances -- predominately "knowledge and /or comprehension-based" understandings of Piagetian theory and guided-discovery based pedagogical practices, and in the worst, incorrect/nebulous understandings. These findings suggest it is important for teacher educators to explore how to train teachers to do more than define theories surrounding student-directed learning. Instead, they need to understand how, and when, to put those theories in practice.

To address this extant question, in this study preservice teachers actively participated in two, guided discovery-based lessons, of nominal cost to execute. While doing so, they defined what disequilibrating events "looked like," how they attended to them by assimilating and accommodating new information, what it "looked like" to re-equilibrate to a higher cognitive level, how their schemas changed, and exactly how the teacher – in this case a Director of Instructional Technology – facilitated their learning. These preservice teachers' knowledge of Piagetian theory was assessed -- after a didactic lesson on schema formation, teacher-as-facilitator, assimilation, accommodation, disequilibrium, and re-equilibration -- prior to this immersive experience, and again, after the immersive experience. Also assessed were student's beliefs regarding which pedagogical practices would be optimal to enact in response to a set of instructional scenarios, both before and after having participated.

Literature Review
Learning is a process of conceptual change. Piaget uniquely added to our understanding of this process by asserting that, for students, "learning is in the doing," and as such, their active reconciliations between what is believed to be true and disconfirming evidence facilitates the cultivation of their qualitatively more sophisticated knowledge schemes (Piaget, 1974). These epistemic and pedagogical beliefs are of relevancy to teachers-in-training, who are reconciling their former experiences as a K-12 student with theories of learning and teaching. Their "compartments of learning" informed by personal experience may compel them to view inquiry-based pedagogy as primarily a science-specific teaching tool that is superior to direct instruction (Posner, Strike, Hewson, & Gertzog, 1982; Cobern, Schuster, Adams, Skjold, Mugaloglu, Bentz, & Sparks, 2014). This is consequential: Thomson & Gregory (2013) report that teachers' pedagogical beliefs are tied to their classroom practices. Thus, if their beliefs are not accurate, it is incumbent upon teacher trainers to clarify these misconceptions through various means, which remain unclear.

Clarifying Process of Disequilibration, Assimilation, Acccommodation, and Re-equilibration
Preliminarily, clarification necessitates understanding that problems or cognitive challenges – called disequilibrating events -- emergent in learners' active engagement usually requires them to 1) assimilate new phenomena into existing theory, while concurrently 2) conceptually reorganizing or accommodating their previous understanding. This process is often non-linear and recursive in nature. When a student has reconciled discrepancies to facilitate new, coherent understandings, their re-equilibration to a higher cognitive level is indicative of conceptual change (Posner et al., 1982, Piaget 1930, 1974).

Pertaining to conceptual change. What conditions are necessary for conceptual change? First, a learner must be dissatisfied with a current theory – scientific or otherwise. Posner et al. (1982) asserts that this occurs when learners either detect an anomaly or confront assumptions that are discrepant with those previously held. Second, as defined by Piaget, learners respond to/are not dismissive of a disequilibrating event. Third, "Responding" requires learners to search for intelligibly represented, plausible, and/or fruitful conceptions (Thorley & Stofflett, 1996, Piaget 1930, 1974). The implications for preservice teachers, who wish to facilitate their students' reconciliation between what they know/believe disconfirming evidence, is that they must clearly understand the prerequisites for learners' engagement in conceptual change.

Pedagogical methods used to foster conceptual change. The process of conceptual change is intrinsic to discovery-based learning, which Guthrie (1967) reports is a maximally effective way to facilitate students' transfer of knowledge. Another benefit of problem-based pedagogical practice – which is not synonymous with yet share features with discovery-based learning – is its value in fostering students' integration of new concepts, a result not evidenced by those taught through traditional, didactic means (Capon & Kuhn, 2004, Posner et al., 1982, Thorley & Stofflett, 1996)

As alluded to above, however, despite these assertions, as well as Piaget's singular endorsement of student-directed learning, positive student learning outcomes have resulted from teacher-directed instruction. Cobern, Schuster, & Adams (2010) report that use of both pedagogical models for teaching science, direct instruction and inquiry instruction, resulted in students' performing equivalently as per their post-test scores. Thomson & Gregory (2013) also reiterated the positive student learning gains associated with teachers' use of direct instruction in tandem with a more hands-on learning approach.

Given the academic research indicating the strong, positive association between the degree to which teachers have integrated, elaborate knowledge of guided-discovery pedagogical practices and their students' substantive conceptual understanding (Magnusson, 1991; Bellamy, 1990); evidence indicating the preponderance of K-12 lessons that are transmissive in nature, with minimal guided-discovery based learning opportunities (Banilower & Smith, 2013); and, limited opportunities to refine pre-service teachers' pedagogical content knowledge due to time constraints in methods and related coursework (Cobern, Schuster, Adams, Skjold, Mugaloglu, Bentz, & Sparks, 2014), the authors had preservice teachers, after having reviewed Piagetian theory in class, participate in an immersive, hands-on learning experience entitled, "Inquiry learning in the Classroom Using Technology." As noted previously, students' knowledge of Piagetian theory was assessed after an in-class, didactic lesson prior to this immersive experience, and again, after the immersive experience. Also assessed were student's beliefs regarding which pedagogical practices would be optimal to enact in response to a set of instructional scenarios, again -- both before and after participating in Inquiry Learning in the Classroom Using Technology.

