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Engineering Outreach in Middle School: The Influence of a Long-Term, School-Based Collaboration*

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This paper investigates the long term involvement of graduate level engineering students in middle school science classrooms and reports the impact on participating graduate students and the middle school students they taught. Four years of pre and post data were collected from a total of 19 graduate students, their research advisors, and over 1200 middle school students. Key findings for the graduate students included enhanced communication, teaching, and research abilities. Key findings for students included enhanced perceptions and understandings of engineering.

Keywords: GK-12; engineering outreach; engineer/teacher collaboration

INTRODUCTION

THE NEED FOR GREATER U.S. CITIZEN INVOLVEMENT in engineering-related fields is clear and ongoing [1, 2]. Despite many efforts to increase student interest in engineering-related fields, the number of U.S. citizens choosing careers in engineering is steadily declining [2]. This leads to a series of questions associated with why U.S. citizens are not choosing engineering careers and what can be done to address the underlying issues that cause this phenomenon.

Some have suggested negative attitudes towards careers in science, technology, engineering, and mathematics (STEM) disciplines are associated with perceptions of those working in these fields [3, 4, 5]. Evidence reveals K-12 students, as well as the adults who teach them, have unfavorable perceptions of engineers and hold inaccurate perceptions of the work that engineers do [5]. These perceptions influence students' selection of academic coursework throughout schooling, directly impacting their career opportunities [6]. Current wisdom points towards these negative attitudes and perceptions as a major factor contributing to engineering workforce shortages.

The significance of student attitudes and perceptions is recognized in K-16 STEM education reform efforts [7, 8]. Stressed in these reform efforts is the need for engineers to take part in science and technological education at all levels [7–10]. Towards this end, a number of strategies have been attempted. These include the development of engineering-based curricula in primary and secondary education [11–13], engineering workshops and short courses for teachers [14], and teacher-engineering graduate student teams co-developing lesson plans [15, 16] among others. Each of these approaches has the potential to influence students' understanding of engineering. However, few engage engineers or graduate level engineering students in extended collaborations with teachers and students in the K-12 school context [7, 9, 10].

Hesitation on the part of universities to engage their graduate level engineering students in extended collaborations of this type is understandable. There is not much of a research base focused on it. However, literature evaluating the effectiveness of current graduate education methods is also relatively sparse [17]. It is likely that this condition exists because there is little agreement on what the appropriate measures of success should be [18]. Traditionally, recipients of doctoral degrees are expected to be capable of conducting independent research [19]. Thus, the majority of graduate level experiences focus on research skill development. At the same time, most engineering graduate programs do little to formally develop the graduate students' teaching skills.

ENGINEERING FELLOWS PROGRAM

The Engineering Fellows Program originated as a National Science Foundation (NSF) sponsored Graduate Teaching Fellows in K-12 Education (GK-12) program. GK-12 Fellows are STEM graduate students who serve as resources for K-12 science and mathematics teachers. Since its

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inception, the NSF has provided over 250 million dollars to sponsor approximately 200 university-based GK-12 projects across the country that have foci that vary from Marine Science in Rhode Island to community-based projects in Idaho [20].

The exact nature and scope of GK-12 projects are determined by individual principal investigators; however most follow one of two implementation models [21]. Some projects use an 'Exposition Model' in which Graduate Teaching Fellows do presentations in many schools or districts. Other projects follow a 'Classroom Immersion Model' where the Graduate Teaching Fellow works directly with one or two classroom teachers and their students over an extended period of time. This study focused on one GK-12 project that followed a Classroom Immersion model, the Engineering Fellows Program.

This paper explored the impact that participation in the Engineering Fellows Program had on two stakeholder groups, the Fellows and the middle school students they taught. Specifically, this research examined how participation impacted the Fellows' programs of study and/or research agendas, as well as their communication and teaching skills. It also probed the influence that participation had on middle school students' beliefs and understandings about engineering. The processes used to meet project objectives are supported by four major activities, which are described in the following sections.

Teacher/Fellow retreat

Prior to entering the K-12 classroom, Fellows and Teacher Partners met for a two day retreat. During the retreat, modeling of activities and group discussions were used to make the processes of inquiry and the nature of scientific discovery explicit to the Fellows and Teacher Partners. Teachers also shared their long-range instructional plans with the Fellows. Together, partners discussed how the plans related to state and national curriculum standards, as well as possible connections to the Fellow's professional background. At the end of the first day, each Teacher/Fellow partnership selected one topic from the state curriculum standards. During the evening, Fellows researched available instructional materials and developed a lesson plan concept document. These were used on the second day to facilitate discussions among Teachers and Fellows about teaching and learning in the middle school context, as well as initial roles and expectations for each partner during collaborative instruction.

