# INQUIRY-BASED INSTRUCTION OF EIGHT EMIRATI ELEMENTARY PRESERVICE SCIENCE TEACHERS: A PHENOMENOGRAPHIC STUDY

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***ABSTRACT*** *_ This phenomenographic study summarizes eight elementary preservice science teachers' (ePSTs') experiences with an actual practices related to inquiry-based instruction (I-BI) and the obstacles they encountered to using I-BI. Multiple sources of data, including questionnaires, classroom observations, and semi-structured interviews, were employed. Tracking the ePSTs' background knowledge during their years as secondary school students revealed that the teacher-centred approach was the predominant method experienced by most of the participants; some essential features of inquiry were available to only a few of the ePSTs. Prior to joining the teaching science methods course, five of the eight participants were unaware of I-BI. After participating in the teaching science methods course, the participants gained a strong awareness of I-BI; however, during their teaching practicum, the participants devoted less than 25% of their instructional time to this approach. Additionally, the findings revealed several obstacles that hindered the participants from implementing I-BI, such as the science curriculum that had to be covered, students' maturity and skills, and the dominance of traditional teaching approaches. The implications of these findings are discussed to enhance the preparation level of ePSTs.*

***Keywords****: Inquiry-Based Instruction, Preservice Science Teachers, Science Education, Elementary Education, UAE.*

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## I. INTRODUCTION

Over the past two decades, there has been tremendous reform in teacher preparation intended to improve learning outcomes for students at all levels [1,2]. One of the goals of science education is to prepare elementary preservice science teachers (ePSTs) to teach science as inquiry [3,4,5]. Therefore, based on science education reform documents, it is widely recommended that ePSTs be prepared to implement inquiry-based instruction (I-BI) ([6]; [7]; [8]; [9]; [10]). For example, the National Science Education Standards (National Research Council (NRC) [11] clearly recommend that inquiry be an important component of educators' work with preservice science teachers (Hayes [7]) and that "teachers of science plan an inquiry-based science program" ([11], p. 28). Brown and Melear [12] stated that most teacher-preparation programmes have the same primary goal: to offer preservice and/or inservice teachers authentic, inquiry-based scientific experiences through three main models: courses, institutes, and apprenticeships. International research recommends that I-BI should become an essential part of any science teacher education programme (for example, [13,14].

Teaching science as inquiry has been supported for more than two decades by educational reform efforts worldwide [15,16,17] Although there is some disagreement in the research community, the majority of researchers advocate the use of this approach in science classrooms [18,19,20]. Students participating in inquiry activities and investigations develop, for example, scientific ways of thinking [21], the ability to evaluate models and data [22], the skills to correct scientific misconceptions [22], and positive attitudes toward science [23]. DeBoer [17] believes that engaging students in inquiry activities could help realize the development of citizens who are self-directed and independent thinkers. To engage students in I-BI, teachers must develop a comprehensive understanding of scientific inquiry and inquiry-based teaching and learning [22,24]; however, helping preservice science teachers develop the essential knowledge and capabilities to engage students in science as inquiry remains a challenge [4].

According to the NRC [22,24], I-BI has five "essential features", which are confirmed in the Next Generation Science Standards (NGSS) (NGSS Lead States [25] (1) Learner engages in scientifically oriented questions (question); 2) Learner gives priority to evidence in responding to questions (evidence); 3) Learner formulates explanations from evidence (analyse & explain); 4) Learner connects explanations to scientific knowledge (connect); and 5) Learner communicates and justifies explanations (communicate).

In this study, the term "inquiry-based instruction" refers to "the pedagogical approaches modeling the general process of investigation that scientists use as they attempt to answer questions about the natural world" ([26], p. 718). Therefore, this study adopts the NRC's definition [11] of inquiry teaching: "…providing a classroom where learners can engage in scientific oriented questions to formulate explanations based evidence" (p. 29). Inquiry-based instruction is based on the constructivist theory of learning, which states that all learners internally develop knowledge and understanding from their experiences and interactions with others [27].

## II. The Statement of the Problem

The United Arab Emirates (UAE) has adopted extensive reform initiatives since the beginning of the 21st century with regard to teaching science [28]. More recently, the Ministry of Education introduced the National Science Curriculum Framework (NSCF) [29], which infuses inquiry-based pedagogy throughout the national science education curricula.

In the UAE, research is limited regarding whether science teachers who graduate from science teacher education programmes teach according to scientific inquiry principles. The current study probed ePSTs' I-BI experiences during their secondary school years and during their enrolment in undergraduate courses prior to joining a teaching science methods course (hereafter referred to as "eSEM"; [5]) and at the end of the eSEM. Moreover, observational data were collected about ePSTs' actual I-BI teaching practices in their classrooms during their teaching practicum to draw a clear picture about the degree to which they implemented essential features of inquiry. As will be discussed later, the literature indicates that teachers carry their previous experiences with them—in other words, teachers are influenced by what they "bring with them from their years as students in elementary and secondary schools" ([30], p. 306). These experiences, in turn, could affect preservice teachers' teaching practices.

It is anticipated that our findings will highlight issues relating to current practices of inquiry in Emirati schools, suggest ideas to promote science education, and potentially improve the effectiveness of ePSTs' teaching. This study contributes to understanding the actual implementation of I-BI and science teacher education programmes because it sheds light on inquiry teaching/learning in a setting other than the European-American model [31]. Moreover, a study of teacher inquiry practices has the potential to provide valuable sources of knowledge on teacher practices of inquiry, and this knowledge is provided by teachers themselves [31]. The current study investigates ePSTs' inquiry experiences, practices, and challenges to add to the knowledge base internationally and locally. The study also responds to the concerns of previous researchers, such as Davis, Petsih, and Smithely (as cited in [15]), who stated that the "literature tells us very little about new teachers' understandings of inquiry, how they teach inquiry, or what specific challenges they face in doing so" (p. 31). Notably, Arabian Gulf countries share similar social, cultural, and economic conditions and accordingly face similar educational problems [32]. Additionally, the study provides measures of the actual presence of I-BI in schools, in science education programmes, and in student teaching practice in the UAE and in the context of other Arab Gulf countries.

