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Abstract

In scientific practices, students are frequently asked to conduct investigations to produce data that will serve as the basis for evidence that meets the goals of an investigation. But however, assisting in the formulation and implementation of students' investigations is often a difficult task for many teachers because authentic investigations include using multiple variables and further providing of evidence to support explanations or solutions. The purpose of this study was to gain a better understanding of the potential of a nanotechnology activity on encouraging the formulation and implementation of students' investigations. The "Can Nanotechnology Keep Us Dry in the Rain?" activity was developed as part of an in-service teacher training designed to assist science teachers in implementing inquiry-based science practices in their own classrooms. To discuss the potential of the activity, the author has provided the detailed analysis from the classroom visits of four case teachers in three governmental schools. The qualitative data was collected through video recordings, feedback of teacher trainers, and pre- and post-interviews. The results of this research provide supporting evidence that the nanoscale changes could be a powerful tool for four case teachers to provoke students for deeper inquiry. The present research, therefore, contributes to a growing body of evidence suggesting the direct demonstration of conducting hands-on experiments to formulate and implement the investigations of nanoscale phenomena.

Introduction

In scientific practices, students are frequently asked to conduct investigations to produce data that will serve as the basis for evidence that meets the goals of an investigation (see also NRC, 2012, p.54). Thus, one of the key elements of inquiry-based practices has always been to engage students in planning and conducting investigations (Bergman et al., 2012). However, teachers frequently encounter difficulties while assisting students in processes such as developing research questions and planning and conducting investigation (van Uum et al., 2016). Because authentic investigations include using multiple variables and further providing evidence to support explanations or solutions. Indeed, Zhang et al. (2015) found that teaching these inquiry skills is one of the greatest challenges for most teachers. The recent literature is still looking for ways to ensure providing students with learning opportunities to plan an investigation procedure in inquiry teaching (Chen et al., 2020). Some of these studies

offers a variety of ways such as helping teachers in practice argument-based inquiry investigations (Choi et al., 2021; Kabataş Memiş & Çakan Akkaş, 2020), engaging them in authentic scientific research that is easily transferable to their teaching (Kite et al., 2021), and assisting them in the implementation of new or more challenging teaching activities (Furman et al., 2021).

The present activity was developed within the framework of the second stage activities of a research focused on in-service science teacher training (Arabacıoğlu, 2019). The research aimed at evaluating and developing science teachers through their own classroom practices so that they could effectively implement inquiry-based science education pedagogy. Therefore, the activity "Can Nanotechnology Keep Us Dry in the Rain?" discussed in this paper contributes to the below mentioned sub-objectives of the mentioned research (see Arabacıoğlu, 2019):

- a. Developing a process as a good practice for in-service training of science teachers through their own classroom settings,
- b. To provide a support procedure through which the teacher could monitor and evaluate his/her individual development in the context of the school setting and in accordance with the features of inquiry-based science education,
- c. To enable teachers to gain experience and understanding through implementing authentic inquiry-based science teaching and learning activities in their classroom,
- d. To observe and analyze the transfer of teachers' inquiry-based science education methodology to the classroom environment during teacher-student interaction.

The purpose of this paper is to gain a better understanding of how an authentic nanotechnology activity might be used to encourage students to formulate and implement their own investigations. Hence, through providing evidence on teachers' interactions with students and students' investigation plans in its implementation, the activity aims to improve our understanding.

Theoretical Framework

Inquiry-based Learning and Authentic Science Practices

The teaching of inquiry, as briefly outlined by Deboer (2006), represents an almost 200-year tradition of scientific thinking, starting from the laboratory experiments confirming scientific theories to the National Science Education Standards. According to Minner et al. (2010), at least three distinct categories of activities that represent the inquiry in science classroom are (i) conducting investigations by scientists using scientific methods, (ii) actively inquiring students through thinking and doing into a phenomenon or problem and reflecting students on the processes used by scientists, (iii) and designing or using a pedagogical approach used in the teaching process. During the teaching and learning practices, inquiry has always been at the foundation of scientific inquiry, science learning, and teaching. Thus, inquiry-based teaching and learning resembles scientific inquiry by involving students in learning that is similar to scientists' work (Capps and Crawford, 2013). While learning scientific concepts and theories, they can develop skills and experience about doing real science. They engage actively in activities in a scientific manner to develop scientific explanations, to connect current scientific knowledge, and to emphasize the value of justifying and communicating (Bybee, 2006, p.9).