Accordingly, the **Research Questions are:**

1. Does the conceptual integration and understanding of Piagetian theory as well as guided-discovery based lessons change after preservice teachers have engaged in two immersive, guided-discovery learning experiences, and if so, in what ways?
2. Do preservice teachers preferred pedagogical approaches, in response to several, realistic science scenarios (i.e. "Thinking About Science Teaching, available at **http://www.wmich.edu/science/inquiry-items/index.html** **[Appendix B]**) change after preservice teachers have engaged in two immersive, guided-discovery learning experiences, and if so, in what ways?
3. What are the preferred pedagogical approaches in response to several realistic science scenarios (i.e. "Thinking About Science Teaching, available at **http://www.wmich.edu/science/inquiry-items/index.html** **[Appendix B]**) and what are some of the reasons for these preferences? Are explanations for having chosen preferred pedagogical methods consonant with the preferred pedagogical methods chosen?

Our work addresses a key aspect of these extant questions by examining the associations between preservice teachers' depth of understanding Piagetian theory and guided-discovery based learning, preferred pedagogical practices, and rationales for these preferences. If preservice teachers are being trained to facilitate their K-12 students learning, and if the degree to which their conceptual understanding of guided-discovery based learning is positively associated with their K-12 students levels of understanding, then how do we cultivate substantive, integrated knowledge schemes of these practices?

Methods

In this study, participants included pre-service teachers enrolled in a sixteen-week three-credit hour Educational Psychology Course with an emphasis on serving learners in poverty at a small university located in suburban area within the southeastern United States. All students ($n = 48$) were Education majors in their freshman or sophomore year of undergraduate study. The relative proportion of males to females, as well as African American and Caucasian students in this study mirrors the larger population of pre-service teachers in this program. A prerequisite to the course was successfully completing a three-credit course focused on the fundamentals of education.

Context of the Course

Study participants were matriculates in a 200-level course, taught in-person with a corresponding 21-hour field component, focused on exploring the multifaceted development of learners from preschool to adolescence. Grounding student participants' emergent understandings of course content were the theories and tenets of Educational Psychology. Theories from this academic literature base, as well as those illustrating the intersection between theories of learning and teaching with the unique needs of learners in poverty – particularly those residing in rural areas, were examined extensively in class and in the field.

Procedures

First, preservice teacher participants learned, through didactic means, Piagetian theories and developmental stages, including assimilation, accommodation, teacher-as-facilitator, disequilibrating experiences, re-equilibration, characteristics of various developmental stages – such as conservation of matter and reversibility -- and how students construct knowledge. It is important to note that throughout the entire lesson/s, the authors explained the relative efficacy of using guided discovery pedagogical methods, as opposed to the unguided discovery-based learning methods endorsed by Piaget. Thus, these preservice teachers were applying Piagetian theories of learning and teaching, yet doing so in reference to guided-discovery based lessons. They were then asked to respond to a series of reflections – described in the "Measures" section below – and to indicate how they would teach a lesson in response to scenarios within "Thinking About Science Teaching," (Cobern et al., 2014 [Appendix B]).

Second, they participated in the lesson in the Instructional Technology Center (ITC), which commenced with the ITC Director asking students to describe their knowledge of specific theories of learning and teaching. To that end, she asked, "What is adaptation?" "What learning processes are intrinsic to adaptation?" "What is assimilation and accommodation?" "What is a disequilibrating event or experience?" "What is a knowledge scheme – what does it 'look like' or how can we conceptualize it?" "Let's think about the Hierarchy of Learning in Bloom's taxonomy?" What learning goals are at the lower levels of the pyramid?" "What learning levels are at the higher end of the pyramid?" "What might it 'look like' for students to 'create' as opposed to 'comprehend'?"

Third, after this introductory discussion, the class was randomly divided into two groups. One-half of the class was asked to create a product within the context of a budget, height requirements and other parameters (entitled, "Economics – Wants and Needs, Goods and Services"), while the other was asked to program Mbots (entitled, "Math – Distance, Speed and Measurement") to perform tasks that are described in detail – along with field notes (please see Appendix C). By the middle of the class period, groups (of preservice teacher participants) completed their activities and went to the other side of the ITC (i.e., those who completed "Math –Distance, Speed and Measurement worked on "Economics – Wants and Needs, Goods and Services" and vice versa).

No more than twenty-four hours after having participated in the immersive experience described above, participants were asked to complete a different version of "Thinking About Science Teaching," (Cobern et al., 2014 [Appendix B]), which included three questions that were the same as the first. Participants were also provided with an opportunity to substantively describe the reasons by their answers, for extra credit. Approximately 20% of participants (N=10) chose to do so. Finally, all participants were asked – through an open-ended question on their final exam -- to describe how they would facilitate their students' active construction of knowledge.

