An interactive practicum course: How it affects instructional practices of pre-service science teachers

**Abstract (max. 250 words)**

Teachers often implement dated instructional practices when teaching. There has been much research into the effects of teacher preparation programs on pre-service science teachers’ instructional practices. Specifically, how do the various programs influence the strategies that pre-service science teachers use when teaching science, and how do these strategies develop and change?

Here, we examined the efficacy of an interactive practicum course that is an important component of a science teacher preparation program for elementary-school science teachers. This program lasted one academic year and involved interactions among three parties: a pre-service science teacher, an in-service science teacher, and an academic supervisor.

We used a mixed-methods approach involving self-administered questionnaires, real-time classroom observations, and semi-structured interviews to address 1) How pre-service science teachers’ instructional practices were influenced following participation in the interactive practicum course; 2) To what extent are pre-service science teachers’ instructional practices aligned with the Portfolio of Lesson Plans (2018) and the spirit of the Next Generation Science Standards (NGSS); and 3) Which components of the practicum course were responsible for any change(s) in these teachers’ teaching practices.

Our results indicated that the interactive practicum course helped the pre-service elementary science teachers shift from traditional teacher-centered science instructional practices to more modern student-centered practices. The third stage, that included triangulation between the pre-service teacher, the tutor, and the academic supervisor and had the greatest effect on the pre-service science teachers’ science instructional practices.

**Keywords**: elementary science education; next generation science standards; pre-service science teacher; science instructional practices; teacher preparation program

# **Introduction and rationale**

Science teacher preparation programs in general, and practicum courses in particular, play an important role in improving the quality of education and science education systems (Carrier et al., 2017; Dabney et al., 2020; Lippard et al., 2018; NSTA, 2012; 2017). Sahlberg (2012, p. 1) emphasized that “research and experience both suggest one factor that trumps all others: excellent teachers.” Clearly, then, preparing excellent teachers who are familiar with and use the most up-to-date instructional practices must be the goal for any teacher preparation program. Mamlok-Naaman et al. (2007) indicated that science teachers play an essential role in structuring and guiding their students’ understanding of the changing world in which they live. One essential way to ensure that science teachers are equipped to undertake this important role is to involve pre-service science teachers in training and preparation tracks that improve personal, pedagogical, and professional and other aspects of their educational knowledge and expertise, and as well prepare them to use up-to-date science instructional practices before they commence their science teaching careers.

Clinical experiences and practicum courses are considered to be key components—even “the most important” components—of pre-service teacher preparation (Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2006; Darling-Hammond & Bransford, 2005; Levine, 2006; National Council for Accreditation of Teacher Education [NCATE], 2010; National Council for Teacher Quality [NCTQ], 2011, p. 3). Musset (2010) draws an important correlation between teacher preparation and student outcomes that aligns with the findings of an OECD (Organization for Economic Co-operation and Development) report (2005, p. 26), suggesting that “quality of teaching” is “the single most important school variable influencing student achievement.” A well-designed practicum course that helps pre-service science teachers change their teaching practices and use up-to-date science instructional practices will help achieve this aim (Iordanou & Constantinou, 2014).

Many countries experience difficulties in hiring and retaining effective teachers (McKenzie et al., 2005). Windschitl and Stroupe (2017, p. 251) argue that “educators should use powerful principles for instruction, derived from the research referenced in the Framework, to inform the design of courses and other preparatory experiences for novice teachers.” The preparation of teachers and the implementation of appropriate teaching strategies are critical factors for improving the quality of education systems, thereby better preparing students (Musset, 2010; Wayne & Youngs, 2003).

There has been an ongoing research in the field of teacher preparation for optimal ways to train teachers for the future. It is increasingly recommended to focus on ways of enhancing the quality of education through teacher preparation programs. Importantly, such programs prepare teachers to support children in the most difficult circumstances and when they require the most assistance (Darling-Hammond & Baratz-Snowden, 2007).

Instructional practice programs for teachers offer pre-service teachers the opportunity to improve their teaching skills by providing them with an environment encouraging mutual reflection and discussion (Healy et al., 2001). During their internship process, pre-service teachers learn to implement what they have learned during their preparation program while supervised by mentors (Evagorou et al., 2015). Levine (2006) claims that pre-service teacher education is a crucial link in producing quality science teachers, stating that “the quality of tomorrow will be no better than the quality of our teacher force” (p. 11).

Throughout the world, science education has undergone many reforms and improvements including how the sciences are taught. For instance, in 2013, many states in the United States established new standards for science education, the Next Generation Science Standards (NGSS Lead States, 2013). Similarly, in 2018, Israel’s Ministry of Education published the “Portfolio of Lesson Plans” emphasizing the development of students’ scientific skills and the establishment of a new era of instructional strategies for the sciences. The main factor shared by all these reforms is the call for significant shifts in science teaching, from traditional teacher-centered approaches (using direct science instruction, science demonstrations, and worksheet or textbook work) to approaches that enable all students to actively engage in scientific practices and apply crosscutting concepts to core disciplinary ideas.

Thus, in the spirit of the new standards of science education, it is vital to build a well-structured practicum course for pre-service science teachers. This should include collaboration among the various partners responsible for pre-service science teachers’ preparation along with their implementation of what they have learned during their academic training. Furthermore, it should involve new and up-to-date science instructional practices, which reflect the latest science education standards and enable students to acquire the updated and required scientific skills that will enable them to become effective and creative citizens in their community (NGSS Lead States, 2013; Portfolio of Lesson Plans, 2018). Therefore, measuring the effect of a practicum course that pre-service science teachers take during their teacher preparation program for their science instructional practices can demonstrate the effectiveness of the practicum course. It can also identify what, if any, modifications the course requires to elicit the required change and bring the instructional practices of the pre-service teachers to the required level.

This study draws on social constructivist theories of teaching and builds on existing and emerging research in discipline-general and discipline-specific science teaching practices. It highlights the importance of a well-structured, collaborative practicum course within teacher preparation programs to provide pre-service science teachers with the most current student-centered instructional practices needed to impart to their students new and up-to-date knowledge of the processes of science and scientific thinking, including problem-solving, communication, collaboration, and critical and creative thinking (National Research Council, 2012; NGSS Lead States, 2013). We examined the effects of an interactive practicum course that formed part of a pre-service science teachers preparation program, including whether it induced changes in pre-service science teachers’ instructional practices, from teacher-centered to student-centered, in line with the latest science education standards both internationally (NGSS Lead States, 2013) and in Israel (Portfolio of Lesson Plans, 2018).