All of these processes can only be experienced through learning activities that have a considerably more dynamic character than traditional approaches. For this, the Inter Academy Partnership's (IAP) has defined widely accepted framework that students' learning through inquiry includes making observations, raising investigable questions, planning and conducting investigations, reviewing evidence in light of what is already known, drawing conclusions, and communicating and discussing ideas with others in which ideas are shared, explained, and defended (Harlen, 2013). The open-ended and student-centered characteristic of inquiry also broadens the teacher's role in the classroom. Some of the tasks that teachers can perform include facilitator, collaborator, mentor, diagnostician, motivator, innovator, experimenter, researcher, modeler, and learner (Crawford, 2000; Novak ve Krajick, 2006). Under of these different roles, teachers seek ways to enhance their interactions with their students and, in some way, hook their student. Therefore, they are often on the search for authentic problem or questions about the world around the students that would encourage or motivate students to get involved in at least one of these activities in the classroom. This aspect of inquiry-based activities is frequently defined in many European Commission-funded projects as: tackling authentic and problem-based learning activities in the Pri-Sci-Net Project (Gatt & Armeni, 2014), designing an intentional process of diagnosing problems and critiquing experiments in the ESTABLISH Project (European Union, 2018), and assisting students in trying to find answers to questions about the world around them in the Fibonacci Project (Bergman et al., 2012). Thus, it's helpful to define what the term "authenticity of the activity" implies, which is one of the concepts discussed in this study. The term "authentic" is used in the studies to describe scientific skills (Burrows et al., 2016), real-world work of scientists and technicians in science-related areas (Hsu et al., 2009), and the way science is actually practiced (van Eijck & Roth 2009). Authentic science practices, according to Burrows et al. (2016), is real-world science experiences that work to/towards a solution summarize information, use technology, analyze data, use findings for conclusions, develop questions, procedures, and methods, communicate the work, collaborate with others, and make results accessible to others. And these authentic open-ended science learning tasks are commonly addressed in schools in activities that are well-defined and organized by the teacher as an expert (Liljeström et al., 2013).

Supporting Teachers' Inquiry-Based Development

Engaging teachers in authentic inquiry that is parallel to the actual work of scientists is pretty difficult for training programs with high levels of participation (Capps et al. 2012). Studies have long underlined that teacher need examples of successful implementation as well as an opportunity to apply them in their class (Asay & Orgill, 2010; Biggers, 2018; Blanchard et al., 2009; Capps & Crawford, 2013; van Uum et al., 2016). Indeed, in real classroom settings, teachers are not always able to easily utilize well-defined and organized authentic activities. The implementation of such activities requires expertise, but at the same time, it is often not possible to be an expert without first experiencing such kinds of activities. Zhang et al. (2015) found that teachers, after participating in a long-term teacher development program, identify finding hands-on activities to engage students as a need for development. Capps et al. (2012) also suggest that teachers' engagement in authentic inquiry experiences may be a required intervention to assist them in supporting their students in designing and carrying out investigations. This study focuses on the fact that teachers need activities that serve as good examples or activities that lead to concrete and specific practices. According to Penuel et al. (2007), even if such teacher support is not part of professional development, it is crucial to assist them in developing strategies to encourage

student inquiry and to evaluate the potential effects of their improvement on practice. And, as van Uum et al. (2016) point out, they may gain experience in fostering students' understanding of scientific inquiry by referring to authentic scientific inquiry or providing explanations to them during the design of the investigation and at its conclusion, much as scientists do.