GRAD 800—The graduate student as instructor

This 1-credit course concentrated on pedagogy, teaching principles, communication skills, cognitive processes, and learning styles. Course goals focused on providing an overview of current educational theory applicable in K-12 classrooms. As a result Fellows developed knowledge of teaching strategies used in middle school laboratories, classroom, and group settings, in addition to instructional strategies appropriate for different learning styles and effective lesson planning. Faculty from the Colleges of Education and Engineering co-taught the course, which Fellows took during both fall and spring semesters.

Fellow-teacher partnering

Typically, Fellows spent one or two days a week in schools and were involved in a number of school-based activities. Initially, they were immersed in the classroom before receiving any instruction through GRAD 800. During this time Fellows observed, reflected on, and wrote about, teaching and learning in middle school. These observations contributed significantly to the discussions and learning that occurred during preliminary GRAD 800 class meetings.

As the semester progresses, Fellows played an active role in the instruction that took place on the days they were in schools. In some cases the Fellows supplemented existing lessons and activities, while in others they found and/or developed lessons and activities at the request of their Teacher Partners. During GRAD 800 Fellows developed an understanding of active, inquiry-based teaching strategies, thus the majority of these lessons emphasized this type of instruction. Most instructional opportunities also followed a co-teaching model. Further, Fellows were encouraged to share their research projects/agendas with students. In some cases research agendas were presented as stand alone lessons. In others the Fellows' research agendas were incorporated into concepts-based lessons.

Institute for teachers

During the summer following their teaching immersion, Fellows taught a series of workshops for teachers. To develop the workshops, each Fellow contributed one or two of the best activities that he/she implemented during the school year. These activities formed the basis of the workshops. Teachers who attended received the written lesson plans, as well as any materials needed to repeat the activities in their own classrooms.

RESEARCH DESIGN

A mixed method research design was employed in the study [22]. This process allowed findings to be corroborated across different approaches, leading to greater confidence in the conclusions reached.

Data collection

Four years of pre and post data were collected from a total of 19 Fellows and their research advisors, as well as over 1200 of the middle school students they taught. Participant information and specific forms of data collection for each participant subgroup are described in the following sections.

Participants

A total of 10 female and 9 male Fellows took part in the Engineering Fellows project during this study. Thirteen were Caucasian, 3 Hispanic, 2 African American, and 1 Asian. All Fellows were graduate level students. Seven were studying Mechanical Engineering, while others studied Chemical Engineering (4), Civil Engineering (3), Computer Science and Engineering (3), Electrical Engineering (1), and Nuclear Engineering (1).

Slightly more than 1200 students participated in the study. Participants attended a mixture of urban and rural schools, and represented a wide range of economic and ethnic backgrounds. Detailed information regarding the demographic and socio-economic status of the student population is shown in Table 1.

Forms of data

Fellows completed pre/post-surveys and interviews that measured the effect of program participation on teaching and communication skills, programs of study, and content understanding. Fellows also completed weekly journal reflections focused on teaching experiences. Fellows' research advisors completed post-interviews focused on the Fellows' teaching and communication skills as well as how participation impacted the Fellows' programs of study.

Students completed pre/post-surveys focused on beliefs and understandings about engineering and their Fellow's specific field of study. Other forms of data collection included a pre/post-Draw an Engineer Test (DAET) [23, 24], which measured students' perceptions of engineering. The DAET required students to draw a picture of an engineer working and write a story describing the action taking place in their drawing. A subset also completed interviews designed to confirm or refute the researcher's interpretations of students' perceptions of engineering apparent in their DAET.

Data analysis

Data were analyzed separately by instrument type for each participant group. Qualitative analysis was completed on Fellows' interview, observation, and journal data following the Constant Comparative method developed by Glaser [25] and Glaser and Strauss [26]. Appropriate quantitative analysis was also conducted on all survey and student DAET data. Data were then examined collectively within groups for relevant patterns and are reported collectively by participant group.

A ten-point numerical coding system [23, 24] was used to measure the perceptions of engineering portrayed in students' DAET. Drawings and writings were collected from all students while interviews were conducted with a subset. Initial analysis of students' DAET informed the development of the interview questions and protocol. In this way the researchers were able to discuss emerging issues directly, tap into participants' perspectives, and expand understanding of the phenomenon being studied [27].