## ***Conceptual framework and background literature***

### *A new era of elementary science education*

In the United States, the Framework for K-12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013) emphasize the science instructional practices (SIP) necessary at the elementary level, recommending that they be rooted in scientific abilities and skills, including scientific thinking, inquiry, and the performance of scientific investigation. They also highlight that each student who learns science at the elementary level must advance as a result of learning science. Furthermore, student interactions with both the content and processes of science should be facilitated, enabling students to behave as active learners. While these standards and the framework describe what is expected from students in the science classroom, there is little guidance provided for science teachers about which SIP to use and how to use it while teaching science, as well as how to help science learners achieve the expected goals (Martinez et al., 2012; Windschitl et al., 2012).

NGSS Lead States (2013) emphasized that engaging students who learn science through a genuine process of science and scientific thinking that includes problem-solving, communication, collaboration, and critical and creative thinking helps them develop an in-depth understanding of scientific content while also preparing them to be scientifically minded and oriented citizens. However, initiating this level of engagement is often difficult for many teachers, especially at the elementary level, because they lack the specific preparation and training required as well as a first-hand understanding of scientific processes and of what scientists do (Duschl et al., 2007). This more engaged style of teaching is often contrary to the more traditional teaching approaches many teachers experienced during their own learning as students (Schwartz et al., 2000). As a result, elementary teachers rarely implement this type of instructional practice, and those who do are often considered to be “going against the grain” (Capps & Crawford, 2013; Carlone et al., 2010).

In 2018, the Israeli Ministry of Education announced the Curriculum Portfolio for Teaching Staff (Portfolio of Lesson Plans, 2018), that emphasized the use of new, student-centered instructional practices in general, and science instructional practices specifically, to ensure that students acquire up-to-date scientific skills, such as making observations, asking scientific questions, writing scientific arguments, and planning and performing scientific research (Portfolio of Lesson Plans, 2018; Kisa, & Stein, 2015).

Efforts to improve teachers’ delivery of reform-based SIP, however, must recognize that limitations exist and these can make implementing reforms more complex. Efforts toward change should be implemented gradually and should include incremental goals and gains that are meaningful to the teacher (Jones, & Eick, 2007; Loucks-Horsley, 1998), thereby providing more opportunities for the teacher to succeed during the implementation process. These efforts should also be informed by context, as it is within their teaching environments that teachers are able to create practical instructional knowledge (Darling-Hammond, 1994; Van Driel et al., 2001). Approaches to this can include peer coaching and collaborative action research (Van Driel et al., 2001). Moreover, a well-structured science practicum course that includes collaborative work among the various partners responsible for preparing pre-service science teachers, namely, in-service teachers (tutors) and academic supervisors, could provide a supportive environment for implementing new, student-centered science instructional reform efforts.

### *Science instructional practices (SIP)*

Measuring science teachers’ instructional practices (SIP) is considered one of the most pressing issues of concern to science education researchers recently because of the importance of these practices and their effect on students’ engagement with and learning of science (Kloser, 2014), with a particular emphasis on SIP’s effectiveness in improving student engagement in science learning pathways and their achievement because it focuses on the “work of science teaching” (Ball & Forzani, 2009, p. 497; Gallimore et al., 2009; Grossman & McDonald, 2008; Kazemi et al., 2009; Windschitl et al., 2008). For example, Pianta et al. (2008) used instruments such as the Classroom Assessment Scoring System (CLASS) to assess classroom quality from pre-kindergarten to grade three classes based on teacher–student interactions rather than on the physical environment or a specific curriculum as a Measure of Effective Teaching (MET). Kane and Staiger (2012) suggested that SIP is a better predictor of student achievement than a science teacher’s number of years of teaching experience or attainment of a master’s degree. Science teachers’ use of SIP has an important influence on students’ scores and outcomes in learning science. Recognizing a core set of pre-service science teachers’ SIP will be particularly helpful for the effective preparation of science teachers in general and in Israel in particular. Generally, foundational SIP may affect the coherence of science teachers’ classroom practice and limit the ability of science teachers and science teacher educators to share a common language and understanding of classroom instruction (Roth & Garnier, 2006).

A wide variety of science instructional methods may be used by science teachers, ranging from teacher-centered to more student-centered ones (Hayes et al., 2016; Treagust & Tsui, 2014). Hayes et al. (2016) conducted a comprehensive literature review of science instructional methods and categorized them into five major areas, on a continuum from teacher-centered to student-centered: (a) Traditional Instruction, (b) Engaging Prior Knowledge, (c) Science Discourse and Communication, (d) Evaluation and Explanation, and (e) Empirical Investigation.

## ***The interactive science practicum course***

The interactive practicum course was designed with the goal of strengthening the relationship between the tertiary academic system and the grade school system (Neapolitan & Levine, 2011; Shroyer et al., 2007). It was structured to meet three objectives: (a) advancing science teaching according to up-to-date science teaching strategies; (b) concurrently advancing the professional development of student teachers and their academic supervisors; and (c) shaping the teaching career from the pre-service stages.

Darling-Hammond (1994) and Van Driel et al. (2001) indicated that a teacher preparation program must provide opportunities for collaboration among teachers and university faculty members that can lead to genuine professional development in situ, including collaborative action research and curriculum development. In light of this theoretical background, the current study examined an interactive science practicum course that was created and based on interactions among pre-service science teachers (apprentices), experienced in-service science teachers (tutors), and academic college faculty supervisors (academic supervisors), with a view to implementing change pre-service teachers’ SIP.

The experienced in-service science teachers (tutors) were science teachers with more than 10 years’ experience of teaching the sciences at the elementary school level and who had participated in professional development courses during the past five years in student-centered, up-to-date science teaching strategies for elementary level students according to the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013). Each tutor had undergone 150 hours of professional development in these science teaching strategies during the previous five years (30 hours of professional development per year).

According to this program, the pre-service science teachers practice for two days per week in schools under the supervision of an experienced in-service science teacher (tutor), to bring together any overlap between the academic level and the schooling level. In this way, an affinity can be developed that will facilitate improved professional development for both pre-service and experienced science teachers. The pre-service practicum course is divided into three stages that take place over the course of one year. Table 1 summarizes the details of these stages.

Each day comprises five practical hours and one workshop hour (six hours in total); during the practical sessions the pre-service science teacher observes the tutors, co-teaches science lessons, and teaches science on their own in accordance with the pre-service teacher’s level (see Table 1). In the workshop hour, led by the academic supervisor, the pre-service science teacher, tutor, and academic supervisor conduct a workshop focusing on various topics. The topics are centered on science teaching strategies for elementary level according to the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013). A variety of teacher preparation scenarios are presented during the workshops to help pre-service science teachers implement instructional practices during the practical part of the practicum course. These could include: (a) an inverted classroom in which the pre-service teacher presents a new science teaching strategy in front of the other workshop participants and leads a discussion around it; (b) an inquiry-class, in which a video-taped science lesson by a different pre-service science teacher is watched and analyzed by the workshop participants according to specific pre-defined criteria; (c) a round-table discussion of new science teaching strategies, which could be led by the academic supervisor or a tutor; and (d) a talk by an external science education expert invited from the academy or the science inspection department of the Ministry of Education.

