Full research paper

EXPLORING THE EFFECTS OF EXPLICIT SCIENCE PROCESS SKILL INSTRUCTIONS ON PRIMARY SCHOOL PRE-SERVICE SCIENCE TEACHERS NATURE OF SCIENCE CONCEPTION

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ABSTRACT

Informed Nature of Science (NOS) conception is among the professional competencies of science teachers. As a result, extensive research is being conducted on the development of NOS conceptions among pre-service science teachers (PSSTs). However, it remains a significant challenge, particularly because NOS is a meta-concept that necessitates higher-order cognitive skills. In this study, we explored the influence of explicit Science Process Skill (SPS) instruction on the PSST's NOS conception using a quasi-experimental pretest-posttest design with experimental and control groups. SPS is instructed using the four-component instructional design (4C/ID) model. Findings indicated that PSSTs had a less informed conception of NOS, its various themes, and laws vs. theories and methodologies in scientific investigation. Observation and inference, the tentativeness of scientific theories/knowledge, the existence of creativity and imagination in science, and scientific methodology were significant themes of NOS.

On the other hand, laws vs. theories and society and cultural influence on science themes do not show significant improvements. This study demonstrated that explicit SPS instruction is a better framework for developing specific themes of NOS conception. However, it also highlighted the limitations of a single method in altering entire themes, emphasizing the need for an appropriate method for each theme.

KEYWORDS

Explicit skill instruction, four-component instructional design, nature of science, science process skill

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Highlights

- *PSSTs had a less informed conception of NOS as a whole and its various themes.*
- *Explicit SPS instruction significantly improved observation and inference, the tentativeness of scientific theories/ knowledge, the presence of creativity and imagination in science, and the NOS themes of scientific methodology.*
- *A single method has limitations for developing all NOS themes; thus, it needs to adopt an appropriate strategy for each theme.*

INTRODUCTION

Improving students' scientific literacy is a pivotal objective in primary school science education and is advocated by various national educational standards (Neumann et al., 2017). A comprehensive grasp of the Nature of Science (NOS) constitutes a fundamental aspect of scientific literacy. Furthermore, it is recognized as a crucial professional competency of science teachers. Research shows that science teachers with an informed understanding of NOS effectively integrate NOS teaching methodologies into their classrooms (Capps & Crawford, 2013) and are more adept at cultivating dynamic inquiry-based learning settings (Abd-El-Khalick, 2013). Driver et al. (1996) highlighted five benefits of students learning about the NOS, namely: understanding the science process, making informed decisions on socio-scientific issues, appreciating science, being aware of scientific community norms, and learning deeper science content. Nevertheless, prior studies have revealed that the majority of both in-service and pre-service science teachers (PSSTs) harbor misconceptions about NOS (Abd-El-Khalick and Akerson, 2004; Liang et al., 2009; Cofre et al., 2019).

Teachers' preparation at the higher education level is a crucial stage for professionalization and competence enhancement, making it an essential initial step in fostering an informed understanding of the NOS. Various research studies have previously been conducted to identify effective strategies for improving PSSTs' understanding of NOS in their preparation programs. The widely used strategies are implicit and explicit instructions. Implicit instruction strategies involve using the history of science and hands-on inquiry-based scientific activities (Khishfe & Abd-El-Khalick, 2002; Allchin et al., 2014). On the other hand, explicit instructions are provided through NOS themes in explicit-reflective (stand-alone topic) form or integrated into a scientific context (Bell et al., 2011). Mesci and Schwartz (2017) highlight that efforts to enhance PSSTs' NOS have been limited successes, since it is more difficult to understand certain aspects of NOS than others. According to Erduran and Kaya (2018), one critical reason is that the NOS is a metacognitive concept that demands higher-order cognitive skills.

Science process skills (SPS) are cognitive and psychomotor skills used by scientists to investigate and acquire scientific knowledge (Ozgelen, 2012). They encompass scientific practices such as observation, experimentation, prediction, data analysis and interpretation, inference, and hypothesis formulation. Several studies (Dirks & Cunningham, 2006; Coil et al., 2010; Shah & Hoeffner, 2002; DebBurman, 2002; Kruit et al., 2018; Aktamis & Ergin, 2008; Aslan & Kilic, 2022) indicated explicit instruction of SPS was effectively used for the development of SPS among students and teachers. For instance, Kruit et al. (2018) argued that explicit instruction of inquiry skills by using a four-component instructional design model (4C/ID) (Van Merrienboer et al., 2002) effectively aids in the acquisition and transfer of students' science inquiry skills across various content areas. Moreover, studies indicate SPS developments are helpful for mastery of contents in constructivist, discovery, problem-based, experiential, and inquiry-based teaching approaches (Kirschner et al., 2006; Lazonder & Harmsen, 2016), improve students' control of variables when combined with practice (Dean & Kuhn, 2007), aid in metacognitive skill development (Tanner, 2012), and play a crucial role in facilitating the transfer of skills beyond the initial learning environment (Klahr & Li, 2005).