The three main limitations of the current study are worthy of consideration for future research. First, one should observe student teachers during actual teaching while they are implementing inquiry-based lessons of their own formation in order to investigate how they carry out their plans; additionally, their teaching practices should be observed during their first year as inservice science teachers. Second, the qualitative methodology lacks inter-observer reliability. Instead, the validity and reliability of the observations were established by observing each ePST 10 times during 10 different periods. Third, the use of a small convenience sample could affect the generalization of the research findings. Therefore, future replication studies at other institutions in the UAE might provide additional data for comparison and increase the generalizability of the findings.

## III. RESEARCH QUESTIONS

The purpose of this study is to answer the following three questions:

1. What are the prior I-BI-related experiences of Emirati ePSTs?
2. Do Emirati ePSTs' prior experiences with I-BI during their secondary school years, their undergraduate courses and a teaching science methods course influence their implementation of this teaching method in their teaching practicum?
3. What barriers hinder Emirati ePSTs from implementing I-BI during their teaching practicum?

## IV. LITERATURE REVIEW

Preservice science teachers' I-BI experiences

For the current study, ePSTs' I-BI experiences refer to ePSTs' knowledge about I-BI and their participation in implementing any features of I-BI while they were in secondary school, while enrolled in graduate courses and while engaging in their teaching practicum. Preservice science teachers usually experience science teaching while they are students at both the secondary and undergraduate levels [10,33,34,35,36,37].

For example, [10] concluded that science teachers' previous learning experiences from secondary school or science teacher programmes affect and sustain their inquiry-based teaching. These experiences can have a positive or negative impact on the development of a teacher's confidence in the use of classroom inquiry [38]. Melville et al. [35] suggested that science teachers should reflect on their own experiences as a strategy to develop preservice teachers' positive disposition toward and capacity for inquiry.

The literature indicates that few studies have investigated the influence of science teachers' I-BI experiences on their knowledge of, skills in, and views of inquiry [26]. In addition, these experiences could also affect science teachers' identities [39], personal histories [40], self-efficacy [41], and understanding of the meaning of inquiry [26], which in turn could affect their ability to teach science as inquiry.

Eick and Reed [40] examined the influence of "personal histories" on the formation of early role identity as inquiry-oriented science teachers. These researchers used two cases selected from a multi-case study of 12 secondary science student teachers. In that study, preservice teachers with stronger inquiry role identities appeared to benefit from supporting experiences in teacher education; they also more easily put these roles into action. The study revealed that past experiences in school and experience teaching and performing science appear to support or filter the critical aspects of an inquiry-oriented programme.

Few studies have examined the effectiveness of elementary science teachers' inquiry experience on their inquiry teaching practice. For example, in a study with six ePST students enrolled in eSEM, Hubbard and Abell [42] compared students with experiences in inquiry-based science courses to those without such experiences and found that students who had taken a teacher-preparation inquiry-based science course were more ready to consider I-BI than their counterparts.

Melville et al. [35] investigated how preservice teachers' inquiry experience affected their ability to reflect on the challenges involved in implementing inquiry in the classroom. These researchers collected data from the personal narratives of 12 preservice science teachers registered in an eSEM. The primary finding revealed that teachers with extensive inquiry experiences perceived implementation challenges primarily in terms of teaching and student learning. However, the main concerns of preservice teachers with limited inquiry experience related to the negative perceptions of others, materials, time, and the curriculum.

Preservice science teachers' I-BI practices.

In the present study, ePSTs' I-BI practices refers to the degree to which the ePSTs implemented various essential features of inquiry in their classrooms during their teaching practicum. According to Leonard, Boakes, and Moore [43], the studies investigating preservice teachers' ability to carry out I-BI have been widely reported in the literature; however, few studies have investigated ePSTs' I-BI implementation in primary classrooms. Therefore, research on ePSTs' actual I-BI practices is scarce, and the majority of studies have focused on secondary preservice science teachers (for examples, see [12,15,40,44,45].

Studies examining ePSTs using I-BI have focused mainly on various variables, such as ePSTs' knowledge of, skills and beliefs in and planning for I-BI (for example, [46]). A previous study with some similarities to the current study regarding primary preservice science teachers' actual I-BI practices is [43], which examined the impact of an intervention designed to promote I-BI among eight childhood/elementary preservice teachers in earth science.

Leonard and her colleagues used the Science Teacher Inquiry Rubric (STIR) [47] to record their participants' actual implementation of I-BI. These authors' results indicated that four participants practised I-BI to some degree and that the other four participants engaged their students in teacher-centred practices. The authors concluded that appropriate conceptions and supportive school environments are very important for sustaining preservice teachers' I-BI.

Barriers hindering preservice science teachers from implementing I-BI

Research shows that preservice science teachers' implementation of I-BI is hindered by several barriers and obstacles [4,10,35,48]. Crawford [44] pointed out that there are complex interactions between many factors that can impede a teacher's success in teaching science as inquiry. Notably, Anderson [49] grouped these barriers and dilemmas into three dimensions: technical, political, and cultural. The technical dimension includes the limited ability to teach, the political dimension consists of conflicts due to the lack of resources and time, and the cultural dimension embraces the perceived need to prepare students for the next level of schooling.

By examining the inquiry lesson preparation, practices, and reflections of preservice elementary teachers, Yoon et al. [37] grouped these difficulties into two categories. The first category comprised difficulties related to missing teaching practices, such as developing children's own ideas and curiosity, designing valid experiments for hypotheses, and scaffolding children's data interpretation and discussion. The second category included difficulties related to problems with preservice teachers' conceptualization of a task, such as tension between guided and open inquiry, incomplete understanding of hypotheses, and lack of confidence in science content knowledge .

However, the most frequently reported challenges that teachers faced when they carried out inquiry activities were classroom management and classroom control [50,51,52] and time limitations in terms of covering the mandated curriculum through inquiry instruction [51].

Leonard et al. [43] concluded that the learning environment, such as mentors and cooperating teachers, strongly influences preservice science teachers' I-BI practices. Teachers' partial understanding of the nature of science, the subsequent narrowing of their teaching capacity [53,54] and their limited experience with the range of inquiry-based methods, such as preservice teachers' own K-16 experiences, are also barriers [43,49].