(Table 1 near here)

# **Materials and methods**

## ***Research population***

The research population consisted of pre-service elementary science teachers studying for a Bachelor of Science Education (B.Ed.) in elementary science teaching (students from grades one to six) in an academic college for teacher education in the Arab sector of Israel.

## ***Research sample***

The research sample consisted of 57 second-year pre-service science teachers. The characteristics of these teachers are shown in Table 2.

(Table 2 near here)

This research was approved by the Research and Assessment Authority of the academic college where the pre-service teachers studied (study number 190219). Participation in the study was voluntary, with each pre-service teacher deciding whether or not to participate in the study, and all the participants gave written consent to participate. Parents of the students who studied with these teachers also provided written consent for their child to participate in this research; any who declined to participate were not included in the research.

## ***Research questions***

* How are pre-service science teachers’ instructional practices affected after participation in the interactive practicum course?
* To what extent are pre-service science teachers’ instructional practices aligned with the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013)?
* Which components of the practicum course were responsible for the change(s) in pre-service science teachers’ teaching practices?

## ***Research tools***

To answer these research questions, this study employed a mixed-methods approach, based on the assumption that this could provide a more complete picture (Glaser, & Strauss, 1967; Tobin, 1995). The quantitative component consisted of a Science Instructional Practices Survey (SIPS) questionnaire, previously developed by Hayes et al. (2016). The qualitative component consisted of semi-structured interviews followed by thematic analysis (Nowell et al., 2017) and an analysis protocol based on the constructs in Hayes et al.’s survey (2016) and real-time observations, followed by analysis protocol based on the constructs in Hayes et al.’s survey (2016).

### *Science instructional practices survey questionnaire*

The SIPS questionnaire developed by Hayes et al. (2016) was intended for elementary- and middle-school science teachers. The survey questions ask teachers to rate the science instructional practices that they employ with their students during science classes. This questionnaire has been used by numerous researchers (e.g., Bancroft et al., 2019; Hayes et al., 2019) to evaluate to what extent science teachers implement NGSS-oriented instructional practices in their science classrooms.

The SIPS questionnaire was translated into Arabic to eliminate language difficulties as a source of error in our research results (Cassels & Johnstone, 1984). The internal validity of the questionnaire was assessed by sending the translated version to four science education experts to obtain their feedback, and the final version of the SIPS questionnaire was prepared according to that feedback prior to disseminating the final version.

The original and the translated SIPS questionnaire consisted of 24 items. Each item offered response options using a 5-point Likert scale, with 1 representing *strongly disagree* and 5 representing *strongly agree*.

Internal consistency checks were conducted for the Arabic version of the SIPS questionnaire by calculating Cronbach’s alpha. The reliability test score for the entire questionnaire was 0.82, indicating that it was reliable.

The SIPS questionnaire covered six scales of instructional practice, four of them linked to science teaching strategies for elementary level according to the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013), while the remaining two related to traditional instructional practices and science teaching using the student’s prior knowledge, rather than according to the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013 More details about the SIPS questionnaire can be found in Table 3.

(Table 3 near here)

### *Administration of the SIPS questionnaire*

The pre-service science teachers were asked to complete the questionnaire twice, once at the beginning of stage three of the practicum course (pre-SIP; Table 1) and once at the end of the second academic year (post-SIP), after completing the practicum course. The respondents were given about 20 minutes to complete the questionnaire.

*Semi-structured interviews*

A semi-structured interview technique (Merriam, 2009) was used to guide each interview, with a sample of ten pre-service science teachers who had already completed the questionnaire at the end of the academic year and after completion of the practicum course. This allowed for the interview to focus on topics of importance and provided flexibility in the interview topics, enabling participants to explore avenues in the conversation that were salient to them. Pre-service teachers were interviewed to determine (a) how they viewed their role in facilitating science classes in accordance or not in accordance with the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013), (b) which aspects of the practicum course were responsible for any changes in their teaching practices, and (c) why they employed a specific SIP while teaching science.

### *Real-time observations*

The same pre-service science teachers (*n* = 10) who were interviewed while teaching science at the practicum schools were observed in real time. The duration of each science class was 45 minutes. Each pre-service science teacher was observed twice: once at the beginning of stage three (see Table 1) of the practicum course (pre-SIP), and once at the end of stage three (post-SIP). The observations were video recorded and then transcribed.

## ***Data analysis***

### *Quantitative data analysis*

 The results of the quantitative questionnaires were analyzed statistically. The data from the questionnaires were recorded on a Microsoft Excel® spreadsheet and analyzed using the SPSS® program for statistical analysis.

Cronbach’s alpha was estimated to determine the reliability of the findings. The averages and standard deviations of the scores for each of the six factors were calculated. Following this, a comparison was conducted between the means of each factor for the pre- and post-data.

### *Qualitative data analysis*

Analysis of pre-service teacher-student interactions from the videotapes

 Real-time observations were transcribed, digested, and coded. This methodology was applied to the pre- and post-real-time classroom observations and is similar to work conducted by Krystyniak and Heikkinen (2007), who analyzed the verbal interactions between students and their instructors during an undergraduate science laboratory course. To conduct this analysis, we first transcribed all the videotapes, and the transcription accuracy was confirmed by the researcher. All pre-service science teacher–student interactions were identified and noted in the transcripts by the researcher, as well as any intervals, including short pauses (<15 seconds), long pauses (15–45 seconds), and long silences (>45 seconds).

All verbal discourse between pre-service science teachers and their students was considered to be a pre-service science teacher–student interaction. Encounters were considered to have ended when the topic of conversation shifted and no further pre-service teacher’s comments were noted.

Development of categories for pre- and post-real-time observations analysis

We developed categories to analyze the videotapes of the verbal discourse between pre-service science teachers and their students while they taught in their science classrooms. We developed the analysis protocol based on the constructs in Hayes et al.’s (2016) survey. Each interaction between pre-service science teachers and their students was assigned to an appropriate scale (code). Pre-service science teacher–student discourses were separately coded by the researcher, twice.