Measures

Prior to going to the Instructional Technology Center (ITC), yet after having studied in class the developmental stages Piaget operationalized, as well as assimilation, accommodation, disequilibration, re-equilibration, schema formation and teacher-as-facilitator, students were asked to respond to the following prompts:

In thinking about Howard Gardner's Theory of Multiple Intelligence (MI), Piaget, Vygotsky, Maslow, the Jensen text, Stereotype Threat, and Identity (Erikson) how do these concepts intersect with experiences you have had in your own life or things you have observed in the field as of late? While doing so, be sure to describe how these experiences and observations are linked to concepts in the Jensen text or according to the theories we have learned.

Based upon what you have learned regarding identity, best practices in teaching, and MI theory, what are some of the key behaviors you will enact or techniques you will use while in the field for this course, or when you become a practitioner (either in teaching, coaching or guidance counseling)? Please be as specific and comprehensive in your description as possible.

Preceding their participation in the ITC, preservice teacher participants also completed Cobern et al.'s (2014) assessment, "Thinking About Science Teaching," a 16 item, multiple-choice measure designed to both foster students' understanding of and reveal their preferences for using specific pedagogical approaches. Two different versions of this measure were used, one for the pre-test and another for the post-test. In both versions student participants were asked to read an instructional scenario and indicate, of the four instructional approaches -- on a continuum varying from direct instruction to inquiry instruction --, "Which one would be most similar to what you would do?" (see Appendix B) Notably, all of the pedagogical approaches were sound. The four options from which participants could choose one were:

- didactic direct instruction (teacher engaged in direct instruction with the provision of examples and/or demonstrations, but no student activities);
- active direct instruction, (teacher directly teaching the science content while incorporating corresponding student activities);
- guided inquiry (teacher facilitating his/her students' active discovery of science concepts); and,
- discovery-based (student inquiry-based learning with little to no teacher guidance) (Cobern et al., 2014).

Presented differently per each scenario was the order of each instructional approach.
The author's took field notes of all participants' behaviors and stated responses in the ITC, and – as noted above -- student participants were offered extra credit if they submitted substantive descriptions of why they chose each answer on the "Thinking About Science Teaching" measure (Cobern et al., 2014. A subset of participants did so on two occasions, that is, both prior to participating -- in the immersive learning experience -- and then afterwards.

Finally, all student participants were asked to answer the following questions on their final examination: "Describe how you would "facilitate" your students' active construction of knowledge for a specific lesson in the discipline you will be teaching (as defined by Piaget). What would you do? How would you do it?"

Data Analyses

At both time points, that is – after having learned about Piagetian theory didactically, prior to the immersive experience and then again afterwards, descriptive statistics of participants' responses on "Thinking About Science Teaching" were calculated (each nominal response was recoded numerically). A Wilcoxon matched-pairs signedranks test was also computed to compare the scores on students' responses to "Thinking About Science Teaching" time one to their scores time two. In addition, participants' self-generated rationales for their answer choices, field notes documenting their responses while participating in the ITC, as well as their responses to the question posed regarding how they would facilitate a guided-discovery lesson, were qualitatively analyzed. Analysis was conducted using constant comparative analysis to detect emergent themes (Strauss & Corbin, 1998) that could be triangulated with numerically coded nominal data.

Results

Time One Reflections (prompt in Appendix A)

The dominant themes fell into two, broad categories. The first was that *any* kind of active learning, didactic active, generating an explanation, and the like, were all consistent with Piagetian theory – according to the students. The second was that the features of Piaget's theories were understood (by the students) in a disjointed, non-conceptual way (some of their quotes include statements such as: "I will facilitate the [my k-12] students," or a technique I plan to enact as a teacher is "schema-knowledge frame," or I plan to have "more assimilative learning" [instead of accommodation]). Weaved within all of this was a preference for active learning as a way for students to "remember" the material and be motivated/curious; this was reflected in their explanations for preferred pedagogical approaches in response to the scenarios.

Enumerated below are specific quotes illustrative of the themes listed above:

My main key behavior that I will enact while in the field or in my own classroom is student engagement and motivation. I will do my best to make sure my students are all involved and not just "fitting in" but they know what is going on. This way I will be using Piaget's theory and making sure that all my students are being involved regardless if the other people are more skilled.

During the field study, I also noticed how the teacher was incorporating Piaget's theories when he said that teachers give students information and the students just add the information to what they already know. For example, the teacher was teaching the students about George Washington. She gave them information on him then showed them a $1 bill so that they could see that he was on it. Some students may have already seen a $1 bill before and know what is it, but they didn't know that it was George Washington on the front of it.

Based of[n] the various theories, as a teacher, I would practice Piaget's Pedagogical Practices. He suggests that teachers should expose children to objects and experience and motivate them by stimulating curiosity. I would incorporate this in teaching my students by allowing them to do hands on activities instead of always doing book work or sitting down at a desk. To incorporate experience into learning I would try to take them on field trips or go outside as much as possible to explore if we are having a science lesson. I would also try to keep the students engaged as much as possible so that they can be curious about the topic and want to learn more about it without me having to force them.