As summarized in the previous sections, the majority of studies investigating preservice science teachers' I-BI experiences and practices have focused on secondary preservice science teachers (e.g., [51.55]). In addition, other studies have focused on short-term effects by investigating the influence of teaching science methods courses and their particular field experience on preservice science teachers' I-BI practices (e.g., [42,56]). Concerning data collection strategies, previous studies have used participants' personal narratives (e.g., [35]) or observation to investigate ePSTs' actual teaching practices [26,41]. however, no previous studies have examined ePSTs' I-BI experiences and practices in the UAE. This study summarizes ePSTs' I-BI experiences during their years in secondary school and during their undergraduate courses, their actual practices during their practicum, and the challenges they face to using an I-BI approach.

## V. METHOD

The study adopts a phenomenographic approach, and the phenomenon under study is I-BI [26]). Phenomenographic studies focus on developing, recognizing, describing, and apprehending the qualitatively different ways in which people experience certain phenomena or certain aspects of the world around them [57]. In the current study, the phenomenographic research purpose was to identify the range of meanings of and experiences with I-BI of the participants as a group and as individuals. Therefore, the similarities and differences among the participants were also highlighted in various aspects during the analyses and reported in the summary of the findings [58]. This design was selected because phenomenography focuses on how ePSTs experience, see, know, and possess skills related to I-BI. Phenomenography helps researchers probe how participants understand, construct, and use knowledge and skills related to I-BI. Moreover, phenomenography provides a very rich detailed description of the participants' experiences with I-BI.

The data for this study were obtained over one and a half years (i.e., three full semesters: fall 2013, spring 2014, and fall 2014). The data were collected from multiple sources, including questionnaires, classroom observations, and semi-structured interviews. Using data from several sources capitalizes on the benefits of qualitative research design [59] and enhances the validity of the research [60].

Context of the study

The current study took place in what is considered to be the leading research-intensive, comprehensive governmental university in the UAE. The university offers a full range of accredited, high-quality undergraduate and graduate programmes through nine Colleges, including the College of Education (CEDU) and the College of Science. The CEDU offers undergraduate, master's, and doctoral programmes in three academic departments: Curriculum and Instruction, Foundations of Education, and Special Education.

The Department of Curriculum and Instruction oversees the four-year science teacher education programme, which was developed according to international standards and uses the methods of the National Science Teacher Association in the United States. The participants in the current study completed science-related courses at the College of Science and education-related courses at the CEDU. Examples of the educational courses that the participants completed prior to graduation were Teaching Science Methods in Elementary Schools (eSEM), Development of Science Content and Pedagogy, and Capstone Experience in Elementary Education Mathematics & Science, as well as a teaching practicum.

The eSEM is being taught from an inquiry perspective and requires involvement in open, guided, and structured inquiry. This course was designed to enable science teachers to engage elementary school students in regular and effective science inquiry and other advanced teaching strategies to facilitate an understanding of the role that inquiry plays in the development of scientific knowledge. As part of the course requirements, ePSTs observe actual science teaching in schools, carry out practice teaching/microteaching, and design several lesson plans based on inquiry teaching and learning. The course focuses on topics related to inquiry teaching and learning, such as the nature of science, current international and national science standards documents, science process skills, constructivist learning theory, types of inquiry investigations, teacher questioning and assessment strategies, and science teaching planning.

Participants

The eight ePSTs who participated in this study were enrolled in an elementary mathematics/science education programme, and they were given the pseudonyms of Merah, Shahlah, Azah, Sarah, Marwah, Amerah, Rayah, and Aayah. The purposeful selection approach [59,61,62] was used to select the eight participants, who represented one cohort of undergraduate students registered in an eSEM with the researcher. The participants were conveniently selected to provide information that was particularly significant to the research questions—this information could not be obtained from other sources. "Selecting those…individuals [who] can provide you with the information that you need to answer your research questions is the most important consideration in qualitative selection decisions" ([62], p. 97). The eight participants had similar secondary school experiences, such as number and types of science classes. The participants were from different Emirates (Abu Dhabi, Dubai, Ras Al-Khaimah, and Al Fujairah) and did not have any form of professional teaching experience. The participants had received their general secondary certification-division of science and had scores on the general secondary school diploma ranging from 75.3–90.2%. The class sizes during the last three years of the participants' secondary school experience ranged from 20–28 students, and their GPAs ranged from 2.13–2.86 out of 4.00 during their enrolment in the eSEM. This obviously moderate range of GPAs could be attributed to the ePSTs' moderate achievement in the science courses they studied in the College of Science. To avoid any possible weaknesses in scientific knowledge the ePSTs might exhibit during their teaching practicum or during their careers as teachers, the CEDU offers students a course after the eSEM called Development of Science Content and Pedagogy. The main objective of this course is to increase ePSTs' science content knowledge. Among the various course requirements, ePSTs analyse the science content included in science textbooks for grades 1-6 and build concept maps for the main scientific themes covered in these textbooks.

The majority of the participants chose to study at the CEDU because they had a desire to teach, and they selected science/mathematics teacher education because these subjects promote thinking skills and problem solving. During their teaching practicum, all the participants used English as their teaching language except for Amerah and Aayah, who used Arabic. More information about each ePST is provided below.

Merah favours teaching methods that promote practical investigations and support a student-centred approach. Merah's practicum had 58 girls in two sections of third grade, and she taught 28 mathematics/science periods per week.

Shahlah prefers classroom discussion, practical investigations, and cooperative learning. During her practicum, Shahlah taught 55 girls in two sections of third-grade mathematics and science for 28 periods per week.

Azah prefers teaching methods that promote cooperative learning and technology, not just question/answer strategies. Azah's practicum consisted of mathematics and science for 40 girls in two sections of second grade for 28 periods per week.

Sarah prefers teaching methods that encourage engagement, enhance inquiry and research, and bring joy to the classroom. Sarah's practicum consisted of 45 girls in two sections of fifth grade for 14 periods per week.

Marwah prefers problem solving, discussion, and student-centred approaches. In her practicum, Marwah taught mathematics and science to 24 third-grade girls for 14 periods per week.