To estimate inter-rater reliability, selected portions of transcribed discourses were given to an independent coder, together with the preliminary set of codes and directions for coding the transcripts. The coder, a science education researcher who had experience with qualitative research and data coding, was instructed to classify the transcribed discourses and also to identify discourses for which no appropriate scales (codes) had been defined. After completing the task, the external coder and the researcher met to discuss their experiences with the preliminary coding scheme. The coders and researcher agreed on the coding assignments for eight out of nine discourses. Cohen’s kappa, an expression of inter-rater reliability, was 0.89 for all coded discourses (Lunn, 1998). The full set of codes and illustrative verbal interactions are summarized in Table 4. The codes for all discourses within each encounter were tabulated and the percentage (frequency) of each coded category was calculated for all pre-service teacher–student discourses.

(Table 4 near here)

Analysis of semi-structured interviews

The aim of the semi-structured interviews was to secure a deeper understanding of (a) the reasons that pre-service teachers use SIP during their science teaching; (b) which aspects of the practicum course were responsible for any changes in pre-service science teachers’ SIP; and (c) why they employed a specific SIP while they were teaching science.

The responses obtained from the semi-structured interviews were recorded and then transcribed in Microsoft Word. Transcription was conducted by the researchers with the aid of an online transcription application (https://transcribe.wreally.com/). All identifying information was eliminated from the transcripts.

A narrative content analysis approach was employed to analyze the interview data (Goodson, 2013; Riessman, 2008;). We applied the approach of “bathing in the data” (Goodson 2013, p. 40), reading through the transcripts slowly, recording the main emergent and common ideas, and gauging when the common ideas and conclusions became saturated.

An inductive approach was used. It helped the researchers to achieve descriptions and explanations in accordance with the previously mentioned aims of the semi-structured interviews.

# **Results**

***Results of the quantitative part of the study***

The means and standard deviations of the scores for science teaching practices were calculated for all participants. We divided the teaching practices into two groups. The first consisted of traditional instruction and the use of prior knowledge, which we called “traditional, non-Portfolio of Lesson Plans (2018) and not in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP.” The second consisted of investigation instigation, data collection and analysis, critique, explanation, argumentation, and modeling, which we called “Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP.” This distinction was made according to the scientific skills that each approach tends to develop within the learner.

The data that we obtained from the SIPS questionnaire were statistically analyzed; pre-SIP data were compared with the post-SIP data using a quantitative *t*-test. The results are shown in Table 5 and demonstrate that pre-service science teachers significantly changed their science instructional practices after they had experienced the interactive practicum course. More specifically, the use of the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP had significantly increased from the outset of the teacher preparation process for all scales; namely, investigation, data collection and analysis, critique, explanation, argumentation, and modeling. Concurrently, the use of non-Portfolio of Lesson Plans (2018) and in spirit of NGSS (NGSS Lead States, 2013)-oriented SIP significantly decreased from the outset of the teacher preparation process for two scales, traditional instruction and using prior knowledge. These results indicate that the interactive practicum course succeeded in influencing pre-service science teachers’ SIP to make them more oriented to the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013).

(Table 5 near here)

Figure 1 shows the SIP for the pre-service science teachers at the end of the practicum course. It is clear from Figure 1 that SIP for pre-service science teachers after completion of the practicum course were more Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013)-oriented. Additionally, the pre-service teachers were likely to use SIP, such as investigation, data collection and analysis, critique, explanation, argumentation, and modeling as new science teaching standards (Reiser, 2013).

(Figure 1 near here)

*Results for the qualitative part of the study*

Results of the real-time observation

We performed real-time observations of ten science lessons by the ten pre-service science teachers who were interviewed at the beginning of stage three of the practicum course (“pre-observations”), as well as at the end of that stage i.e., at the end of the academic year (“post-observations”).

The main aim of the observations was to validate and triangulate the results that we obtained from the quantitative part of the study and to determine whether the situation in reality was similar to the students’ answers to the questionnaires.

The average number (mean) of pre-service science teacher–student discourses during all ten of the observed pre-service science teachers’ classes was calculated together with the percentages for the pre- and post-observations. The results of the observations are presented in Table 6.

We conducted a statistical comparison between the pre- and post-observations. Table 7 shows this statistical comparison of pre- and post-discourses between pre-service science teachers and their students of Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP and non-Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP. The results indicate that pre-service science teachers had significantly changed their SIP from teacher-centered, old-fashioned, non-Portfolio of Lesson Plans (2018) oriented and not in the spirit of NGSS (NGSS Lead States, 2013) SIP to student-centered, up-to-date, Portfolio of Lesson Plans (2018) oriented and in the spirit of NGSS (NGSS Lead States, 2013) SIP by virtue of participating in the interactive practicum course.

Results of the semi-structured interviews

Semi-structured interviews with a sample of the pre-service science teachers who had filled out the SIP questionnaire and who had been observed were conducted at the end of the practicum course. The main aim of the interviews was to obtain explanations for the results that we obtained either from the quantitative or the qualitative tools. We hoped to gain a better understanding of (a) why they chose the specific SIP that they used when we conducted the real-time observation in her/his classroom and (b) which component(s) of the practicum course were responsible for the change(s) in pre-service science teachers’ SIP.

During the interviews, the pre-service science teachers were asked a number of questions. These questions and some representative responses are outlined below.

1) Give an example of a topic that you teach and briefly describe how you teach that topic within the practicum in the school. The following are some sample responses:

When I taught the topic “types of rocks,” I divided my class into five working groups, provided each group with two types of rocks, and ask them students to compare between two types of rocks by themselves.

When I teach my students “plants and their components,” I distribute them into working groups and let each group to gather three to four observations about the plant that they get and write down them on a worksheet.

For example, when I taught the topic “water solubility,” I demonstrate in front of my students dissolving salt inside water, then I ask them to write up to three questions that interest them that are correlated to that demonstration.

2) Regarding the question what are the main component(s) that influence your SIP and let you adapt and implement your gained SIP, the following are some sample responses:

The guidelines that I got them during our discussion meetings was very helpful for me. During the discussion meetings, I switched my teaching methods many times as a result of the guidance that I received after that discussion meetings.

I am very thankful to my academic supervisor and my mentor for their continuing advice and structure they gave me and that helped me change my teaching strategies to stay up-to-date.

The triangulation between me, the tutor, and the academic supervisor was very helpful and made me change my ideas and make modifications according to the advice and comments that they constantly provided me.

During the period that I got comments and tips either from the tutor or the academic supervisor, I really changed my teaching methods and strategies dramatically. It can be said that the comments that I got dramatically affected my thoughts and perceptions regarding science teaching.