Authentic Nature of Nanotechnology Activities

This study demonstrates how teachers implement a nanotechnology activity as an authentic inquiry-based science practice to gain experience and understanding about students' planning and conducting investigations. Nanotechnology's interdisciplinary nature and remarkable applications have prompted science education experts to highlight its potential in science practices (e.g., Blonder & Mamlok-Naaman, 2016; Ghattas & Carver, 2012; Mandrikas et al., 2020). Sakhnini and Blonder (2016) indicate that finding insertion points for nanotechnology concepts into current scientific curricula is critical for integrating nanotechnology concepts and applications into science education. As a solution to this, the scientific practices in the programs might be used as a basis for this sought-after insertion points. Studies identify that students' ability to comprehend the true size and scale of objects is a major conceptual challenge in learning in nanoscience and nanotechnology (Mandrikas et al., 2020). This circumstance may push students to just use scientific thinking to solve problems that they cannot see with their five senses (i.e., touching, smelling, hearing, sighting, and testing). In other words, scientific investigation and testing could be the only tools available for them to gather evidence of nanoscale modifications. According to the National Science Foundation book *Inquiry, Thoughts, Views, and Strategies for the K-5 Classroom*, the inquiry process is also defined as one's own curiosity, wonder, interest, or desire to comprehend an observation or solve an issue. The learning process starts when the learner observes something that intrigues, surprises, or stimulates a question - something new, or something that doesn't make sense regarding the learner's prior experience or present understanding. Therefore, students' curiosity, wonder, interest, or desire to comprehend the nanoscale's invisible nature could easily be evolved into a real authentic inquiry.

Method

The author has provided a detailed analysis from the classroom visits of four case teachers using qualitative research methodology to discuss the potential of the activity in an intensified and holistic approach.

Intervention and Teaching Sequence

Teacher Preparation

The "Can Nanotechnology Keep Us Dry in the Rain?" activity was carried out in the second phase of an in-service teacher training designed to assist science teachers in implementing inquiry-based science practices in their own classrooms. Throughout the training sessions, teachers were provided with expert support enabling them to monitor, evaluate, and regulate their individual development through their own video recordings.

Before the implementation of the activity, a preliminary visit to the classrooms of the four teachers was arranged

and videotaped. This visit was planned by the teachers to reflect on their own understanding of inquiry. After the visit, teachers received video feedback on inquiry-based science practices using the observation protocol (Bergman et al., 2012). Therefore, they were prepared for the activity discussed in this paper, knowing which inquiry features would be evaluated by training providers.

Activity Design Framework

The activity reported in this paper is organized in accordance with guidelines provided by the IAP Science Programme (Harlen, 2010; Harlen et al., 2015). Based on model of learning through inquiry (see Harlen et al., 2015, p.38), the activity includes the process of building understanding by collecting evidence to test possible explanations and the ideas behind them in a scientific manner. Additionally, materials, worksheets, and a teacher activity manual supplied to teachers as activity kits (see figure 1).

Description of the Practices

In the activity named "Can Nanotechnology Keep Us Dry in the Rain", it is aimed that the students determine the most suitable and useful fabric for raincoat production among the sample fabrics offered to them by conducting an authentic inquiry. For this aim, teacher give students a task in which they are in charge of selecting textiles at a factory and must selecting the right fabric. To do so, teacher ask them to observe and touch a different set of fabrics and express their starting ideas based on their existing ideas and previous experiences (see figure 1).



Figure 1. Activity Kit and the Sample Fabrics

Through a series of observations on fabrics, the teacher progressively leads them to think about how they may utilize kit components to develop a prediction (for example, the thin fabric will pass water) and plan investigations or fair tests (for example, sliding water comfortably over fabrics). The teacher can provide them with some water and encourage them to just do small tests to plan an investigation. Because of the preliminary manipulation of fabrics using water-resistant nanotechnology sprays (see Figure 2), the teacher encourages them to notice that the fabrics behave abnormally with water. Due to the obvious challenges caused by this unexpected situation, students are encouraged to think more deeply and to include fair tests in their investigation plans. This challenge frequently elicits feelings of wonder, curiosity, and willingness to participate.