Amerah prefers classroom dialogues and facilitates cooperative learning, field trips, research and shared learning activities. During her practicum, Amerah taught mathematics and science to 23 second-grade boys for 11 periods per week.

Rayah favours teaching methods that encourage students and promote their participation. During her teaching practicum, Rayah taught mathematics and science to 44 fifth-grade girls enrolled in two sections.

Aayah appreciates group work, videos, field trips, and allowing students to construct scientific models. During her practicum, Aayah taught science to 44 fifth-grade boys for 12 periods per week.

## Instruments

### Questionnaire

In the fall 2013 semester, a questionnaire was administered during the first and the last class meeting before the final to collect information about the ePSTs' personal experiences as secondary school students. The questionnaire focused on the teaching of science topics and knowledge and experiences with I-BI from the time the ePSTs were secondary school students until they enrolled in the eSEM. The questionnaire, which was designed to probe the ePSTs knowledge about I-BI at the end of the eSEM, was developed by the researcher based on his knowledge and experiences and on a review of science education reform documents such as the National Science Education Standards [11] and Inquiry and the National Science Education Standards: A Guide for Teaching and Learning [22].

The questionnaire consisted of 32 items, including 15 open-ended questions. These 15 open-ended questions were designed to collect information about the participants' experiences selecting teaching science and mathematics as their major, the teaching strategies and other instructional activities typically used in their secondary schools, and the students' participation in teaching and laboratory activities during their secondary school years. The last open-ended item in the questionnaire asked the ePSTs to summarize what they knew about I-BI. This item was employed to compare the ePSTs' experiences with and knowledge of I-BI before and after their enrolment in the eSEM. Other questions had a Likert-scale rating form, and seven of the questions asked the ePSTs to choose Yes, No, or Sometimes based on whether their secondary school science teachers allowed them to implement the essential features of inquiry. Other Likert-scale items focused on collecting information about the ePSTs' participation in secondary science classrooms, their awareness of I-BI, and when they built this awareness—during secondary school or university.

The validity of the questionnaire was determined by content-related evidence. A panel of three professors and four associate professors from the CEDU was established. The panellists were chosen based on their knowledge of secondary science education, science teaching and learning, and assessment. The panellists' responses were collected and mainly focused on the structure of a few items. The questionnaire was revised according to the feedback received from the panel members

### Classroom Observation

Classroom observations were conducted in the fall 2014 semester during the ePSTs' teaching practicum. The observations began after the ePSTs had been teaching for six weeks. Each ePST was observed by her cooperating teacher 10 times during 10 different periods because the literature suggests that it is preferable to observe ePSTs multiple times in order to obtain a more accurate picture of how inquiry is being implemented [21] and to enhance the validity and reliability of the study [60]. The final version of the observation form included 30 items and 19 sub-items representing the five essential features of inquiry [21]. The 30 observational items were developed as instructional activities. These instructional activities can be described as follows: (1) Four items represented the "question" essential feature of inquiry. (2) Nine items represented the "evidence" essential feature of inquiry and focused on planning and conducting investigations. These observational items were divided into four categories: (A) design a simple experiment and identify procedures to collect/record data/results (3 items); (B) use simple scientific skills (processes of science) such as "measure," "cut," and "connect," (9 sub-items); (C) use simple instruments to collect, organize, analyse, and interpret data, such as rulers, thermometers, watches, beam balances and spring scales, magnifiers, computers, calculators, and charts (10 sub-items); and (D) carry out an investigation and collect evidence (4 items). (3) Four items represented the "analyse & explain" essential feature of inquiry. (4) Three items represented the "connect" essential feature of inquiry. (5) Seven items represented the "communicate" essential feature of inquiry and included items such as displaying/reporting procedures, data, and conclusions to the whole class; justifying investigation procedures; using speech, writing, or/and drawing to communicate findings; discussing the findings of students' investigations; critiquing other students' findings; and asking questions to further understanding. To develop a suitable observation form, the researcher reviewed several previous publications such as the NRC's Inquiry and the National Science Education Standards: A Guide for Teaching and Learning [22,63,64,65]. To ensure the content validity of the observation form, three science education professors and four associate professors commented on the form and revised it. Feedback was collected, and changes were made.

Interviews

Exit interviews were conducted during the third period of the capstone course nearly two months after the student teachers started their teaching practicum. The objectives of the interviews varied: clarify the student teachers' pedagogical philosophy or reasoning behind their practice and identify the real barriers hindering the ePSTs from implementing I-BI. Each interview was transcribed and lasted approximately one hour. Writing down text enhances validity and reliability [60]. Each ePST read her transcript and had the opportunity to make changes to ensure accuracy [40]. The interview protocol included 15 questions covering issues that corresponded to the teaching practices of the ePSTs. The interview protocol included several questions that were borrowed with partial modification from other previous studies, such as [26 .[

Data Analyses

Data analysis procedures were developed to answer three research questions built around the five essential features of I-BI. These features included question, evidence, analyse & explain, connect, and communicate. Evidence was divided into sub-features, which included plan, use simple scientific skills, use tools & instruments, and implement a plan to collect evidence. One feature, explain, appears as analyse & explain because students should analyse collected evidence to generate their explanation of a phenomenon [22].

Three different methods were implemented to analyse the data collected through the questionnaire items. First, categorical coding matrix methods were used to identify the dominant teaching methods and determine how lab experiments were typically conducted in science secondary school classrooms. Second, statistical analyses were performed to examine the implementation of scientific skills and the essential features of inquiry in secondary school science classrooms. Third, the definition of I-BI provided by each ePST was compared with the meaning of I-BI as documented by the NRC [11] and [22].

For the second research question, the observational data were analysed to identify the percentage of instructional time that each ePST devoted to carrying out each essential feature and sub-feature of I-BI. To perform the analysis, each observational rating scale was given a score ranging from 1–5: A great deal=5, Quite a bit=4, Some=3, Very little=2, and Not at all=1. The results of this analysis grouped the ePSTs according to the degree to which they carried out each essential feature and sub-feature (Table 3).