FINDINGS

Results are discussed in terms of their influence on the Fellows and the middle school students they taught.

Fellows

Data analysis revealed that participation in the Engineering Fellows Program primarily impacted the graduate students within two domains: *Program of Study/Research* and *Communication and Teaching Skills.* These domains are discussed in detail in the following sections.

Impact on program of study/research

Participation in the Engineering Fellows Program had a mixed influence on the Fellows' university research and programs of study. In a small number of cases (N = 4), Fellows self-reported that program participation slowed progress towards degree completion. The extent of this delay was estimated to be a semester as evidenced by interview statements such as, 'My research advisor knows I am not getting as much done as I normally would. If I had not done the Engineering Fellows Program, I would have graduated last December. So it is taking me an extra semester to finish school' (Fellow 15). In each of these cases, research advisors confirmed the Fellows' assessments that program participation had slowed degree progress. In all other cases though, Fellows and their research advisors reported that program participation did not slow degree progress.

Other outcomes for Fellows were found to be positive in nature. For example, every Fellow reported that 'the benefits of participating in the program outweighed any consequences' (post-survey). When asked to describe the most significant benefits, many Fellows mentioned enhancement of their research abilities. Fellows reported that

Table 1. Minority and socio-economic status of student population

	Race				Socio-economic status		
	Caucasian	African-American	Asian	Hispanic	Free lunch	Attend urban school	Attend rural school
Students	44%	52%	2%	2%	50%	41%	59%

program participation provided them with frequent and varied opportunities to discuss research. Although these were conversations with non-engineers, middle school students and teachers, Fellows reported that these interactions enhanced their thinking related to research. As a Fellow stated, 'One thing is the new perspective on my research. I have different questions and more fundamental questions. The kids always ask why, what are you doing, what is this? So, I am asking the same kinds of questions when I make decisions. I analyze things at a more fundamental level' (Fellow 6).

One subgroup of Fellows ($N = 8$) focused on the ways program participation enhanced their ability to communicate thinking about research. Not only did this include communication about research to non-engineering audiences, it also included communication about research to other professional audiences. A Fellow discussed this notion during his post-interview, 'The program has taught me to be more patient. I am able to explain my research ideas to my research advisor and others in a better way' (Fellow 4).

Another subgroup of Fellows ($N = 5$) reported that these experiences helped them generate ideas for research itself. This notion is discussed in depth by a Fellow.

> The program helped give me ideas, as far as research goes. Engineers do engineering, the biologists do biology, and the chemists do chemistry, and there is really not a mixing there. The Engineering Fellows Program provides what you would consider low level understanding, broad based understanding of science and math concepts. I think that really helps in trying to find areas of research others have not explored before. It is usually in the mixing of biology and engineering, or chemistry and engineering, or something like that where new research ideas emerge (Fellow 18).

Although focused on different aspects of research, the majority of Fellows indicated that participation in the program enhanced their research abilities in some way. Across the group, Fellows focused on how talking about research in general, as well as their specific research ideas, through Engineering Fellows Program activities acted as a catalyst for research-related thinking. This benefit, although substantive, should be contrasted with the potential delay in degree progress reported by a small percentage of Fellows.

Communication and teaching skills

As might be expected, both Fellows and their research advisors reported that program participation enhanced Fellows' communication skills. Comments such as this one were typical of those made during post-interviews,

> Participation in the Engineering Fellows Program has helped a lot in just getting ideas of how to present material and get it to where the audience can understand it better (Fellow 14).

The enhancement of communication skills learned in the classroom also positively impacted Fellows' presentation and communication to other audiences. This notion is discussed by a research advisor as he talks about his advisee's participation in the Engineering Fellows Program,

> After going through the program he was much more comfortable in front of other groups and clearer about what he intended to say than he was before he took part in the Engineering Fellows Program' (Advisor 13).

The enhanced communication skills were closely tied to self-reported gains in teaching abilities. For example, all Fellows indicated agreement or strong agreement with the post-survey statement, 'Partnering with a teacher in the classroom improved my communication and teaching skills.' Further, during post-interviews fourteen Fellows identified opportunities to learn teaching methods as one of the most beneficial aspects of program involvement.

Fellows also completed pre/post surveys focused on their self-perceived teaching abilities. Significant, positive pre to post change was found on a number of survey items, a few of which are reported in Table 2 (see Appendix A for complete survey results). The survey employed a continuum scale, from 1 = *I am not yet competent* to 5 = *I am very competent*, for each item.