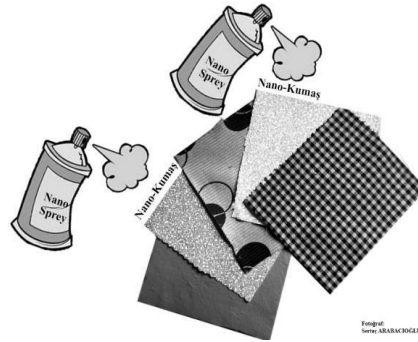


Figure 2. The Preliminary Manipulation of Fabrics

Teachers help them to gather evidence with different choice of fair tests using the materials. They may test fabric samples, including nano-hydrophobic ones, through a variety of tests, including water-repellenting/waterproofing, water-sliding, and water-absorption. Teacher can encourage them to record their findings on worksheets and compares the results they reach with their predictions. Based on the evidence obtained, teacher support them to draw a conclusion.

Participants

To the detailed examination of classroom practices, the activity was implemented by four volunteer in-service teachers from three public schools. The participants' background is summarized in Table 1.

Table 1. Participants' Background *

Descriptors	**T1	T2	T3	T4
	(Female)	(Female)	(Male)	(Male)
Professional experience year	10 years	10 years	14 years	7 years
Postgraduate education (M.A.)	Yes	No	Yes	No
To have received in-service training on inquiry-based instruction	Yes	Yes	Yes	Yes
To follow the in-service trainings continuously	Yes	No	Yes	No
To follow the science education current methodology closely	Yes	No	Yes	No
Intensive science course schedule in school	No	No	No	Yes
Experience inquiry-based instruction with their students	Yes	No	Yes	No
Student group in visits	7 th grade (12-13 age group)	7 th grade (12-13 age group)	7 th grade (12-13 age group)	7 th grade (12-13 age group)
Number of students in visits	10	23	28	20

* Teachers' statements from pre-interviews such as following the trainings continuously and so on are reflected in the table as Yes / No.

** Local pseudonyms in the original dissertation text was changed to Oya (Teacher 1), Fatma (Teacher 2), Ahmet (Teacher 3), and Hasan (Teacher 4).

Data Sources and Analysis

The qualitative data was gathered through video recordings, teacher trainer feedback, and pre- and post-interviews. Because of the broad theoretical and conceptual framework on the practices, each data set was

thematically analyzed with content analysis over pre-determined codes outlined by Strauss and Corbin (2008). Methodological triangulation of many sources and researchers (analysis was done independently by two researchers and the codes were compared) was ensured to validate the findings, in addition to member checking. Teacher-student interactions in video records were analyzed with the observation protocol of 'Diagnostic Tool for CPD Providers: Teacher-Pupil Interactions (Section A)' developed by Bergman et al. (2012). This protocol composed of 17 items and evaluate each lesson in three stages: Building students' ideas, supporting pupils' own investigations, and guiding analysis and conclusions. The records were transcribed and coded with NVivo 11 qualitative data analysis software to generate the timespans and calculate the duration of time in a transcript entry. The digital records of reflections were analyzed with the same conceptual framework presented by Bergman et al. (2012). Semi-structured interviews were conducted with each teacher before and following the programme. The content of the data from the interviews were analyzed to determine teachers' views on instruction and PD activities.

Results

Teachers' Understanding Prior to the Activity Implementations

The idea behind the preliminary interviews, the first classroom visits, and the trainer feedbacks on these visits was to capture a clear image of the teachers' understanding on inquiry-based science practices without any prior supervision or assistance. The activity "Can Nanotechnology Keep Us Dry in the Rain?" was not selected randomly for the second visit to teacher training. During the first visits, teachers were unable to adequately support their students in planning and conducting out investigations. Therefore, this activity was presented them as a learning task by the researcher. From the first visiting data derives that case teachers tended to engage students in data collection and analysis on teacher-centered questions. Encouragement of students to participate in scientific questions, perform fair tests, produce evidence-based statements, and associate scientific knowledge and their peers' conclusions with their explanations, on the other hand, is practically never witnessed. The visiting videos clearly illustrated that teachers were never involved or intended to incorporate features such as encouraging students to ask questions, helping in the formulation of productive (investigable) questions, and encouraging students to make predictions. In general, the investigation plans were mostly established by the teachers. In other words, they actually provided a well-defined testing procedure. As a result of this, students only collected data by following these well-defined investigation plans to find a solution.