To answer the third research question, the categorical coding matrix method was used to analyse the data that were collected via the interviews to identify obstacles to carrying out I-BI. For this purpose, columns and rows were established to represent the names of the ePSTs and the primary interview protocol questions as a Themes × Data structure. Quotes from each ePST that addressed these themes were placed in the appropriate matrix cells. The results that emerged from this analysis revealed several factors that negatively affected how ePSTs implemented I-IB during their teaching practicums.

These multiple data sources and the selected data analysis methods were necessary to answer the three research questions concerning the ePSTs' experiences with, practices regarding, and obstacles to carrying out I-BI. The data sources were checked against one other for consistency while writing descriptive summaries that concentrated on the five essential features of I-BI for each ePST.

As previously noted, several techniques were applied to enhance the validity and reliability of the data collection methods. However, since the researcher conducted the data analysis procedures alone, he shared the categorical coding matrices with a faculty member who had expertise in the area of quantitative research methodologies. The two researchers reviewed and discussed the categorized data together, which resulted in the transfer of a few quotes from their original cells to other cells in the matrices. This procedure was followed to ensure interrater reliability for the data collected specifically via the interviews and the open-ended items in the questionnaire.

## VI. RESULTS

This section summarizes the findings for each research question. The findings reported in this section focus on the "how" and "what" aspects of I-BI that the ePSTs experienced during their secondary school years, before and after their enrolment in the eSEM, and during their teaching practicum. The focus is generally collective, and similarities and differences in some instances are highlighted with regard to the I-BI experiences and practices reported by the participants. Quotes are provided here as examples to support the main findings. The presented findings are based on the questionnaire for research question one, the classroom observations for research question two, and the interviews for research question three.

Research question 1

The author examined several aspects to explore the prior I-BI-related experiences of the ePSTs, including the following: How were science subjects taught in secondary school classrooms?

The ePSTs' responses indicated that teacher-centred approaches were dominant in their secondary school classrooms. The primary objective of the science teachers was to use teaching strategies that allowed students to memorize content knowledge. The students' practical participation included performing some applications and exercises typical of traditional classrooms. There was no indication of inquiry activities. Example responses from the ePSTs highlight these findings and show no indication of I-BI implementations. As Merah described, "…the teacher led the instruction, concentrating on memorizing scientific ideas. [there was] …little teacher-student discussion and few field trips or connections with students' lives." According to Shahlah "…the teacher introduced the lesson, taught; the students did applications, wrote a summary".

Marwah described the memorization aspect: "…usually in three phases: the teacher described and explained the lesson, students tried to memorize the main facts and concepts, students read about the topic in the textbook".

Rayah: "…the teacher introduced the lesson by showing a video, explained the topic starting from the easy to the difficult parts, and finally asked the students to do homework".

Aayah reported that students performed exercises and experiments: "…the teacher introduced a topic, explained it, defined concepts and laws, students did applications, exercises, and sometimes experiments".

How was laboratory work conducted in secondary school laboratories?

Teachers conducted the majority of lab experiments while the students observed. Occasionally, there was an opportunity for students to repeat the work or conduct the experiment under the teacher's guidance. In such situations, the students followed steps prepared for them by the teachers or described in workbooks.

Merah and Marwah reported that students had opportunities to conduct lab work following steps outlined by the teacher. According to Merah: "…the teacher explained the experiment, introduced tools, instruments, and materials, talked about the steps, students conducted the experiment, and finally, students wrote the findings and their observations." Marwah added that "…the teacher explained the experiment as it is in the book, and then the students conducted the experiment in groups".

Sarah specified that students repeated the experiment after the teacher: "…the teacher introduced tools and materials and the experiment steps, the teacher conducted the experiment and asked students to repeat it in groups".

Shahlah wrote that teachers guided students to conduct lab work: "…the teacher read the experiment, grouped students, and gave the instructions, and each group—with the teacher's help—conducted the experiment".

Rayah mentioned that students had no opportunity to perform experiments: "…sometimes the teacher conducted the experiment, and the students observed." Similar observations were reported by Azah.

Opportunities provided to ePSTs to engage in science activities

To some degree, the ePSTs were provided with the opportunity to engage in a variety of activities. For example, the ePSTs sometimes participated in group activities, completed exercises, searched the internet, prepared drawings, engaged in discussions, or taught for a short period of time. The ePSTs were not allowed to independently conduct activities in and out of the classroom.

Rayah was the only participant who clearly indicated that she was allowed to engage in science activities: "Yes, we were allowed to conduct in-class/out-of-classroom activities by ourselves to investigate scientific phenomena. For example, we sometimes conducted an experiment and responded to worksheets provided by the teacher".

Merah responded by saying that "…yes, we sometimes prepared worksheets, organized laboratory material, and responded to the teacher's questions".

Shahlah indicated that "…sometimes, we did the exercises and helped the teacher to prepare the lab for experimentation." Similar remarks were provided by Azah, Sarah, and Rayah.

In reference to information searches, Sarah noted that students "searched for something that related to the topic covered and prepared worksheets for other students in the class".

Marwah mentioned that students performed activities under the teacher's guidance: "We sometimes did activities as groups under the teacher's supervision. In these activities, we used our own ideas and efforts, where the teacher worked as a supporter and supervisor, and she interfered when students were unable to move forward or were facing something difficult and were unable to solve it".

Amerah said that students went on field trips: "…we worked in groups to search the internet, did some applications and went out on field trips".

Aayah added, "We sometimes brought thoughts and ideas from outside the book and talked about them in class ".

Opportunities provided to ePSTs to carry out scientific processes (science skills (

One questionnaire item was developed to collect data about the degree to which the ePSTs were allowed—by their science teachers and the instructors of their undergraduate courses prior to the eSEM—to use selected basic and integrated scientific processes (skills). Table 1 shows the similarities and differences in the degree to which the ePSTs used scientific skills in secondary science classes and undergraduate courses.