Studies that focus on the contribution of SPS development through explicit instruction on NOS conception are limited in the literature. Researchers argue that NOS conceptions are connected to understanding how knowledge is built (Abd-El-Khalick & Akerson, 2004) and involve metacognitive concepts that demand higher-order cognitive skills (Erduran & Kaya, 2018). SPS are among the ways of doing science and metacognitive skills. This study explores PSSTs' understanding of NOS and the effect of 4C/ID-based explicit SPS instruction on their NOS conceptions in science. The study hypothesizes that enhancing PSSTS's SPS practices will positively impact their NOS conceptions, considering the overlap and mutuality between these themes. We included the following section: literature reviews on SPS and NOS conception; the study's methodology, including the basic concepts of the four-component instructional design; results on NOS conceptions and their change due to the intervention; discussions; and, finally, conclusions.

REVIEW OF LITERATURE

Science Process Skills (SPS)

SPSs are the foundational abilities that develop and are utilized in the process of scientific inquiry and investigations. They are typically categorized into basic and integrated skills (AAAS, 1967). Basic skills encompass: observation, measurement, classification, inference, prediction, communication, and questioning. Conversely, integrated skills include: defining operations, identifying and controlling variables, formulating hypotheses, conducting experiments, analyzing and interpreting data, graphing, and modeling processes. These skills are universally transferable; therefore, they are not only essential in science classrooms but also in various aspects of everyday life and in other academic disciplines.

The development of SPS among teachers is crucial for enhancing the quality of science education. Evidence from research indicates teachers with strong SPS have the capability to design and facilitate engaging, inquiry-based lessons that promote active learning (Anderson, 2002), promote student academic achievement, critical thinking, and problem-solving skills, and mastery of subject matter (Susantia et al., 2018), and introduce effective learning and development of SPS among students (Mutisya et al., 2013). Teachers with a deep understanding of SPS can contribute to the development of curriculum materials that align with best practices in science education (Bybee, 2013) and to more effective and accurate assessment of students' understanding of SPS (National Research Council, 2014). Moreover, Bybee (2013) suggests that teachers cultivating their own SPSs foster a similar learning mindset, incorporate new technologies, and promote a culture of scientific discovery and innovation in their classrooms.

Gizaw and Sota (2023) provided a detailed review of the literature on possible strategies for developing science process skills across studies. The findings revealed that integrating SPS into curricular materials, classroom lesson presentations, and assessments, using multiple-representation teaching approaches, and explicitly instructing students in science process skills help develop students' science process skills. Multiple representation teaching approaches involve employing various teaching methods, such as descriptive, mathematical, analogical, and kinesthetic, in combination in the same lesson or using multiple media like models, flowcharts, real specimens, and video within the same lesson. Explicit instruction or training of SPS entails utilizing programmed instruction methods by developing teaching or training materials similar to those used for content delivery.

Many studies (Kirschner et al., 2006; Lazonder & Harmsen, 2016) underscore the importance of explicitly teaching skills in constructivist, discovery, problem-based, experiential, and inquiry-based teaching. These studies indicate that more effective learning occurs when the aforementioned teaching methods are accompanied by explicit skill instruction. Research also underlines that explicit skill instruction is more effective when combined with practice. For instance, Dean and Kuhn (2007) showed that explicit instruction, particularly when students were prompted to compare and identify various features of catalogs, improved students' control of variables more when combined with practice. Moreover, explicit skill instruction with a direct focus on task awareness and the utilization of metacognitive strategies could aid in metacognitive skill development (Tanner, 2012). According to Klahr and Li (2005), explicit instruction in skills appears to play a crucial role in facilitating transfer beyond the initial learning environment.

SPSs are rarely explicitly taught to students and scaffolded, as it is believed they are acquired through learning by doing (Dean & Kuhn, 2007). However, researchers argue that SPS needs to be taught with intentionality because it does not develop spontaneously (Zimmerman, 2000). There is ample evidence that explicit instructions foster SPS and related variables. For instance, Dirks and Cunningham (2006) reported that providing explicit instructions on SPS helps undergraduate students enhance SPS, content acquisition, and interdisciplinary thinking. Coil et al. (2010) noted earlier that explicit teaching of SPS is essential to improving student success and retention in the sciences and to enhancing general science literacy among undergraduate students. Shah and Hoeffner (2002) found that students who received explicit instruction in generating and interpreting scientific graphs benefited from improved learning and reinforcement of course content. Likewise, DebBurman (2002) reported that explicitly teaching SPS integrated with content helped students acquire the content more readily and prompted them to recognize the need to improve their proficiency in these areas. Moreover, Kruit et al. (2018) argued that explicitly teaching SPS effectively improves students' SPS at primary education levels. Aktamis and Ergin (2008) argued that SPS education led to meaningful changes in middle school students' scientific creativity and academic achievement. The literature reviewed confirms that explicit instruction in SPS, implemented systematically and structured for pre-service teachers and other students, significantly contributes to the development of their SPS. In this study, SPSs were instructed in PSSTs using the 4C/ID framework, and their influence on NOS conception was investigated.