Teachers prepared for the activity reported in this paper through their first visit performances. Regarding the analysis of data from trainer feedback provided after the first visits, the trainer remarks focused on qualities related to assisting students with their own investigations. Furthermore, trainer comments indicated which initial teacher learning needs were promoted. The analyses of trainers' comments included feedback on the most effective aspects of performance, how the next sequence could be improved, how they could direct teacher-student and student-student communication, how they could introduce new practices, and how they could determine the level of inquiry. In interviews, findings revealed that teachers' understanding of inquiry-based science practice were quite naive. Before the visits, for example, they shared ideas on teaching. Their definitions mainly focused on conducting an experiment (Teacher 2 and 4, PreInt), provoking curiosity (Teacher 2 and 3, PreInt), asking students

questions and defining predictions (Teacher 1, PreInt), producing knowledge (Teacher 3, PreInt), and acquiring scientific process skills (Teacher 2, PreInt) (Teacher 1 and 3, PreInt). There were no specific examples to define a particular phase or any specific indicator for classroom inquiry identified.

Teacher-Student Interactions During the Activity "Can Nanotechnology Keep Us Dry in the Rain?"

The findings from our data derives how four case instructors guided students to deeper inquiry, including related nanotechnology application areas, using elements of teacher-student interaction that they provided during their class visit. Actually, the analyses of video recordings interpreted using the observation protocol involved a wide spectrum of teacher-student interaction, from building students' ideas to supporting students' own investigations to guiding analysis and conclusions. But, for clarity to the research problem, this paper focuses on providing evidence on items related to supporting students' own investigations (see Table 2).

Table 2. Analysis of Classroom Video Records

The framework items (see Bergman et al. 2012)	Classroom visits			
	Teacher 1	Teacher 2	Teacher 3	Teacher 4
<i>Total duration of coded classroom records for supporting pupils' own investigations</i>	00:32:00	00:27:00	00:23:00	00:23:00
2a. T encourages Ps to ask questions,	✓	✓		✓
2b. T helps Ps to formulate productive (investigable) questions,		✓	✓	
2c. T encourages Ps to make predictions,	✓		✓	
2d. T involves Ps in planning investigations,	✓	✓	✓	✓
2e. T encourages Ps to include fair testing in their planning,	✓	✓	✓	
2f. T encourages Ps to check their results,	✓	✓		✓
2g. T helps Ps to keep notes and record results systematically	✓	✓	✓	✓

“✓” symbolize the interaction occurred and that it was relevant in the context of the observation. Blank boxes symbolize that the interaction did not occur at all or occurred only rarely, but that it was relevant in the context of the observation. “n.a.” symbolize that the interaction is not relevant in the context of the session observed.

The video recordings revealed that teachers employed a variety of instruments to encourage pupils to ask questions. One of them is to turn whole-classroom talk about the characteristics of the raincoat fabrics into teachable moments. For example,

Teacher 1: In spring, the rain is very nice, it smells of earth. If we have a raincoat, isn't the rain beautiful?

Student: I knew we were going to do something about raincoats.

Teacher 1: Now you are in charge of the selection of fabrics here.

Student: Are we tailors?

Teacher 1: Now I have four different fabrics. Do you think the fabric for the raincoat is (interrupted)?

Student: Teacher, it should be nylon,

Student: It should not put water in.

Teacher 1: You say it shouldn't pass water.

Student: It should not be cold air.

Student: It must be wind resistant. It's not going to stop the rain, but it's going to keep you warm. Woolly, it shouldn't tear right away.

Teacher 1: You say it must be durable. Now, I'm going to have to ask you to plan an investigation (Video recording: Teacher 1).

Second, activity materials (e.g., fabric samples) were also used as thought-provoking prompts to encourage students to ask questions. For example, Teacher 2 said, "Now, imagine yourself as a raincoat designer, ... Yes, as many of you are thinking, our teacher gave us a set of pieces of fabric. "What are we doing now?" (Video recording: Teacher 2) and asked students to think about the unusual situation. Thus, she triggered the curiosity of the students and presented the problematic situation. This also aided dialogues with students about the kinds of questions that may lead to an investigation. For example,

"What I'm asking you to do is to decide which one I'd prefer if I made a raincoat." (Video recording: Teacher 3)

"There are four different types of fabrics recommended for you to design raincoats. You need to choose one of these fabrics. How to choose the most suitable fabric? (Video recording: Teacher 2)

They ensured that students were involved in the planning of the investigation and provided some procedures for making decisions about how the fabrics would be tested.