**Table 1**
**The degree to which ePSTs used scientific skills in secondary science classes and undergraduate courses**

| | Scales & Scientific Skills | | | | |
|---|---|---|---|---|---|
| EPSTs | Always | Sometimes | Often | Rarely | Never |
| Merah | | | ob & pr | ro, sp, iv, & re | mr, cl, se, & ce |
| Shahlah | | ro & pr | sp | ob, mr, cl, iv, se, ce, & re | |
| Azah | ro, pr, & iv | ob, cl, se, ce, & re | mr & sp | | |
| Sarah | | se | mr | ob, ro, cl, sp ce, iv, & re | pr |
| Marwah | | cl & se | pr | ob, ro, mr, sp iv, & ce | |
| Amerah | | ob & pr | ro, sp, iv, se, & re | mr, cl, & ce | |
| Rayah | | se | ob, ro, mr, & ce re, cl, pr, sp, & iv | | |
| Aayah | | ro & cl | ob, mr, pr, sp se, & ce | iv & re | |

ob=observing, ro=reporting observation, mr=measuring, cl=classifying, pr=predicting, sp=stating a scientific problem, iv=identifying variables, se=conducting simple experiments, ce=conducting complex experiments, and re=reporting experiments

Opportunities provided to ePSTs to implement the essential features of I-BI

In the seven questionnaire items about the essential features of I-BI, the ePSTs were asked to report to what degree they were given opportunities to participate in any essential features of inquiry during their secondary science classes by selecting No, Yes, or Sometimes.

Table 2 illustrates the overall group mean of the participants in terms of their engagement in the different essential features of inquiry activities. The aim here was to explore the engagement of the participants as a group, not as individuals. The overall group means for each essential feature of inquiry ranged from 1.75 (collect evidence) to 2.25 (question). The individual responses to the questionnaire items indicated that six of the ePSTs had partially engaged in different essential features of inquiry activities and that two of them had fewer opportunities than the others.

**Table 2**

**Overall mean group of opportunities provided to the ePSTs regarding engagement in the different features of inquiry (No=1; Sometimes=2; Yes=3)**

| Features of Inquiry | Overall Group Mean |
|---|---|
| Question | 2.25 |
| Evidence | |
| Plan | 1.88 |
| Implement | 2.00 |
| Collect Evidence | 1.25 |
| Analyse & Explain | 2.13 |
| Connect | 1.75 |
| Communicate | 2.00 |

ePSTs' actual knowledge about I-BI prior to their enrolment in eSEM

When the ePSTs were asked to report whether they had received any information about I-BI during their secondary school years or during college prior to their enrolment in the eSEM, three of them—Merah, Azah, and Rayah—said yes. These ePSTs indicated that they gained this knowledge not from their school but from courses they studied in the CEDU and the College of Science.

When these three students were asked to summarize their knowledge about I-BI, they responded as follows. Merah's answer concentrated on students conducting research and activities under teacher guidance: "…students should do research and activities to get the information they need, while the teacher leads students toward their need." Merah specified that "classroom activities depend on the students." Rayah concentrated on student independence and research: "Inquiry-based teaching depends on students who do research looking for new knowledge." Azah did not provide a summary. With regard to the initial question, Sarah and Aayah said no, Marwah and Shahlah said they could not remember, and Amerah did not reply .

ePSTs actual knowledge about I-BI at the end of the eSEM

At the end of the eSEM, the ePSTs summarized their understanding of I-BI. Five of the ePSTs—Sarah, Marwah, Amerah, Rayah, and Aayah—mentioned five essential features of I-BI and distinctly reported them: question, evidence, analyse & explain, connect, and communicate. Two of the ePSTs—Merah and Azah—reported four of the five essential features of inquiry instruction. For example, Merah mentioned all the features of I-BI except planning and implementing, which she partially mentioned; she summarized her responses as follows: "…students do observation, measurement, deducting, and experimenting." These activities are part of the implementation phase of I-BI. Azah, on the other hand, failed to mention phase 4 "…connecting findings with previous scientific knowledge." Only one ePST, Shahlah, mentioned general ideas about the features of I-BI. Shahlah summarized I-BI as follows: "…the inquiry-based instruction approach is identical to the discovery approach; inquiry-based instruction is a method that encourage students to think, make decisions, solve problems; it is an important modern teaching method. I-BI helps student to be creative and reflective; inquiry-based instruction helps student to correct, modify, and advance old knowledge when they gain new knowledge." Shahlah added that "All these happen through discovery, conducting research, reading, and experimenting".

Research question 2

The observation forms revealed that the ePSTs generally practised I-BI between 1% and 25% of their instructional time (Shahlah, Sarah, Amerah, Rayah, and Aayah) during the 10 observed periods. Our analyses showed that Merah practised I-BI between 1 and 50% of the instructional time and that Marwah practised I-BI between 25 and 50% of the instructional time. Azah exhibited the lowest levels of I-BI practice among the participants. Our analyses of the actual implementation of each of the essential features of I-BI for each ePST are listed in Table 3. None of the ePSTs used 50–100% of the instructional time to implement features of I-BI, and there was weakness in implementing the connect and communicate features.

**Table 3**
**Percentage of instructional time the ePSTs used to implement the I-BI features**

| | Percentage of Instructional Time the ePSTs Used to Implement the I-BI Features | | | | |
|---|---|---|---|---|---|
| I-BI Features | Not at All 0 % | Very Little 1–25% | Some 25–50% | Quite a Bit 50–75% | A Great Deal 75–100% |
| Question | None | Ra & Az | Mr, Sh, Sr, Ar, Mw, & Ay | None | None |
| Evidence | | | | | |
| Planning | Az & Ra | Sh, Ar, & Ay | Mr, Mw, & Sr | None | None |
| Use Skills | Sh, Az, Sr, & Ra | Mr, Ar, Ay | Mw | None | None |
| Use Instruments | Sh, Az, & Ra | Mr, Sr, Mw, Ar, & Ay | None | None | None |
| Collect Evidence | Sh, Az, & Ra | Sr | Mr, Mw, Ar, & Ay | None | None |
| Analyse & Explain | Az & Ay | Sh, Sr, Ar, & Ra | Mr & Mw | None | None |
| Connect | Sh & Az | Mr, Sr, Ar, Ra, Mw, & Ay | | None | None |
| Communicate | Sh, Az, & Ra | Mr, Sr, Ar, Mw, & Ay | None | None | None |

Mr=Merah, Sh=Shahlah, Az=Azah, Sr=Sarah, Mw=Marwah, Ar=Amerah, Ra=Rayah, & Ay=Aayah

The students' use of scientific skills and instruments also exhibited flaws. In general, very little of their instructional time was devoted to student practise of the I-BI features. Student engagement in questioning activities, in planning, and in collecting evidence occurred more frequently during the ePSTs instructional time than the other essential features of inquiry .