Research suggests that one's beliefs about his/her capabilities to produce designated levels of performance, known as self-efficacy, is predictive of success at a given task [27, 28]. A large body of research on self-efficacy in teaching demonstrates that teaching self-efficacy has a substantial influence on teaching success [29–31]. The growth in Fellows' teaching self-efficacy is important to note. It suggests that the types of experiences described in this paper can serve to enhance graduate level

Table 2. Fellow pre/post survey comparison

Survey item	Pre mean	SD	Post mean	SD	T	Sig.
1. Appropriately engage students in problem solving activities that incorporate math and science concepts	3.14	1.35	4.57	0.54	3.33	0.016
3. Manage a class using hands-on/laboratory activities	3.14	1.46	4.00	0.58	2.12	0.048
5. Construct developmentally-appropriate plans	2.83	1.84	4.17	0.75	2.39	0.032
7. Conduct my own inquiry into authentic questions that emerge from student experiences	2.86	1.86	4.29	0.76	2.97	0.025
11. Use appropriate questioning techniques to facilitate student learning	3.00	1.73	4.57	0.79	3.27	0.013
15. Design and implement appropriate investigations	3.14	1.35	4.29	0.49	3.36	0.015

engineering students' teaching abilities. As these students move into the professorate the quality of instruction they provide will also be enhanced as a direct result of participation in the Engineering Fellows Program.

This notion of self-efficacy was not lost on the Fellows themselves. Many indicated that participation in the Engineering Fellows Program resulted in increased engineering self-efficacy. The combination of outcomes, enhanced communication and teaching abilities, in conjunction with clearer understanding of their research, impacted how they viewed themselves professionally. This idea is captured by this Fellow quote,

> It (Engineering Fellows Program) has provided the means to think critically about how I learn and present new information to others. Because of this new perspective on learning, I think I am a better engineer and technical communicator (anonymous post-survey).

Students

Data analysis revealed that participation in the Engineering Fellows Program influenced the students' perceptions and understandings of engineering across four domains. These domains are discussed in detail in the following sections.

Perceptions of engineering

Initial data analysis revealed that project students held typical perceptions of engineering.

Consistent with other research in this area [23, 24, 33], project students viewed engineering as primarily a manual labor occupation that involved building and the physical aspects of fixing. As a result of the Engineering Fellows Program, students moved towards a more accurate perception that engineering involves primarily higher level cognitive work such as designing and mental aspects of fixing. Students also better understood the diversity of fields represented by the term engineering.

Table 3 reveals that students' perceptions of engineering changed significantly across four areas of engineering, as measured by the DAET, due to involvement in the Engineering Fellows Program. In the sections that follow these areas are defined and the students' findings are discussed in detail.

Artifacts

This category awarded some credit for artifacts that an engineer might use occasionally, such as a hammer to build a physical model. However, it awarded greater credit for artifacts that an engineer would more commonly use such as artifacts associated with designing, presenting or experimenting. Examination of the artifacts in students' DAET provided insight into their perceptions of typical engineering tasks. For example, Table 4 shows that the most common pre-DAET artifacts were those associated with mechanical or repair trades, with engineers mainly working on engines and cars. A large number of artifacts associated with building or construction trades were also found. In these DAET, engineers primarily used these artifacts to build or repair structures and machines.

On the other hand, post-DAET contained greater numbers of design, experimentation, and presentation artifacts. Students were more likely to describe and/or show engineers using these artifacts to create products, present information, or share ideas. Finally, post-DAET included more

Table 3. Student perceptions of engineering

	Pre Mean	SD	Post Mean	SD	T	Sig.
Tools or Equipment	0.7539	0.904	0.9974	0.908	3.09	0.016
Diversity of Fields	0.7696	0.579	0.9503	0.371	4.14	0.038
Processes	0.66	0.501	1.07	0.685	4.25	0.000
Portrayals	1.49	0.699	1.75	0.887	2.43	0.019

Table 4. DAET artifacts

Pre		Post	
Artifact	*P*	Artifact	*P*
Tool (hammer, screw driver, etc.)	0.49	Model/blueprint/diagram	0.14
Car/bus/engine*	0.43	Test tubes/beakers/etc.	0.14
Structure/house*	0.18	Computer (as 'tool')	0.11
Train*	0.11	Tool (hammer, screw driver, etc.)	0.11
Construction equipment	0.08	Car/bus/engine*	0.11
Test tubes/beakers/etc.	0.02	Generators/wires/etc.	0.08
		Formulas	0.08
		Clipboard	0.05
		Rocket*	0.05
		House*	0.05
		Train*	0.05
		Plane*	0.05
		Computer*	0.02

Note: * Denotes object of work, *P* = percentage artifacts and references associated with 'experimentation' in engineering work.