Teacher 3: How can we test this? How can we measure it? ...

...

Teacher 3: Well, you said (water) sliding, how can you test this? Can you keep the fabric in oblique plane? For this, I can give you this oblique plane... (video recording: Teacher 3)

They also pushed students to consider and guarantee that some variables remain fixed, thus students enabled only the variables under investigation to change. As a result, they were able to assist students in comparing fabrics and examining fabric types through fair testing.

Teacher 3: Now I'm going to ask you, how many drops of water do you plan to drip into this... well into this..., what about other fabrics?

Student: Two drops

Teacher 3: Why two?...

Teacher 3: You're saying it must be equal, so I'm going to ask you this. You dribbled two drops, and if it's passing it down, you're going to say, good for designing a raincoat? Will you measure the duration? (Video recording: Teacher 3)

They also assisted students in taking notes and recording findings on worksheets in a systematic way. They did, however, provide a framework for recording and organizing their data in different ways. Thus, students designed

detailed representations of their investigation plans.

Representations of Students' Own Investigations

The findings demonstrate that students developed a huge spectrum of fair-testing procedures to solve the problem:

Among the fabrics provided to you, you have only to determine the most appropriate and feasible fabric for the manufacturing of raincoats. How do you select the best fabric?

Thus, they collected different types of evidence in the line of their observations. Classroom records demonstrate that teachers encouraged students to join in group discussions and assisted them in planning their testing plans independently at the beginning. Then they assisted groups in considering variables, what was changed and what was kept under control, and trying to set up fair-tests as appropriate. As a result of these instructional practices, some of the students tested fabric samples, including nano-hydrophobic textiles, for water repellent or waterproof capacity (see Table 3).

Table 3. Student Investigation Plans and Classroom Practices - Water Repellent Capacity

Testing metot	Students' testing plans	Students' observations
water-repellenting/water-proofing capacity <i>Observation: Duration</i>		
water-repellenting/water-proofing capacity <i>Observation: Quantity</i>		

The students attempted to understand the phenomenon of why the fabrics react in an obviously unexpected way in terms of water repellent or waterproof capacity. Thus, they were encouraged to think more deeply about how this unusual situation could be solved, which prompted emotions of wonder, excitement, and curiosity. Some students got materials from the teachers that might be used as oblique surfaces and developed their investigation designs for fabrics' water-sliding capacity. And they concentrated on choosing the best fabric that could quickly slide the water from its own surface (see Table 4).

Table 4. Student Investigation Plans and Classroom Practices - Water-Sliding Capacity

Testing metot	Students' testing plans	Students' observations
water-sliding capacity <i>Observation: Quantity</i>		
water-sliding capacity <i>Observation: Duration</i>		

Table 5. Student Investigation Plans and Classroom Practices - Water-Absorption Capacity

Testing metot	Students' testing plans	Students' observations
water-absorption capacity <i>Observation: Duration</i>		
water-absorption capacity <i>Observation: Quantity</i>		
water-absorption capacity <i>Observation: Quantity</i>		

In relation to the same fabric sample sets, the formulation of different investigation questions and the development

of various investigation strategies against them in a learning environment let students gain a better understanding of scientific practices. Moreover, multiple data sets were generated in the teaching / learning process to encourage students to consider what all their observations may mean and how they might be interpreted. Some of these data sets were related to how quickly the fabrics would absorb water or how much water they would absorb (Table 5).

Students encountered instructional challenges that required them to consider multiple variables together. Nano-sized manipulations of fabrics were made for this purpose using water repellent sprays. Water repellent characteristics were given to two types of fabrics in the activity: extremely thick and very thin. During the decision-making process, students had to select between two fabrics with equal water repellent properties. As a result, they had to consider different variables while interpreting their findings. It has been observed that they discuss manufacturing and user preferences such as textures, colors, weights, and thicknesses of fabrics in their practices.