Research question 3

The analysis of the interviews revealed several reasons or conditions hindering the ePSTs from implementing I-BI in their teaching practicum. These barriers can be categorized into factors that relate to the density of the school science curriculum, students' maturity and skills, the dominance of traditional teaching approaches, the availability of teaching/learning resources, and a lack of support from the cooperating teachers. Merah stated that she preferred to apply what she had studied at the CEDU, such as scientific inquiry and investigations, but she focused on curriculum density: "We faced several constraints to implementing I-BI such as the many scientific topics that we should cover during a short period of time." Merah also blamed the teachers because the "elementary science teachers did not provide students with chances to learn; teachers do everything for the students." Sarah believed that "…the traditional ways of teaching are still dominant. Therefore, some of my students have not shown full engagement with inquiry activities because they were accustomed to these traditional methods…in addition, cooperating teachers do not have enough knowledge and skills to carry out inquiry instruction." Moreover, Sarah found that the science achievement of her students was higher when they engaged in inquiry investigations. Amerah specified that "Elementary students had problems developing or identifying a hypothesis or conducting a simple experiment." Marwah mentioned several issues that hindered her from implementing I-BI, such as "time, shortage of school resources and materials, the curriculum, and families ".

## VII. DISCUSSION

The ePSTs reported that their secondary school science teachers routinely used traditional instructional approaches that emphasised the teacher; there was little time for students to participate. However, there were no indications that the ePSTs were involved in any inquiry procedures as part of the practical work conducted in secondary school laboratories. Generally, the ePSTs' participation did not reflect aspects of actual scientific inquiry.

Prior to joining the eSEM, only three of the ePSTs had some knowledge about I-BI. However, this knowledge was not obtained in secondary school—the ePSTs claimed that they became familiar with the inquiry approach during their undergraduate courses in the CEDU and the College of Science prior to enrolling in the eSEM. However, these students' knowledge of I-BI did not align precisely with the definition of I-BI: none of these three ePSTs pointed out the specific essential features of inquiry. The other five ePSTs reported no ideas regarding I-BI. Therefore, the findings reveal that fewer than half the participants began the eSEM with a general idea of I-BI. These ideas, however, did not reflect the true practice of scientific inquiry. It appears that the participants were unable to differentiate between research and inquiry teaching. At the end of the participants' enrolment in the eSEM, five of the participants reported a complete picture of IB-I that included its five essential features.

Based on these findings, it appears that the ePSTs had not participated in any kind of full scientific inquiry. This finding is inconsistent with that of Eick and Reed [40], Melville et al. [35], and Hubbard and Abell [42]. However, our findings regarding the ePSTs' prior inquiry experience are consistent with those of Demir and Abell [26]. These researchers found that teachers in their study held incomplete views of I-BI based on the NRC's definition of inquiry [11] and [22]. This study found that ePSTs had incomplete knowledge about and experience with I-BI beginning with their time in secondary schools until they joined the eSEM. It seems that the ePSTs sharpened and modified their knowledge about I-BI mainly during their enrolment in the eSEM and partially during other educational courses offered by the CEDU.

During their practicum, the majority of the ePSTs provided very few opportunities for their students to apply the essential features of inquiry. This finding is consistent with previous research that concluded that planning and teaching inquiry-based lessons are difficult instructional tasks for preservice and beginning teachers and that although these teachers are supportive of I-BI, they face difficulties transferring, integrating, and applying inquiry practices from their teacher education programmes to the classroom environment [12,21]. For example, Asay and Orgill [21] found that at the secondary school level, two of the I-BI features, evidence and analyse & explain, were significantly more common in the articles they analysed than were the other features of I-BI. Meanwhile, the other three features of I-BI, question, connect, and communicate, were less frequently found in the analysed articles.

Question. The analysis showed that two of the participants spent very little time engaging their students in scientific questions. These results demonstrate that classroom students had some opportunities to use scientific questions to investigate a topic and that these questions could be provided by school science textbooks, workbooks, or the ePSTs. Asay and Orgill [21] concluded that "the question feature was usually teacher-directed" (p. 70). Previous research has also found that allowing students to generate scientific questions is not an easy task for teachers [50].

Evidence. In general, some of the ePSTs, with some variation, allowed their students to plan their inquiries and implement plans to collect evidence. Similar findings have been reported in previous studies, as summarized in Asay and Orgill's [21] study, which concentrated on secondary science teachers. Findings related to evidence as the second feature of inquiry can be described as four sub-features of I-BI: planning, using simple scientific skills, using simple instruments, and implementing and collecting evidence.

Analyse & Explain. Our results reveal that two of the ePSTs devoted some instructional time to giving students opportunities to analyse evidence to develop descriptions, explanations, and predictions. However, four of the ePSTs allocated very little time to such opportunities. Only two of the ePSTs did not properly share this essential feature of I-BI with their students. This finding is consistent with the findings of Asay and Orgill [21], who reported that teachers do not always let their students handle data or determine how to analyse it and explain the findings. The authors thought that teachers prefer that students not perform data analysis because they believe that their students do not have the necessary skills and because the students' explanations could consume class time. The analyse & explain feature of I-BI expects ePSTs to allow their students to provide explanations of evidence, look for alternative evidence, develop descriptions and explanations, and think critically and logically. Hence, these findings shed light on the ePSTs' ability to involve their elementary-age students in such activities.

Connect. Our findings show that the students of six of the ePSTs had very few opportunities to connect evidence and explanations with previous scientific knowledge; the students of the remaining two ePSTs had no such opportunities. Asay and Orgill [21] reported similar findings in their analyses of secondary science teachers' I-BI classroom practices. In addition, our findings reveal that the connect feature of I-BI may be the most difficult feature for elementary school students to apply because it includes elements such as drawing conclusions based on data and evidence, connecting their findings with previous scientific knowledge, and describing their investigation procedures and findings in a written report. These findings highlight the need to grant this feature of inquiry special attention during preservice science teachers' college education. Moreover, for elementary students, one could suggest another way to implement this feature of inquiry: students at this level could connect what they find through their investigation with scientific knowledge provided in their school science textbooks or with other learning resources. This type of process could be carried out with careful teacher guidance and assistance.