Fields

This category awarded some credit for portrayals that captured a single engineering field while also awarding greater credit for student portrayals that captured a wider range of engineering fields. As a result of the Engineering Fellows Program, students were more likely to understand that the term engineering encompasses many fields and careers. For example, post-DAET referenced six different engineering fields (Civil, Electrical, Chemical, Genetic, Mechanical, and Nuclear). Further, over half of the students interviewed from this group referenced two or more engineering fields. While student references were sometimes lacking a proper name, they communicated understanding that engineering encompasses a wide range of fields and career possibilities. A student discussed this notion during his post-interview,

> There are different types of engineers. Some work in medical fields, like genetic engineers and there's engineers that fix streetlights. There're also engineers that design roads. That's all I know' (Student 11).

At the end of the Engineering Fellows Program students were also more likely to accurately portray the work of engineers in these fields. For example, almost half of the post-DAET contained representations of engineers engaged in tasks associated with a single engineering field. Prior to Engineering Fellows Program involvement, however, students displayed knowledge of few engineering fields. A total of two engineering fields (Mechanical and Electrical) were referenced on students' pre-DAET and only two students named more than one engineering field. During pre-interviews students described engineering fields associated with machine, construction, and repair industries. This was consistent with their DAET representations, which primarily focused on engineers in construction or automotive careers.

Processes

This category awarded some credit for portrayals that captured physical aspects of engineering work. It awarded greater credit for portrayals of mental processes associated with engineering work. Table 5 highlights that both pre and post students were most likely to use the verb 'fixing' to describe what the engineers were doing.

However, it appeared that student understanding of the type of fixing done by engineers evolved over the period of this study. For example, the majority of students who used the term during post-interviews focused on cognitive dimensions of engineering and portrayed fixing as mental work. These students were much more likely to focus on the 'how to' component of fixing as captured by this quote from Student 11,

> Well these are engineers and they are studying what went wrong with this rocket, things that need fixing on the rocket (post-interview).

On the other hand, about a third of the students also mentioned fixing during pre-interviews. However, these students tended to focus on the applied dimension, portraying the fixing that was done by engineers as physical work. These students focused on the 'doing' component of fixing. Student 43 summarized this notion in his representative quote,

> The engineer is fixing the roof. He is using a hammer to repair the holes in it (pre-interview).

A comparison of the other verbs used most frequently on students' DAET showed additional between-group differences. Students were more likely to use verbs associated with mental work such as 'testing', 'researching', or 'inventing' on their post-DAET. Conversely, students were more likely to use verbs associated with physical work such as 'building' or 'driving' on their pre-DAET.

Portrayals

The category was designed to give credit to students who made distinctions between the various types of mental work completed by engineers. For example, some engineers are technicians. However, technical work does not require the same cognitive and creative demands as the work of design engineers. Students who displayed more complete understanding of the connections

Table 5. DAET verbs used to describe engineering work

Pre		Post	
Verb	*P*	Verb	*P*
Fix	0.31	Fix	0.24
Build, Make	0.22	Test, Experiment, Research, Study	0.15
Drive, Operate	0.16	Design, Redesign	0.12
Tell	0.05	Present, Show, Tell	0.11
Hammer	0.04	Invent	0.07
Screw	0.02	Build, Make	0.07
Find Solution	0.02	'See', 'Come up with' (determine)	0.07
Mix	0.02	Paint	0.05
Install	0.02	Hammer	0.02

Note: 'Work' not counted, P = percentage between these higher cognitive demands and engineering earned higher scores in this category.

Prior to Engineering Fellows Program involvement students were more likely to portray engineers as builders, repairmen, or technicians, with the most common portrayal being that of the engineer as an auto repairman. Although these students mainly portrayed engineers as auto repairmen, there was little emphasis on problem diagnosis. Instead students were more likely to describe the tools the engineer would use or the action of the engineer. The second most common portrayal was the engineer as construction worker.