Time Two Responses (prompt in Appendix A)

Results indicate students were reliably able to discern whether a task is more assimilative versus accommodative. When presented with the conservation of liquid, students identified this correctly, and, students demonstrated accuracy in their conceptions of what constituted disequilibrating events in the context of their immersive experience in the ITC. The latter is noteworthy: Understanding what "it looks like" and even "feels like" to attend to a disequilibrating event is important if pre-service teachers are to structure experiences that require students to re-equilibrate at a higher level of understanding (Mascolo & Fischer, 2005). Arguably, participation in the Inquiry learning in the Classroom Using Technology lesson bridged a potential gap between theory (disequilibrating events) and practice (envisioning what cognitive dissonance "looks like"). However, when asked, "Describe how you would "facilitate" your students' active construction of knowledge for a specific lesson in the discipline you will be teaching (as defined by Piaget). What would you do? How would you do it? Their answers indicated the following:

Overall, these pre-service teachers' conceptions of guided discovery is that it is "active" and "motivating to students," which is not inaccurate, yet their self-generated descriptions of guided-discovery were not always consistent with how that pedagogical practice is enacted. In addition, as per student responses to this assessment, the ways teachers facilitate student learning in the context of guided discovery are broadly defined and, again, not always consistent with how the facilitating of student learning was operationalized by Piaget.

Enumerated below are specific quotes illustrative of the themes listed above:

As a teacher, I would 'facilitate' my students by using a guided discovery based learning and by assimilation and accommodation. I would provide anything that would aid me in teaching and relaying the concepts to the students in the best way possible. If one student did not understand, I would change my scaffolding techniques with that student and do what is best for him. I would use assimilation by providing background information and relating it back to what we are learning that day. Maybe one of the students did not understand the math problem because I was talking about animals and he was absolutely afraid of animals, I would change the topic to ensure he understands. However, some disequilibrium is okay in the sense of it is making them think and think critically. So, I would use accommodation by giving the students objects and situations that would cause a negative response to allow them to accommodate.

In the example above, a few misconceptions stand out. First, the preservice teacher is not inducing assimilative and accommodative processes in his or her student, rather he/she is "using" assimilation and accommodation. Scaffolds, while helpful to integrate, are not part of Piagetian theory per say, illustrating the way Vygotsky's theories of teaching are conflated with Piaget's. Again, the preservice teacher plans to "use assimilation," yet accurately notes that this process involves the students' integration of that which is known with new, information so his/her schemas are increasingly accurate, elaborate and conceptually congruent. The preservice teacher believes the presentation of a known topic to a student who may "[have been] absolutely afraid of animals," could be a disequilibrating event as a result of his/her fear. In response to this, the preservice teacher would "change the topic" so as to not hamper his/her understanding, yet note that the students' fear of animals could be an opportunity of sorts, fostering critical thinking. Finally, the preservice teacher-as-facilitator would "use accommodation" to cause a negative response (presumably disequilibrating) that "allows them" to "accommodate."

Active didactic. Notably, "active didactic" was the pedagogical approach participants most frequently indicated they would be likely to implement. In their self-generated descriptions of what it would look like to facilitate student learning via guided-discovery based approaches, they indicated the hallmark features were, "Moving around the room, not just sitting/listening" or "Cutting out shapes to show the phases of the moon." Also mentioned was, "doing an activity on a website," or "giv[ing] them manipulatives instead of having the teachers stand up at the board. In sum, "get up and move, that is 'do activities,' as opposed to being lectured to." This suggests that preservice teacher participants' conflated guided discovery-based learning with active didactic approaches and often view the merits of the former as better than expository or other approaches, such as "open inquiry based lessons" because it is beneficial for students to "do things" and move around the room – yet, unlike open inquiry, students should be told "what to do." (E.g., cut out the phases of the moon.) Facets of this are accurate – presumably according to Piaget, where the learning is in the doing, however, facilitating students' active construction of knowledge is not merely a function of whether students are moving around the room according to a teachers' instruction while studying a particular topic.

Also noteworthy were participants' self-generated definitions of what it means to facilitate their students learning. Often cited was providing students with autonomy, not being overly prescriptive, and/or not providing them with instructions – consistent with discovery-based learning endorsed by Piaget, but not congruent with the focus of our inquiry-based experiences in the ITC, which were guided-discovery lessons. For example:
I would facilitate my students' active construction of knowledge for a specific lesson in the discipline that I will be teaching by only answering the need to know questions. I am not going to stand over each student and hold their hand as they move on to the next set of instructions.

I would tell the students what they would be experimenting and what they need to find, but I will not tell them how or the outcome. If I wanted them to determine how slope, mass, distance, and acceleration are connected, I would tell them to find that out. I would give them the tools they need. There will be no instructions.