Nature of science

According to Lederman (2019), in science education, NOS refers to the values and beliefs of science, the characteristics of scientific knowledge and its production, how science impacts and is impacted by society, and what scientists look like in their professional and personal lives. Science educators view NOS from various perspectives, including the consensus view and the Family Resemblance Approach (FRA). The consensus view conceptualizes NOS as a set of statements, called aspects or themes. As specified by Kampourakis (2016) and Fraser et al. (2012), the most common NOS themes are: observation and inference are different; the tentativeness of scientific theories and knowledge; scientific laws and theories are distinct forms of knowledge; scientific knowledge is influenced by the cultural contexts in which it is developed; scientific knowledge involves human imagination and creativity; and various methodologies are used in scientific investigations. The conceptualization of NOS as tenets is a practical and effective method for teaching and learning NOS in K-12, pre-service, and in-service teacher education (Fraser et al., 2012). Moreover, it enables us to easily address misconceptions about how science works and what scientific knowledge is among teachers and students.

FRA conceptualizes the branches of science as a family, where each member is unique yet shares common features. In each science domain, features such as aims and values, methodologies and methodological rules, scientific activities, and the products of science (knowledge) are applied to describe and explain science and to conduct analysis (Matthews, 2014). This makes FRA widely applicable to various branches of science. FRA is further refined into the Reconceptualized Family Resemblance Approach to Nature of Science (RFN) by including social-institutional aspects of science, such as political and financial dynamics, social hierarchies, and organizational factors, as these factors significantly influence science operations (Erduran & Dagher, 2014). Although we acknowledge the multiple competing ways to conceptualize NOS for K–12 students and teachers, we adopt a consensus conceptualization of NOS in this study. This method is practical and effective in teaching and learning, addressing misconceptions about science and its workings (Kampourakis, 2016).

Effective teachers who are well-equipped with professional competencies are critical factors for student learning. Informed conceptions of NOS are among the professional competences of science teachers. For instance, science teachers with adequate NOS conceptions integrate NOS teaching practices in their classrooms (Capps & Crawford, 2013). They are more adept at cultivating dynamic inquiry-based learning settings (Abd-El-Khalick, 2013). Several studies have shown that pre-service teachers' NOS conceptions are naïve, uninformed, and mixed (Abd-El-Khalick & Akerson, 2004; Liang et al., 2009; Cofre et al., 2019; Mesci, 2020; Zion et al., 2020; Wang et al., 2023).

More frequently, science education researchers apply implicit and explicit NOS instruction approaches to their development. According to Khishfe and Abd-El-Khalick (2002), the implicit approach uses hands-on inquiry-based activities and the historical context of science to teach certain aspects of the NOS, viewing NOS conceptions as a hidden outcome. The explicit approach focuses on the deliberate and systematic teaching of the NOS, presenting philosophical concepts and exercises directly to foster a comprehensive understanding of the NOS as a stand-alone topic or integrated into a scientific context (Khishfe & Abd-El-Khalick, 2002; Allchin et al., 2014). Studies show that explicit instruction is more effective than implicit instruction in promoting NOS understanding, regardless of whether it's explicit-reflective (standalone topic) or embedded in a specific context, such as specific science content, the history of science, socio-scientific issues, or science inquiry (Bell et al., 2011; Fraser et al., 2012).

Mesci and Schwartz (2017) argued that efforts to enhance PSSTs' NOS have been limited successes, even when explicit-reflective instruction is provided. Some aspects of NOS are more difficult to understand than others. This highlights the difficulty in producing comprehensive NOS understanding through specific strategies and encourages the exploration of suitable strategies for specific NOS themes. Regarding several alternative strategies for either approach, different researchers have tested them. For instance, Bell et al. (2016) used a context continuum approach, combining highly science-content-contextualized and non-contextualized approaches. The results indicated that teaching and scaffolding NOS lessons along a science content context continuum can be effective in eliciting desired changes in preservice teachers' NOS conceptions.