At the end of the Engineering Fellows Program students were more likely to portray engineers as inventors, designers, or problem-solvers. The most common portrayal within this group was the engineer as technician. The fields and settings varied, but in these portrayals the emphasis was on the engineer diagnosing a problem and fixing it using a 'known' solution. The next most frequent portrayal was the engineer as inventor or problem-solver. In these representations the engineers worked to create an original solution or to diagnose an unknown problem.

CONCLUSIONS

The Engineering Fellows Program had a positive influence on each of the participant subgroups. Fellows became better teachers and developed enhanced understanding of research. Students developed clearer understandings and perceptions of engineering. Some Fellows did report that program participation slowed progress towards degree completion, but this consequence should be considered negligible in light of the number of positive outcomes reported.

Students and the adults who teach them generally hold unfavorable and inaccurate perceptions of engineering [3–5]. Engineering workforce shortages have been closely tied to these negative and erroneous perceptions [6]. The cry has been loud and clear, something needs to be done to remedy this situation. The findings reported here point towards collaborations like the Engineering Fellows Program as one possible tonic for what ails workforce recruitment into engineering-related fields.

Research reported in this paper suggests there may be a positive correlation between learning to teach in an inquiry-based fashion and the development of research abilities. This notion is worthy of further study. Similar results in other studies could significantly impact the current view of graduate level education in the engineering sciences. Additional supporting data could also shape the nature of the engineering professorate, resulting in a different view of the reward and recognition structures that govern professional decision-making in engineering as well as other STEM disciplines.

These findings also provide important data related to the professional training engineering graduate students receive related to instruction. It is well known that engineering professors generally receive little training in teaching methods. The lack of teaching pedagogy in engineering education creates an additional stress on an aspect of engineering preparation that can not be ignored if workforce shortages in the engineering sciences are to be resolved. Fellows involved in this work expressed increased confidence and abilities in terms of teaching pedagogy. The potential of this type of collaboration as a positive factor in this arena should not be ignored. Further, the gains reported by Fellows are in addition to positive outcomes related to their communication and research abilities.

The findings reported here are derived largely from self-reported data, which reveals a weakness in this research. At the same time, these findings were reported across several years by several different cohorts of Fellows, research advisors, and students. Accumulation of this amount of evidence becomes impossible to ignore and highlights the need to conduct additional studies on these types of collaborations.

Many will argue that this type of engagement is not the work that colleges of engineering should be doing. It certainly is not what is currently valued in university settings. At the same time, the positive outcomes reported here are difficult to ignore. They seem to reveal that what may not be valued in colleges of engineering is the very thing that is most beneficial to them, while also most needed in K-12 education.

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APPENDIX A

Table A1. Fellow pre/post survey comparison

Survey item	Pre mean	SD	Post mean	SD	T	Sig.
1. Appropriately engage children in problem solving activities that incorporate math and science concepts	3.14	1.35	4.57	0.54	3.33	0.016
2. Conceptualize activities that use math and science concepts to solve problems	3.57	1.27	4.43	0.79	1.87	0.111
3. Manage a class using hands-on/laboratory activities	3.14	1.46	4.00	0.58	2.12	0.048
4. Can develop appropriate forms of assessment construct developmentally-appropriate plans	2.83	1.84	3.67	0.82	1.75	0.141
5. Construct developmentally-appropriate plans	2.83	1.84	4.17	0.75	2.39	0.032
6. Aware of individual differences and needs among students	3.00	1.63	3.71	0.76	1.70	0.140
7. Conduct my own inquiry into authentic questions that emerge from student experiences	2.86	1.86	4.29	0.76	2.97	0.025
8. Conduct interviews with students to investigate naïve conceptions	3.14	1.68	3.71	1.11	1.55	0.172
9. Reflect on my own teaching	3.14	1.35	3.71	0.95	1.55	0.172
10. Adjust instructional plans to meet students needs	2.86	1.68	3.57	0.79	1.70	0.140
11. Use appropriate questioning techniques to facilitate student learning	3.00	1.73	4.57	0.79	3.27	0.013
12. Use computer technology and other instructional media as teaching tools	3.57	1.27	3.86	0.90	0.68	0.522
13. Challenge students to accept and share responsibility for their own learning	3.43	1.27	3.57	1.13	0.55	0.604
14. Identify various investigate forms appropriate for children	3.17	1.72	3.83	0.75	1.00	0.363
15. Design and implement appropriate investigations for children	3.14	1.35	4.29	0.49	3.36	0.015

SD = Standard Deviation, T = The calculated t statistic, Sig. = Significance level.

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