These data support the notion that facets of preservice teachers' knowledge of how to construct a guided-discovery based lesson is on the "knowledge" and "comprehension level" of Bloom's Taxonomy. Evidence of this includes preservice participants' assertions that guided-discovery entails students using tools conferred by the teacher, but their teachers will not "hold their [students] hands." Thus, their understanding of Piagetian theories of learning and teaching, as well as guided inquiry based learning, are not the level of application, despite having participated in guided-discovery based lessons and having generated accurate examples of disequilibrating events.

Results of Preferred Pedagogical Practices, Time One (scenarios available at: http://www.wmich.edu/science/inquiry-items/index.html [POSTT 2])

All participants preferred either "Didactic Active" pedagogical approaches or "Guided-Discovery Based" practices; infrequently chosen were "Didactic Direct" or "Open Inquiry-Based Lessons."

Results of Preferred Pedagogical Practices, Time Two (scenarios available at: http://www.wmich.edu/science/inquiry-items/index.html [POSTT 4])

As evidenced time one, all participants preferred either "Didactic Active" pedagogical approaches or "Guided-Discovery Based" practices with the exception of responses to one scenario regarding how to best teach Boyle's Law, in which students almost unanimously preferred use of a "Didactic Direct" pedagogical approach (the scenario pertaining to Boyle's Law will be presented). As noted above, infrequently chosen were "Didactic Direct" or "Open Inquiry-Based Lessons." Repeated between time one and time two were three scenarios. No statistically significant differences -- as per Wilcoxon Signed-Rank Test -- between preferred pedagogical practices emerged.

Discussion

The stability of teachers' beliefs has been documented and is consonant with psychological research indicating the proclivity of attitudinal resistance to change (Nettle, 1998; Kagan, 1992) Nonetheless, the authors believe, as per the results, that concept teaching methods would be an effectual correlate to the immersive learning experience described. The reasons for this is that concept teaching mitigates students' tendency to make classification errors – evidenced by participants in this study -- such as "overgeneralization, misconception and undergeneralization" (Tennyson & Cocchiarella, 1986, p. 40). The concept-teaching model, adapted to facilitating preservice teachers' understanding of Piagetian Theory, discovery-based learning, and guided-discovery based learning would include the following:
Elaborately defining the characteristics of each theory and pedagogical approach;
Providing explicit, examples of each that are accessible and familiar to pre-service teachers (without adulterating their meaning);
Presenting numerous explicit, examples of each that are accessible and familiar to pre-service teachers (again, without adulterating their meaning);
Facilitating a discussion among preservice teachers regarding why one representation was an example, and why another was not (that is, what aspects characteristics of the example are consonant with the definition, and what aspects of the non-example are not?)

Requiring students explain when these theories and pedagogical techniques are used as well as how they are implemented (Merrill & Tennyson, 1977).

For example, a concept-teaching lesson on the vocabulary term hirsute would include the following. First, the teacher would define the term hirsute, its parts of speech, and provide a visual representation of something that is shaggy or hairy. Second, the teacher would provide several visual examples of people, animals or other "things" that are hirsute. Third, the teacher would provide several visual examples of people, animals or "things" that have hair, but are not hirsute. That is, the teacher will provide non-examples and students will have to describe why each example is not consistent with the definition of hirsute. Fourth, the students would be asked to craft several sentences using the term hirsute, as an adjective, to clearly describe someone or something that is shaggy/hairy. These would then be reviewed for accuracy, so students are not apt to make overgeneralizations – anything with hair is hirsute; undergeneralizations – Godzilla is hirsute, but the man with a long beard is not; and misconceptions – all dogs are hirsute.

Suggestions for Future Research

Future research involves tracking our students' progress over time to establish their conceptual understanding of Piagetian theory, the intersection between these theories and practice, and their ability to create discovery and guided-discovery based lessons. This is important, as time constraints in science education courses, as well as the secondary priority science is given in the elementary school setting, render this research germane to examining effective ways to instruct pre-service teachers on how to integrate discovery-based learning into their lesson planning (Capon & Kuhn, 2004, Thorley & Stofflett, 1996).

Implications for Practice

The educational implications are twofold: initially, increasing the conceptual understanding of science standards for pre-service teachers using the notion of accommodation to influence this new conception is the first step. Strengthening the conceptual ecology of the pre-service science teacher will provide a foundation for the second goal, to apply effectual teaching methods to science and other content-area standards (Posner et al., 1982). These two goals can be accomplished through the intentional integration of concept-teaching, as was described above. Challenging the pre-service teacher's basic assumptions about teaching science – as well as other subjects -- and using the various types of instruction will foster a stronger conceptual understanding of theories regarding learning and teaching of centrality to those who are effective educators.

References

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 National Survey of Science and Mathematics Education. *Horizon Research, Inc.(NJ1)*.

Bellamy, M. L. (1990). Teacher knowledge, instruction, and student understandings: The relationships evidenced in the teaching of high school Mendelian genetics. Unpublished doctoral dissertation, The University of Maryland, College Park, MD

Blooms Taxonomy (2018). *Vanderbilt University Center for Teaching*. Retrieved from https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

Capon, N. & Kuhn, D. (2004). What's so good about problem-based learning? *Cognition & Instruction,* 22(1), 61-79.