3) Regarding the question what do they think is the purpose of teaching science to their students, the following are some sample responses:

I think that the main purpose of science teachers nowadays is to enable their pupils to think scientifically and practice scientific skills like the science researchers in any discipline do, such as chemistry, biology, physics…

No doubt that today, gaining scientific skills is an important issue that every student who learns science must achieve. Students nowadays are very pleased to

I think that it is very important to allow the pupils who learn science to practice scientific practices such as investigations, analyses, etc.

4) Regarding the question what do they think the main role of their students during science lessons, the following are some sample responses:

I changed my perception of my role as a future science teacher. Now, I plan my science lessons taking into my account how I will provide my pupils with scientific skills, which I **did not** use at the beginning of this practicum course.

I think that my students are an important component during my teaching process, I mean that they must participate actively during the science lessons, they must make observations, collect data, ask questions, and so on.

No doubt that the student who learns science must act such as scientist. In order to achieve that we must they them practice those skills which enable them to act like a scientist, such as planning investigations, performing them, gathering data, presenting results and so on.

5) Regarding the question what do they think their main role as a science teacher is during science lessons, the following are some sample responses:

At the beginning of this year, I used to do that comparison by myself because I thought that my role was to transfer the digested and ready data to my students, but later I found that this was incorrect as I learned from the workshop meetings.

I think that my role is a facilitator during the science lessons. That means I must help my students, support and advise them to achieve their activities that they perform during the science lessons.

My role is supporter, structure-provider, advisor to my students.

It can be inferred from this sample of quotes that the interactive practicum course provides pre-service science teachers with a unique opportunity to change their SIP from teacher-centered, old-fashioned SIP, to up-to-date, student-centered SIP in accordance with the Portfolio of Lesson Plans (2018) and in the spirit of NGSS, which is suitable for the new era of science teaching worldwide (National Research Council, 2012; NGSS Lead States, 2013). More specifically:

* Pre-service science teachers used up-to-date student-centered SIP in accordance with the Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) while teaching science.
* The third stage of the practicum course, which included triangulation between the pre-service teacher, the tutor, and the academic supervisor, was the most influential step in the course, affecting the pre-service science teachers’ SIP and causing them to change their SIP.
* Pre-service science teachers perceived that the main goal of learning science was to gain scientific skills and to act as a scientist.
* Pre-service science teachers changed their perception of a science teacher, from a teacher providing raw scientific data to their students to a teacher who paves the way for their students to achieve their objectives and to acquire the required scientific skills.
* Pre-service science teachers put their students at the center of the learning process, recognizing them as being the persons responsible for performing the required scientific activities during science lessons.

## **Discussion and conclusions**

A new era of science education has begun since the publication and adaptation of the Framework for K-12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) in the United States, and in Israel since the publication of the Portfolio of Lesson Plans (2018). In 2018, the Israeli Ministry of Education published the Portfolio of Lesson Plans as a new standard for teaching of all disciplines for the new generation of students in general and science education in particular. In April 2013, the United States released a document detailing the Next Generation Science Standards (NGSS) that set the stage for educational reforms at the national, state, and local levels (NGSS Lead States, 2013). The NGSS provide a new and up-to-date science standard that formulates the pathway for teaching and learning science for science students. Both the Portfolio of Lesson Plans (2018) and the NGSS (NGSS Lead States, 2013) focus not only on student-centered SIP but also on imparting to students skills and abilities that are scientifically oriented and typically performed by scientists, such as data collection, critical thinking, scientific explanation, scientific argumentation, and scientific investigation.

Pre-service science teachers play an important role in the science education system, as they are destined to become in-service science teachers once they complete their science teacher preparation programs (Boyd et al., 2007; Brownell et al., 2005). Boyd et al. (2007) emphasized the importance of teacher preparation programs and identified a correlation between the quality of teachers and the quality of teaching outcomes. Pre-service teacher education programs aim to prepare graduates to become quality teachers equipped with pedagogical practices that will help them meet the increasing demands associated with the teaching profession (Bransford et al., 2005). Over the past decade, the focus on developing quality teachers has received increasing attention in the field of education (Barber & Mourshed, 2009; Bransford et al., 2005; Hattie, 2004). There has been a greater interest in using pedagogical teaching practices that enhance intellectual thinking and problem-solving while fostering a sense of belonging and connectedness among students.

The current study examined an interactive science teacher practicum course that was designed as a part of a science teacher preparation program for pre-service science teachers at the elementary level. This course lasted around one academic year and involved triangulation among three partners: a pre-service science teacher, a tutor, and an academic supervisor. This interactive practicum course was based on dialogue and multi-pronged advice given to pre-service teachers by both their in-service tutor and their academic supervisor during the preparation process.

The current study used a mixed-methods research methodology that included an SIP questionnaire developed and validated by Hayes et al. (2016), semi-structured interviews, and real-time observation of the pre-service science teachers’ science lessons. The aim was to triangulate the effect of this interactive practicum course on the SIP of pre-service science teachers who were in science preparation programs for teaching in primary schools and nearing the completion of their Bachelor of Science Education degrees.

The results of the current study indicate that the interactive practicum course helps pre-service elementary science teachers shift from traditional, teacher-centered SIP to a student-centered, Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP.

Teachers tend to implement traditional old-fashioned instructional practices when teaching science (Crawford, 2007; Davis et. al., 2006; Jones & Leagon, 2014; Luft, & Roehrig, 2007; Marshall et. al., 2010; Van Driel et. al., 2014). This argument calls for and requires us to build a continuous and interactive practicum course that helps science teachers change their beliefs and implement new and up-to-date science instructional practices. The current study investigated an interactive practicum course that led pre-service science teachers during their clinical stage to change their old-fashioned SIP to a more up-to-date SIP in accordance with the new science education standards (Portfolio of Lesson Plans, 2018; National Research Council, 2012). The pre-service science teachers perceptions changed about their role and the role of their students during science classes. They also developed a new understanding of the main role played by science education for the new generation of science students.

The emergence of a consensus that demands and emphasizes a shift from viewing science teacher education as a training problem (i.e., training pre-service science teachers to carry out specific tasks) to a learning problem (i.e., teaching pre-service science teachers to think like a teacher) (Loughran, 2007; 2014) led us to consider how the thinking of pre-service science teachers might change during their teacher education course. The current study found that the triangulation among the three partners involved in the practicum course, namely, the pre-service teacher, the tutor, and the academic supervisor on the one hand and the different and multiple mentoring tactics on the other had led pre-service science teachers to change their SIP and implement to what they exposed.

Hutner et. al. (2021) investigated the alignment of the goals of pre-service science teachers with the instructional practice emphasized in teacher education and found that pre-service science teachers adopt goals reflective of many, but not all, of the pedagogical strategies emphasized in teacher education. In the current study, we found that pre-service science teachers who took the interactive practicum course had significantly changed their science instructional practice.