Discussion and Conclusion

The primary purpose of this paper was to learn more about the potential of a nanotechnology activity to encourage students to formulate and implement authentic science investigations. In accordance with the background described in the introduction and method sections, it is worth focusing on the finding from the three different perspectives. *In teacher development perspective*, the results of this research provide supporting evidence that all case teachers engage in qualified and skilled interactions with students to formulate and implement authentic science investigations. Previously, researchers identified that supporting teachers in developing their own inquiry-based lessons and engaging them in authentic research experiences could be the missing link in implementing inquiry-based instruction (Capps et al., 2012). Crawford (2016) stated that teachers should be provided ample opportunity to experience in authentic scientific inquiry in contexts that are similar to those in which they would engage students in their classes. In furtherance, the current study provides supporting evidence that the authentic activities described in this paper can be a tool for them to experience authentic investigations in their own class. These findings are in line with earlier research, which implies teachers expect their needs for gathering resources, examples, and activities to be addressed to guarantee effective teaching (Paik et al., 2011). *In students' authentic inquiry experiences perspective*, the findings indicate that because of teachers' effective and efficient implementation of teacher-student interaction in supporting students' own investigations, students defined a huge spectrum of fair-testing procedures to deal with the problems.

This existing evidence is consistent with previous literature, which suggests that the tasks that instill developing the thinking strategies, making hypotheses, weighing different solutions, and looking for the consequences of investigations into students could be mediators of authentic science inquiries (Liljeström et al., 2013). In addition, it has been expressed by teachers as a very realistic task rather than an artificial for students to find the most suitable fabric. The present result is consistent with van Eijck & Roth's (2009) work that deals with how "authentic" science experiences may mediate students' orientations towards science. *In a nanotechnology or nanoscale hands-on activity perspective*, the present study is the first direct demonstration that nanoscale modifications designed to focus on nano fabrics related to the self-cleaning application area of nanotechnology

are an effective option for encouraging students to design authentic investigations. Studies have revealed several different school activities such as nanoscale science awareness, nanotechnology-related activities (e.g., stain testers, magic sands), nanoscale materials (e.g., Lotus effect), imitation of a natural gecko foot, and investigation into silver nanoparticles as antimicrobial agents (Ghattas & Carver, 2012). The most persuasive explanation for the current set of findings, in my view, is that the activity was much more than a small piece of evidence to demonstrate case teacher development. Taken together, our findings strongly implied that the "Can Nanotechnology Keep Us Dry in the Rain?" activity with the lack of visible access to nanoscale changes on fabrics enables case teachers to provoke their students to deeper inquiry.

There are at least three potential limitations concerning the results of this study. The first limitation is the context of the in-service training program that provides the platform for the activity discussed in this paper. Although the present results clearly support the potential of the defined activity to allow students to engage in authentic scientific inquiry, several interventions on teacher understanding should be recognized as potential limitations resulting from teachers' in-service training, interactions with researchers, and the support of the kits provided. A second potential limitation is that the activity only focuses nano fabrics related to self-cleaning application area of nanotechnology.

Despite these limitations, these results suggest several theoretical and practical implications. One is that teachers' experience of authentic activities through the materials, worksheets, and a teacher activity manual in their classrooms may help them acquire a holistic understanding of inquiry-based science practices. Second, this study suggests that scientific practices, particularly authentic scientific inquiry, might be used as an insertion point to integrate nanotechnology concepts and applications into science education. As a result, it contributes to a growing body of evidence revealed by earlier studies (e.g., Ghattas & Carver, 2012; Mandrikas et al., 2020; Sakhnini & Blonder, 2016). The study offers insights deeply into one of the teacher trainings visits that evaluates teacher development in long-term practices; it would be useful to extend the current findings by examining the sequential courses to develop a more holistic understanding of teacher development and how they assist students with new or unanswered questions arising from their authentic investigations. Also, further research in the areas of nanomedicine, nanoelectronics, photovoltaic cells, nanobots, and self-cleaning (as indicated by Sakhnini & Blonder, 2016) may give insight on the integration of nanotechnology into science education. The present research, therefore, contributes to a growing body of evidence suggesting the direct demonstration of conducting hands-on investigations to formulate and implement the investigations of nanoscale phenomena.

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