Cobern, W. W., Schuster, D., Adams, B., Skjold, B. A., Muğaloğlu, E. Z., Bentz, A., & Sparks, K. (2014). Pedagogy of Science Teaching Tests: Formative assessments of science teaching orientations. *International Journal of Science Education*, *36*(13), 2265-2288.

Guthrie, J. (1967). Expository instruction versus a discovery method. *Journal of Educational Psychology,*58(1), 45-49.

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62,* 129-169.

Magnusson, S. J. (1991). The relationship between teachers ' content and pedagogical content knowledge and students ' content knowledge of heat energy and temperature, unpublished doctoral dissertation, The University of Maryland, College Park, MD.

Mascolo, M.F., & Fischer, K.W. (2005). Constructivist theories. In B. *Hopkins (Ed.), The Cambridge encyclopedia of child development*. New York, NY: Cambridge University Press.

Merrill, M. D., & Tennyson, R. D. (1977). *Concept teaching. An instructional design guide.* Englewood Cliffs, NJ: Educational Technology.

Nettle, E. B. (1998). Stability and change in the beliefs of student teachers during practice teaching. *Teaching and Teacher Education, 14*(2), 193-204.

Pedagogy of Science Teaching Test (n.d.). *Mallinson Institute for Science Education*. Retrieved from http://www.wmich.edu/science/inquiry-items.

Piaget, J. (1930). *The child's conception of physical causality*. London: Kegan Paul.

Piaget, J. (1974). *Understanding causality*. New York: W.W. Norton.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211-227.

Tennyson, R. D. & Cocchiarella, M. J. (1986). An empirically based instructional design for teaching concepts. *Review of Educational Research, 56*(1), 40-71.

Tessier, J. (2010). An inquiry-based biology laboratory improves preservice elementary teachers' attitudes about science. Journal of College Science Teaching, 4, 84-90.

Thorley, R. & Stofflett, R. (1996). Representation of the conceptual change model in science teacher education. *Science Education*, 80(3), 317-339.

Thomson, M. & Gregory, B. (2013). Elementary teachers' classroom practices and beliefs in relation to us science education reform: reflections from within. *International Journal of Science Education,* 35(11), 1800-1823.

Appendix A

Time 1 Reflection Prompt:

In thinking about Howard Gardner's Theory of Multiple Intelligence (MI), Piaget, Vygotsky, Maslow, the Jensen text, Stereotype Threat, and Identity (Erikson) how do these concepts intersect with experiences you have had in your own life or things you have observed in the field as of late? While doing so, be sure to describe how these experiences and observations are linked to concepts in the Jensen text or according to the theories we have learned. Based upon what you have learned regarding identity, best practices in teaching, and MI theory, what are some of the key behaviors you will enact or techniques you will use while in the field for this course, or when you become a practitioner (either in teaching, coaching or guidance counseling)? Please be as specific and comprehensive in your description as possible.

If you were to create a graphic organizer or diagram of your "future self" in contact with learners who are dealing with stressors or poverty, what would that look like/who will you be, given what you know now?

Time 2 Application-Based Question:

"Describe how you would "facilitate" your students' active construction of knowledge for a specific lesson in the discipline you will be teaching (as defined by Piaget). What would you do? How would you do it?,

Appendix B

Time 1 Scenarios: Thinking about Science Teaching (**http://www.wmich.edu/science/inquiry-items/index.html** **[POSTT 2]) - Example Below-**

Insert Figure 1 here

Time 2 Scenarios: **http://www.wmich.edu/science/inquiry-items/index.html** **[POSTT 4]) - Example Below –**

Insert Figure 2 here

Appendix C
To engage in "Economics – Wants and Needs, Goods and Services," preservice teachers were told the following in order to complete their first task:
"You just moved to a new town in Nevada called Stubbornville. After you arrived, you realized that there is only one store in the town, the Everythingorium. Surely this can't be! There must be a demand for more goods and services than this one store can manage.
"You decide to open a new store in this town across the street from the Everythingorium. Your store carries a wide variety of goods and services, however you notice that customers are set in their ways and won't venture into your store. "There must be ONE thing that they can't live without?" you think to yourself. "What is the one thing that I can carry in my store that the citizens of Stubbornville NEED to have? Maybe if I can get them in the store for this one item, they will realize that the other items I carry will be of value to them too. I have to make this work!"
"Ah-ha! I've got it! I will show the citizens that they can't live without a/an ____!"
"Now I need to go build one, to show the citizens just how important this item is. There's only one problem. I've spent all my money opening this store and I've only got $20 in my bank account. I need at least $10 to eat for the rest of the week, so it looks like I've only got $10 to spend on supplies for this nifty new gadget. It's a good thing my friend has a 3D printer and owes me a favor, and at least I have the Everythingorium across the street for some additional supplies."