It is worth noting that initiating work with science teachers at the teacher preparation stage (Levine, 2006; Musset, 2010; Windschitl & Stroupe, 2017) and during their practicum course, when they are the most open to guidance and influence, is a very useful means of affecting change and ensuring the implementation of the desired SIP in teachers’ science lessons, given that this stage is the most pivotal in characterizing the future instructional practices adopted by teachers.

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## **Declaration of interest**

The authors have no conflicting interests, either directly or indirectly.

# **References**

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education, 60*(5), 497–511.

Barber, M., & Mourshed, D. (2009). *Shaping the Future: How Good Education Systems can become Great in the Decade Ahead.* Report on the International Education Roundtable: 7 July 2009, Singapore: McKinsey and Company.

Bancroft, S. F., Herrington, D. G. & Dumitrache, R. (2019). Semi-quantitative Characterization of Secondary Science Teachers’ Use of Three-Dimensional Instruction, *Journal of Science Teacher Education, 30*(4), 379 408, http://doi.org/10.1080/1046560X.2019.1574512

Boyd, D., Goldhaber, D., Lankford, H., & Wyckoff, J. (2007). The effect of certification and preparation on teacher quality. *The Future of Children, 17*, 45–68.

Bransford, J., Darling-Hammond, L., & LePage, P. (2005). Introduction. In L. Darling- Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 1–39). San Francisco: John Wiley and Sons.

Brownell, M. T., Bishop, A. M., & Sindelar, P. T. (2005). NCLB and the demand for highly qualified teachers: challenges and solutions for rural schools. *Rural Special Education Quarterly*, *24*(1), 9–15. https://acres-sped.org/journal.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*(3), 497–526.

Carlone, H. B., Haun-Frank, J., & Kimmel, S. C. (2010). Tempered radicals: Elementary teachers’ narratives of teaching science within and against the prevailing meanings of schooling. *Cultural Studies of Science Education, 5*, 941–965.

Carrier, S. J., Whitehead A. N., Walkowiak, T. A., Luginbuhl, S. C. & Thomson, M. M. (2017). The development of elementary teacher identities as teachers of science. *International Journal of Science Education, 39*, 1733–1754.

Cassels, J. R. T., & Johnstone, A. H. (1984). The effect of language on student performance on multiple choice tests in chemistry. *Journal of Chemical Education*, *61*, 613-615.

Cochran-Smith, M., & Zeichner, K. (Eds.). (2005). *Studying teacher education: The report of the AERA Panel on Research and Teacher Education*. Mahwah, NJ: Lawrence Erlbaum.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44(4)*, 613–642.

Dabney, K., Kimberly G., Scott, M. R., Johnson, T. N., Chakraverty, D., Milteer, B., & Gray, A. (2020). Pre-service Elementary Teachers and Science Instruction: Barriers and Supports. *Science Educator, 27*, 92-101.

Darling-Hammond, L. (1994). *Professional development schools: Schools for developing a profession*. New York: Teachers College Press.

Darling-Hammond, L. (2006). *Powerful teacher education: Lessons from exemplary programs*. San Francisco, CA: Jossey-Bass.

Darling-Hammond, L., & Bransford, J. (Eds.). (2005). *Preparing teachers for a changing world: What teachers should learn and be able to do*. San Francisco, CA: JosseyBass.

Darling-Hammond, L., & Baratz-Snowden, J. (2007). A good teacher in every classroom: Preparing the highly qualified teachers our children deserve. *Educational Horizons*, *85*(2), 111-132.

Davis, E. A., Petish, D., & Smithey, J. M. (2006). Challenges new science teachers face. *Review of Educational Research, 76(4)*, 607–651.

Duschl, R., & Shouse, A., & Schweingruber, H. (2007). What Research Says about K-8 Science Learning and Teaching. *Principal,* 17-22.

Evagorou, M., Dillon, J., Viiri, J. & Albe, V. (2015). Pre-service Science Teacher Preparation in Europe: Comparing Pre-service Teacher Preparation Programs in England, France, Finland and Cyprus. Journal of Science Teacher Education, 26(1), 99-115, http://doi.org/ 10.1007/s10972-015-9421-8

Gallimore, R., Ermeling, B. A., Saunders, W. M., & Goldenberg, C. (2009). Moving the learning of teaching closer to practice: Teacher education implications of school-based inquiry teams. *Elementary School Journal, 109*(5), 537–553.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Hawthorne, NY: Aldine.

Goodson, I. F. (2013). *Developing narrative theory: life histories and personal presentations*. Routledge: New York.

Grossman, P., & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. *American Educational Research Journal, 45*(1), 184–205.

Hattie, J. (2004). It's official: Teachers make a difference. *Educare News: The National Newspaper for all Non-government Schools, 2004*(44), 24-31.

Hayes, K. N., Lee, C. S., DiStefano, R., O’Connor, D., & Seitz, J. C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *Journal of Science Teacher Education, 27*, 137–164.

Hayes K. N., Wheaton, M., & Tucker, D. (2019). Understanding teacher instructional change: the case of integrating NGSS and stewardship in professional development, *Environmental Education Research, 25*(1), 115-134, http://doi.org/10.1080/13504622.2017.1396289

Healy, L., Ehrich, L. C., Hansford, B., & Stewart, D. (2001). Conversations: A means of learning, growth and change*. Journal of Educational Administration, 39*(4), 332-345.

Hutner, T. L., Petrosino, A. J. & Salinas, C. (2021). Do Preservice Science Teachers Develop Goals Reflective of Science Teacher Education? A Case Study of Three Preservice Science Teachers. *Research in Science Education, 51*, 761–789. https://doi.org/10.1007/s11165-018-9816-6

Iordanou, K., & Constantinou, C. P. (2014). Developing pre-service teachers’ evidence-based argumentation skills on socio-scientific issues. *Learning and Instruction, 34*, 42–57.

Jones, M. T., & Eick, C. J. (2007). Implementing inquiry kit curriculum: Obstacles, adaptations, and practical knowledge development in two middle school science teachers. *Science Education, 91*(3), 492-513.

Jones, M. G., & Leagon, M. (2014). Science teacher attitudes and beliefs. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 830–847). New York: Routledge.

Kane, T. J., & Staiger, D. O. (2012). *Gathering feedback for teaching: Combining high-quality observations with student surveys and achievement gains*. Seattle, WA: The Bill and Melinda Gates Foundation. Retrieved from http://www.metproject.org/reports.php

Kazemi, E., Franke, M. L., & Lampert, M. (2009). *Developing pedagogies in teacher education to support novice teachers’ ability to enact ambitious instruction*. In Annual Meeting of the Mathematics Education Research Group of Australasia, Wellington, New Zealand.