Communicate. Our results revealed that five of the ePSTs spent very little time allowing students to communicate about the procedures, evidence and explanations of their investigations; three ePSTs did not provide students with the opportunity to share their findings. This result indicates that the students of these three ePSTs did not develop skills related to reporting procedures, data, and conclusions to the whole class; justifying investigation procedures; discussing the findings of other students' investigations; using forms of communication; commenting on other students' findings; and asking questions to further their understanding. A possible explanation for this finding might relate to the limited time in each school period, as the students were typically unable to complete the cycle of any inquiry activities. In addition, providing fewer opportunities for students to analyse evidence and explain their findings could also lead to less clear opportunities for them to communicate and justify their data. Presenting and justifying one's work to and with a group of other students should be a strong feature of I-BI, even as part of non-inquiry activities.

First, the author found that the ePSTs who showed a high degree of awareness of I-BI at the end of the eSEM performed well in their teaching practicum with regard to I-BI, with the exception of Azah and Rayah. Second, the I-BI secondary school experiences of the ePSTs had no clear influence on their abilities to implement I-BI. For instance, Marwah, Amerah, and Aayah, who had more opportunities during secondary school than the other ePSTs to practice some features and sub-features of I-BI, exhibited very high awareness of I-BI after finishing the eSEM. The students of these ePSTs were obviously given the opportunity to practice some features and sub-features of I-BI during the teaching practicum. Third, Azah and Rayah's students were not provided with sufficient opportunities to carry out the features and sub-features of I-BI, although these two ePSTs had engaged in very good I-BI practices during their secondary school years and had furthered their knowledge during the eSEM.

The findings from the interviews demonstrate that several barriers in elementary schools hindered these ePSTs from completely implementing I-BI in their classrooms during their field experience. Among these barriers as perceived by ePSTs were the density of the school science curriculum, the maturity and skills of elementary students, the dominance of traditional teaching approaches, the shortage of some teaching/learning resources, and a lack of support from the cooperating teachers. These obstacles varied among the schools where our students engaged in their practicums. Internationally, these findings are not new (see, for example, [4,49,51,66,67,68]). Fazio et al. [55] found that although preservice teachers improve their understanding of and competences in using I-BI through a methods course, the role of the practicum in supporting teachers' teaching practice is challenging. Those authors referred to the challenges posed by issues such as the availability of resources, the need to address curriculum standards, and time constraints. In the context of documenting these barriers/obstacles in the UAE, it would be helpful to find ways to overcome such barriers if we plan to move toward more advanced classrooms. It is important to note here that the ePSTs who participated in the current study did not report that classroom management and control were challenges, as has been reported in previous studies such as those of [50.51,52]. It is important that ePSTs understand that "all inquiry is not created equal" ([69], p. 32) and that each feature of inquiry can vary in its degree of "teacher-directedness or student-directedness," as described by Asay and Orgill ([21], p. 65). Moreover, school students likely show resistance to using I-BI, especially if they are not familiar with such teaching methods.

Summary

The purpose of this study was to answer three research questions about eight ePSTs' prior experiences with I-BI, the nature of their actual I-BI practices during their teaching practicum, and the barriers hindering them from implementing I-BI during their teaching practicum. The data were obtained at several points in time from multiple sources, including questionnaires, classroom observations, and semi-structured interviews. This study attempted to measure ePSTs' inquiry experiences before and after they enrolled in the eSEM, to observe their teaching practices with a focus on I-BI implementation, and to identify barriers hindering them from applying I-BI during their practicum.

Based on the current research findings, the inquiry activities that these ePSTs engaged in before enrolling in the eSEM were not identical to the inquiry activities that reflect true I-BI as defined by today's educational community. In addition, these ePSTs had not participated in any kind of full scientific inquiry during secondary school or in their undergraduate courses prior to enrolling in the eSEM. Instead, the ePSTs built their knowledge and awareness of I-BI during their enrolment in the eSEM.

Although the ePSTs had enough knowledge and willingness to teach science using student-directed teaching methods such as I-BI, the majority of them provided very few opportunities for their students to apply various essential features of inquiry. Several barriers prevented the ePSTs from completely implementing I-BI during their teaching practicum, and those hindrances varied from school to school. These obstacles shed light on a few gaps that need to be bridged in science teacher education. First, ePSTs need more teaching experience to carry out classroom inquiry activities. This additional experience could be gained by allowing ePSTs to serve as inservice teachers. The general conclusion about the implementation of I-BI in schools is that rich previous experiences and strong science teacher programmes alone are not sufficient to facilitate the use of I-BI in today's schools. Other vital factors must be present, such as curricula that advocate inquiry, well-equipped schools, and a supportive environment and culture.

## VIII. RECOMMENDATIONS

These findings have valuable implications for science teacher education and the implementation of inquiry at different school levels. Science teachers should be encouraged to implement student-directed teaching methods such as science inquiry, their implementation of these methods should be monitored, and they should participate in specific professional development programmes to learn student-centred teaching approaches and obtain teaching/learning resources that support applying different types of inquiry.

Preparing students to use I-BI requires science teachers to acquire knowledge and experience about not only different types of inquiry including the essential features of I-BI but also science inquiry from its all its theoretic and practical perspectives. Therefore, the features and practice of I-BI should be clearly described to guarantee that ePSTs integrate them in the classroom. Science teacher educators should provide students with actual models and rich examples of classroom instruction that highlight I-BI implementation in elementary school classroom settings, and this work could occur via classroom observations and deep discussions with science educators and expert science teachers. One teaching science methods course might not be enough. In addition, the structure of the mentoring system needs to be revisited through special measures regarding the nomination, training, monitoring, and evaluation of cooperating teachers.

This article does not contain any studies with animals performed by the author.

Informed consent was obtained from all the individual participants included in the study.

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