Parameters:
- You must work in a group of 2 or 3 classmates
- You only have 10 minutes to build your gadget
- You MUST use one of the 3D printed items in your gadget
- Your gadget must be at least 6 inches long, wide, or tall
- You only have $10 to spend on materials. You must create a budget that shows how much you spent to build this item.

You will have an additional 5 minutes to:
- Determine the name of the gadget
- Determine the cost of the gadget (remember there is only $10 left in your bank account so you do need to make a profit)
- Create a slogan for the gadget that explains its purpose and uses its name
- Explain in a few sentences why someone would WANT or NEED the gadget
- Explain in a sentence or two why your gadget is a GOOD or a SERVICE

Task II
Once your gadget is created, you will roll one die to determine variables that might change your gadget. You will have 5 minutes to make the necessary changes.

If you land on:
1- Oh no! Your dog tried to eat the prototype of your gadget. You must take a piece off of your gadget. Adjust the price of your gadget if needed.
2- Oh no! There was a flood in your office and your gadget was ruined. Take 2 pieces off of your gadget. Adjust the price of your gadget if needed.
3- Oh no! The patent/copyright office called and said that your gadget has the same name as another gadget on the market. You must change the name of your gadget and rewrite your slogan. Adjust the price of your gadget if needed.
4- Congratulations! Your gadget is the most perfect item this town has ever seen! You don't need to make any changes. Adjust the price of your gadget if needed and then assist one other team with their changes.
5- Oh no! You forgot to add something to your gadget. Choose a piece from another team's gadget and add it to yours. Adjust the price of your gadget if needed.
6- Congratulations! Your gadget is almost perfect. You need one more item to make it complete. Choose an additional item from the Everythingorium and add it to your gadget. Adjust the price of your gadget if needed.

Task III
Once your gadget has been modified, there is another variable that you must overcome. Roll one die again. You will have 5 minutes to make the necessary decisions for your situation.
1- Oh no! The town has decided that your item is priced too high. What will you do next?
2- Oh no! The Everythingorium has an industrial spy and they were able to recreate your gadget and sell it for $2 less. What will you do next?

3- Oh no! Your store was robbed and almost your entire inventory of gadgets was taken. What will you do next?
4- Oh no! The citizens love your gadget a little too much and you can't produce them fast enough. What will you do next?
5- Oh no! Your 3D printer suppliers have increased the price for the 3D printed item in your gadget. What will you do next?
6- Oh no! One of the pieces on your gadget is a choking hazard for children under 5. What will you do next?

Task IV
After surviving these 2 variables, you will have 2 minutes to determine:
- What is the new cost (or same cost) of your gadget?
- Do you need to modify your gadget (You can only do this if you spent less than $10 originally to make your gadget)
- Do you need to change the marketing strategy (slogan) of your gadget?

Task V
You will have 2 minutes to plan and only 30 seconds to pitch your idea to the citizens of Stubbornville. Include the name of the item, the price, and the function.

Task VI
The other teams will listen to your pitch and determine if your item is a WANT (something they would like to have) or a NEED (something they have to have).

If your gadget is a WANT then you realize that running a store is not your destiny. You put a For Sale sign on the door, head out of town, and back to your parents' house where you live comfortably for several year.
If your gadget is a NEED then you are a successful business person and you continue producing new gadgets for your store, which you have decided to name Successtopia.

They were provided with the following materials: pipe cleaners, objects created from 3-D printers, blocks/other wooden pieces, small cylindrical bowls, feathers, and other random objects. Students were permitted to use a glue gun, however, use of the glue was costly and they had to create their products within the confines of a budget. As noted above, they had to create a novel, useful item that was no more than 6 inches tall, was sturdy, etc. As students worked with their partners (in pairs or triads) they would routinely pose questions such as, Will this stay? Is this too tall?

By the close of this first exercise, students created the following products: a backscratcher, air purifier, binoculars, scarecrow (owl) for rodents, and a tire swing. They were challenged to create names for the product, craft slogans, finish within a given time frame, and creating a product that is stable/does not fall apart.

Then, each pair of students was required to either overcome one of many possible obstacles, or fruitfully use an affordance such as the ability to "pirate" a piece from another groups' project. In order to do so, they were first asked to roll a die and see what the obstacle or affordance will be (as evidenced in the description above). Sample constraints include word from the manufacturer that they cannot produce the product quickly enough, and as such, are asking those who created the item to alter the product accordingly. Other "disequilibrating" events included having other groups take one "piece" of what the dyads created away from them for use in their projects. As was intended by the Director of the ITC, students altered their goals in response to having lost a part, while others added features as a result of having gained a part. In addition, once group members realized they would have to move their product (in order to hold it up and show it to the class), they grew concerned about its stability. Again, following this, each dyad had to present what they created and sell it to their peers.

Products included the "360 Degree Swing and Shine"; Scratch on the Go!"; "The Brakester 3000: Broom, Rake, and Duster – all in one"; the "Pocket Pooch: The Pooch you can't Leave Behind!"; "The Spaghetti Spinner 500"; and, the "Swing and Sway: For Barbies."