Kisa, M. T., & Stein, M. K. (2015) Learning to see teaching in new ways: A foundation for maintaining cognitive demand. *American Educational Research Journal, 52(1)*, 105–136.

Kloser, M. (2014). Identifying a core set of science teaching practices: A delphi expert panel approach. *Journal of Research in Science Teaching, 51*, 1185-1217.

Krystyniak, R., & Heikkinen, H. (2007). Analysis of verbal interactions during an extended, open-inquiry general chemistry laboratory investigation. *Journal of Research in Science Teaching, 44*, 1160-1186.

Levine, A. (2006). *Educating School Teachers*. Retrieved 16 August, 2008 from http:www.edschools.org/pdf/Educating\_Teachers\_Report.pdf.

Lippard, C., Tank, K., Walter M. C., Krogh, J. & Colbert, K. (2018). Preparing early childhood pre-service teachers for science teaching: aligning across a teacher preparation program. *Journal of Early Childhood Teacher Education, 39,* 193-212.

Loucks-Horsley, S. (1998). The role of teaching and learning in systemic reform: A focus on professional development. *Science Educator, 7*, 1-6.

Loughran, J. (2006). *Developing a pedagogy of teacher education: understanding teaching and learning about teaching*. London: Routledge.

Loughran, J. J. (2014). Developing understandings of practice: science teacher learning. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 811–829). New York: Routledge.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers’ epistemological beliefs: the development of the teacher beliefs interview. *Electronic Journal of Science Education, 11(2)*, 38–63.

Lunn, M. (1998). Applying simple j-sample tests to conditional probabilities for competing risks in a clinical trial. *Biometrics, 54*, 1662–1672.

Mamlok-Naaman, R., Hofstein, A. & Penick, J. (2007). Involving Teachers in the STS Curricular Process: A Long-Term Intensive Support Framework for Science Teachers. *Journal of Science Teachers Education*, *18*(4), 497-524.

Marshall, J. A., Petrosino, A. J., & Martin, T. (2010). Preservice Teachers' Conceptions and Enactments of Project-Based Instruction. *Journal of Science Education and Technology, 19*(4), 37–386.

Martinez, J. F., Borko, H., & Stecher, B. M. (2012). Measuring instructional practice in science using classroom artifacts: Lessons learned from two validation studies. *Journal of Research in Science Teaching, 49*(1), 38–67.

McKenzie, P., Santiago, P., Sliwka, P., & Hiroyuki, H. (2005). *Teachers matter: Attracting, developing and retaining effective teachers*. Paris: OECD.

Merriam, S. B. (2009). *Qualitative research: a guide to design and implementation*. San Francisco: Jossey-Bass.

Musset, P. (2010). *Initial Teacher Education and Continuing Training Policies in a Comparative Perspective: Current Practices in OECD Countries and a Literature Review on Potential Effects*. OECD, Directorate for Education: OECD Education Working Papers.

National Council for Accreditation of Teacher Education. (2010). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers (Report of the Blue Ribbon Panel on Clinical Preparation and Partnerships for Improved Student Learning)*. Retrieved from http://www.ncate.org/LinkClick. aspx?fileticket=zzeiB1OoqPk%3d&tabid=715

National Council for Teacher Quality. (2011). *Student teaching in the United States*. Retrieved from http://www.nctq.org/edschoolreports/studentteaching/docs/nctq\_ str\_full\_report\_final.pdf

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

National Science Teachers Association (NSTA). (2012). *Standards for science teacher preparation*. Arlington, VA: National Science Teachers Association.

National Science Teachers Association (NSTA). (2017). *NSTA Position Statement: Science Teacher Preparation*. Arlington, VA: National Science Teachers Association.

Neapolitan, J. E., & Levine, M. (2011). Approaches to Professional Development Schools. *Yearbook of the National Society for the Study of Education, 110*(2), 306-324.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Nowell, L., Norris, J., white, D., Moules, N. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*, 1-13.

OECD, Organization for Economic Cooperation and Development. (2005). *Teachers matter: Attracting, developing and retaining effective teachers*. Paris: OECD.

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2008). *Classroom assessment scoring system*. Baltimore: Paul H. Brookes.

Portfolio of Lesson Plans. (2018). *Portfolio of lesson plans for science teachers*. Jerusalem: Ministry of Education.

Reiser, B. J. (2013). *What professional development strategies are needed for successful implementation of the next generation science standards?* Paper prepared for K12 center at ETS invitational symposium on science assessment. Washington, DC.

Riessman, C. K. (2008). *Narrative methods for human sciences*. Sage: Los Angeles.

Roth, K., & Garnier, H. (2006). What science teaching looks like: An international perspective. *Educational Leadership, 64*(4), 16–23.

Sahlberg, P. (2012). The most wanted teachers and teacher education in Finland. In L. Darling-Hammond, & A. Lieberman (Eds.), *Teacher education Around the world changing policies and practices* (pp. 1-21). London: Routledge. S

Schwartz, R. S., Lederman, N. G., & Abd-El-Khalick, F. (2000). Achieving the reforms vision: The effectiveness of a specialists-led elementary science program. *School Science and Mathematics*, 181-193.

Shroyer, G., Yahnke, S., Bennett, A., & Dunn, C. (2007). Simultaneous Renewal through Professional Development School Partnerships. *Journal of Educational Research, 100*(4), 211-225.

Tobin, K. G. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics, 90*, 403-418.

Treagust, D., & Tsui, C. Y. (2014). General Instructional Methods and Strategies. In N., Lederman, S., Abell. (2014) (Eds), *Handbook of Research on Science Education, Volume II* (pp 303–320). NY: Routledge.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers’ practical knowledge. *Journal of Research in Science Teaching, 37*, 963-980.

Van Driel, J. H., Berry, A., & Meirink, J. (2014). Research on science teacher knowledge. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 848–870). New York: Routledge.

Wayne, A. J., & Youngs, P. (2003). Teacher characteristics and student achievement gains: A review. *Review of Educational Research, 73*(1), 89-122.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education, 92*(5), 941–967.

Windschitl, M., & Stroupe, D. (2017). The three-story challenge: Implications of the next generation science standards for teacher preparation. *Journal of Teacher Education, 68*(3), 251–261.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878–903.

Table 1. Description of the practicum course in science teaching by stage

|  |  |
| --- | --- |
| Stage | Details |
| 1. Preparatory stage: Observations | The student-teachers observe an experienced teacher and write down their reflections so they can learn and build their own science teaching practice (duration: 1 month). |
| 2. Student-teacher assistant stage | The student-teachers take on a partial role in teaching; they help the experienced teacher teach according to their original lesson plan. They are responsible for some of the lesson activities according to the agreement between them and the experienced teacher (duration: 1 month). |
| 3. Student-teacher stage | This is the most important stage. During this stage, the student-teachers:* Prepare lesson plans in cooperation with an in-service science teacher and an academic supervisor. This step includes much back and forth among the three parties to improve the lesson plans and make any required modifications to render the SIP more NGSS-oriented.
* Teach the planned science lessons for elementary level students.
* Write a reflection piece about the science lessons they taught and suggest adjustments to make their SIP more NGSS-oriented in the future.
* Prepare a reflective portfolio comprising lesson plans, presentations, teaching aids, assessment tools and any other related items that they prepared and used, in addition to their reflections.

Pre-service teachers during this stage are apprentices and receive support from an in-service teacher and an academic supervisor when modifying their SIP to help them employ NGSS-oriented practices and thus teach in alignment with the new science teaching standards (Reiser, 2013) (duration: 8 months). |

Table 2. Characteristics of the research sample

|  |  |
| --- | --- |
|  | *N* = 57 |
| Male (%) | 18.9 |
| Female (%) | 81.1 |
| Average age (years) of the pre-service science teachers (SD) | 20.5 (0.51) |
| Average number of credit hours of learning completed (SD) | 35.8 (0.92) |

SD, standard deviation

Table 3. Descriptive information and reliability values for the SIPS questionnaire (Arabic version)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group | Scale | NGSS science education practice | Sample item | Items | Cronbach’s α-  |
| Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Instigating an investigation | 1) Questioning3) Planning and carrying out an investigation | Generate questions or predictions to explore | 1–4 | 0.81 |
| Data collection and analysis | 3) Planning and carrying out an investigation4) Analyzing and interpreting data5) Using mathematical and computational thinking | Make and record observations | 5–9 | 0.78 |
| Critique, explanation, and argumentation | 6) Construct explanations7) Engaging in argument from evidence | Explain the reasoning behind an idea | 10–15 | 0.81 |
| Modeling | 2) Developing and using models | Use models to predict outcomes | 16–18 | 0.89 |
| Non- Portfolio of Lesson Plans (2018) and in spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Traditional instruction | None | Provide direct instruction to explain science concepts | 19–21 | 0.79 |
| Prior knowledge | None | Apply science concepts to explain natural events or real-world situations | 22–24 | 0.82 |

NGSS, = Next Generation Science Standards

Table 4. Coding scheme for pre-service science teachers discourse (inferred from a representative pre-service science class) (based on Hayes et al., 2016, p.160–1)

|  |  |
| --- | --- |
| Code | Examples from representative pre-service science teachers’ discourse during their science lessons  |
| Instigating an investigation | “In groups that are composed offrom four students, write down three questions, select one of them, and formulate it as a research question.”“Outline the variables that is the research question last lesson and you would like to investigate, define them and decide how to measure them” |
| Data collection and analysis  | “I will distribute a photograph of two animals; write down two observations about each of them.”“Each student must measure the height of five colleages together with their ages. Write the age- height results in a table.” |
| Critique, explanation, and argumentation | “Student A says that the temperature increases in the summer seasons, the pre-service science teacher asks him: ‘why do think that?’After student A answered, the pre-service-teacher responded:: ‘do you have another explanation?’” |
| Modeling | “In groups composed of from four students, design a model that represents the effect of climate change on living creatures.”“Using the material that I will distribute them to you, design a model in partnership with a colleague that help us to minimize water pollution.” |
| Traditional instruction | “Increasing temperatures of the earth cause melting of ice in the polar regions, and as a result the sea level increases.”“Plants are considered producers in the food network”:“animals like elephants and lions are consumers in the food network.” |
| Prior knowledge | “In winter, moisture accumulates on our noses; this is because of condensation of our breath.”“Every one of you washes his/her hands with water and soap, because soap can kill germs and bacteria.” |

Table 5. Statistical comparison of pre-service science teachers pre-SIP and post-SIP

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group |  Scale  | Pre-SIP | Post-SIP | *t*(57) | *p-*value |
| Mean | SD | Mean | SD |  |  |
| Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Instigating an Investigation | 2.57 | 0.63 | 3.09 | 0.54 | 6.57 | ≤0.0001 |
| Data collection and analysis | 3.61 | 0.57 | 3.83 | 0.52 | 3.70 | 0.001 |
| Critique, explanation, and argumentation | 3.77 | 0.52 | 4.08 | 0.43 | 5.80 | ≤0.0001 |
| Modeling | 4.14 | 0.57 | 4.45 | 0.48 | 4.63 | ≤0.0001 |
| Non- Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Traditional instruction | 4.08 | 0.45 | 2.72 | 0.56 | 11.05 | ≤0.0001 |
| Prior knowledge | 3.87 | 0.65 | 2.56 | 0.71 | 10.81 | 0.001 |

Table 6. Average number and frequency of pre-service science teachers-students discourse

|  |  |  |  |
| --- | --- | --- | --- |
| Group |  Scale  | Pre-observation | Post-observation |
| Mean | % | Mean | % |
| Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Instigating an investigation | 1.5 | 6.7 | 2.6 | 11.1 |
| Data collection and analysis | 1.9 | 8.4 | 3.7 | 15.8 |
| Critique, explanation, and argumentation | 2.1 | 9.3 | 6.8 | 29.1 |
| Modeling | 2.2 | 9.8 | 3.8 | 16.2 |
| Non- Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | Traditional instruction | 9.2 | 40.9 | 3.6 | 15.4 |
|  |  |  |  |  |
|  |  |  |  |  |
| Prior knowledge | 5.6 | 24.9 | 2.9 | 12.4 |
| Total | 22.5 | 100 | 23.4 | 100 |

Table 7. Statistical comparison between pre- and post-observations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Group | Pre-observation | Post-observation | *χ*2 | *p*-value |
| Mean | % | Mean | % |
| Portfolio of Lesson Plans (2018) and in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | 7.7 | 34.2 | 16.9 | 72.2 | 16.17 | ≤0.0001 |
| Non- Portfolio of Lesson Plans (2018) and not in the spirit of NGSS (NGSS Lead States, 2013) oriented SIP | 14.8 | 65.8 | 6.5 | 27.8 | 17.28 | ≤0.0001 |

# **Figure**

Figure 1.

# **Figure caption**

Figure 1. Mean scores for the science instruction practices (SIP) of pre-service science teachers after undergoing the practicum course.