Consistent with the lesson guidelines above, after these products were presented/sold, the ITC Director asked the preservice teachers to vote on the product they are likely to need the most. She provided several prompts such as, "Explain why having such-and-such item is a need? Do these other products contribute to your quality of life? What about the backscratcher, why is that a need versus a want? Which is more of a need?"

At the same time, the other half of the class was working in the ITC to program Mbots, which are robot kits that can be programmed using a tablet. Preservice teacher dyads were provided with a tablet, an Mbot, a maze (taped onto the floor), and a furry object at the end of the maze. They were told that their Mbot would have to "find fluffy" and do so while remaining in the boundaries of the maze. In the context of this exercise, students detected reasons for unexpected outcomes or disequilibrating events. For example, bubbles in the carpet led to irregularities in movement that caused their Mbot to veer off- course, consequently causing them to hit a "wall" in the maze. Another dyad determined that its Mbot had its wheels on backwards and, as a result, would go in reverse when programmed to move forward, and turned when programmed to travel straight.

<u>Direction for tasks one and two are listed below:</u>
You will have 10 minutes to complete the following tutorials in their entirety.

1. Sequence
2. Speed
3. Loop
4. Stop

- Be sure to take turns with the iPad so that each of you have the chance to complete parts of the tutorial.
- As you work through the tutorials you will become **programmers** and create **algorithms** that tell the robot what tasks to carry out.
- If you make a mistake, you will not be able to move on to the next tutorial. When you make a mistake in programming, you **debug** the program to figure out where you made a mistake and determine how you can fix it.
- Use your recording sheet to note if there were any situations in which you did not complete the steps correctly. Make a note of what you and your partner did to **debug** the program.
- If you finish the tutorial before the 10 minutes are up, find the ITC GA and ask if you can move on to Task II.

<u>Task II</u>
You have lost your favorite stuffed animal and it's bedtime! You are supposed to be going to bed, but how can you sleep without Fluffy?? Your mom insists that you stay in bed, and you love your mom, so reluctantly you follow her wishes and stay in bed. But as you lie there tossing and turning, you realize there must be some way to get Fluffy back so you can sleep.

Then you have a brilliant idea! The mBot robot that you got for your birthday is just a few feet away. Tiptoeing quietly so as not to alert your mom, you open your bedroom door just wide enough for the mBot to slip out, then you grab your iPad from the nightstand and hide under the blanket. OK mBot- it's up to you to find my Fluffy!

Thankfully, you have the layout of the house memorized so you open the mBlock app on your iPad and begin creating an **algorithm** to find Fluffy.

- Click the blue arrow in the upper left corner of the app to get back to the main screen
- Click the CREATE icon in the middle of the screen at the bottom
- Use the MOVE, SHOW, and CONTROL blocks to build your algorithm

Oh wait! There is just one more problem. Your sister left her dirty socks all over the floor so you will have to navigate a certain pathway to find Fluffy. That pesky sister. OK, you take a deep breath and prepare to send mBot on the mission that can end world hunger, oops that's a little too dramatic. The mission will help you fall asleep since Fluffy will be back in your arms.

You will have 15 minutes to complete this task

- Choose an obstacle course in the main room of the ITC
- With your partner, use your **schema** (what you learned in the tutorials) and the process of **assimilation** to develop the algorithm that will rescue Fluffy.
- Try your algorithm
- If it does not work the first time, then use the process of debugging to figure out what your team did wrong and how you can fix it to get to Fluffy.
- Record your changes on the recording sheet
- Continue debugging until your robot has found Fluffy.

As noted above, after completing the first task, groups were required to program their Mbot so it would move according to a sequence of different speeds. In response to this, students deleted their programming, took/recorded measurements, and isolated variables to determine sources of variance. For example, they would determine the angle at which the Mbot had to commence moving in order to reach the next part of the maze without hitting a wall.

Upon completion of these immersive experiences, the Director of the ITC asked students the following:
1. When did you build a schema?
2. When did you have disequilibrating experiences? For example, when you rolled the die, - what was an experience that was not so good? How did you adjust to that experience? Adaptation – made the product better. Notably, some disequilibrating experiences are/were positive.
3. When we started, at what level were we learning as per Blooms Taxonomy?
4. When we applied the knowledge where did that fall in the pyramid?
5. Where did our product development fall on Blooms Taxonomy?
6. How did you use math- measurement, scale, and probability in your work today? If you did this for a week, could you use this for a math class? What concepts could you bring into it?
7. What about English? What if students had to write a sentence about their products or procedures?
8. What other skills are required to perform these tasks? Students noted reading instructions and having to do the tasks in order where just some of the tasks/skills their k-12 learners would have to understand and perform.
9. How might these lessons address student learning outcomes in Science? Students responded by noting how speed, speed per distance, hypothesis generation, and making inferences were all components of these guided discovery lessons.
10. What about social studies? Students responded by noting how discerning wants, differentiating them from needs, examining economics, money, and budgeting would all be addressed in this lesson?
11. Then, the Director of the ITC asked, how did I serve as teacher as facilitator? In what ways/why were these lessons using guided discovery?