On the other hand, Abd-El-Khalick and Akerson (2009) explored the influence of metacognitive training on preservice elementary teachers' conceptions of NOS. The results point to a relationship between improved metacognitive awareness and the development of informed understandings of NOS. More recently, Erduran and Kaya (2018) used visual representations of scientific knowledge and practice aspects as tools for developing and monitoring understanding of NOS conception among PSSTs. Their findings indicated improvements in pre-service teachers' perceptions of the NOS.

SPS focuses on practical methods and techniques used in scientific investigation, while NOS delves into the underlying beliefs about knowledge and its acquisition process. SPS and NOS are not mutually exclusive; rather, they interact (Abd-El-Khalick & Akerson, 2004). For instance, observation and inference are found in both SPS and NOS. Moreover, SPS skills such as observation, experimentation, classification, and prediction serve as methodologies for producing scientific knowledge, which is among the themes of NOS (Erduran & Kaya, 2018). Thus, issues related to NOS can be addressed within the framework of explicit SPS instructions. For instance, Bell et al. (2011) assessed the effect of a process skills-based instruction approach on the NOS views of 17 pre-service teachers. The study found that the process skills-based approach effectively develops informed NOS conceptions among pre-service teachers. Research exploring the relationship between SPS and NOS development is sparse. Specifically, there is a lack of studies investigating how explicit instruction in SPS influences NOS understanding of PSSTs.

Research questions

NOS conception plays a crucial role in enhancing a deeper understanding of science content knowledge, how science works, and how scientific knowledge is generated (Driver et al., 1996). The study aims to investigate the impact of explicit SPS instruction on PSSTs' conception. Therefore, our study addresses the following research questions:

RQ 1. What are the NOS conceptions of PSSTs?

RQ 2. How and in what ways do NOS conceptions of PSSTs affect by explicit SPS instructions?

MATERIAL AND METHODS

Participants

This research enlisted 69 PSSTs undergoing training to teach science subjects in primary schools at Arba Minch Education College. All participants had a science background from their high school education and were in their second year of pre-service teacher training, taking their initial science courses at the college level, including General Biology, General Physics, and General Chemistry. Of the 69 students, 36 were male, and 33 were female, with ages ranging from 18 to 24 years.

Research design

The study used a quasi-experimental pretest-posttest controlled-group design, with participants randomly assigned to either the experimental or control condition. The experimental group received the recruitment: pre- and post-test, pre- and post-interview, and intervention through explicit SPS instruction. In contrast, the control group received only pre- and post-test and pre- and post-interview. The interview comprised 12 participants, including six from the control group and six from the experimental group, selected based on their pre-test scores. In each group, three PSSTs had the lowest pre-test scores, while the remaining three had the highest. The pre-interview took place during the second week of the semester, and the post-interview occurred one week before the semester's conclusion. The aim of the interview was to understand participants' NOS conceptions before and after the intervention.

Intervention strategy

The intervention was undertaken using the four-component instructional design model (4C/ID) developed by Van Merriënboer et al. (2002). According to the designers, it is a new approach to training programs for complex skills where transfer is the primary learning outcome rather than content knowledge. In the past, the common practice was to teach individuals by starting with smaller components or tasks and gradually building up to the complete task. However, the new whole-task approach, known as the 4C/ID model, reverses this process. Instead of starting with parts and moving towards the whole task, individuals are first exposed to simplified versions of the entire task, with complexity gradually increased until the complete task is mastered. The 4C/ID model comprises four components: two task components (learning tasks and part-task practice) and two information components (supportive information and just-in-time information). It was used by Krui et al. (2018) and found to be effective for developing students' science inquiry skills and for their transfer across different contexts.

Learning or whole tasks are concrete and authentic experiences that provide meaningful scientific inquiries for learners, integrating skills, knowledge, and attitudes. They include case studies, projects, and problems organized in easy-to-difficult task classes. Part-task practice is a method of strengthening skills through repeated exposure and practice. It involves refining specific aspects of a skill, allowing learners to perform routine tasks automatically without conscious thought. This process is crucial for achieving proficiency and mastery of the overall task.

Supportive information is crucial for students to undertake tasks or engage in scientific inquiry, yet they often lack it. It is provided early and during task engagement through lectures, data organization exercises, and systematic problem-solving approaches. Supportive information can explain problem approaches, suggest domain organization, or offer foundational knowledge. It bridges learners' existing knowledge with what they need to work on in learning tasks. The process of learning from supportive information is elaboration, connecting new information to existing knowledge. Just-in-time or procedural information refers to the necessary information needed during tasks, such as essential clues, knowledge, feedback, and prompts, to help students gain proficiency in skills. It outlines how to perform routine tasks until students gain proficiency in the skills, and then withdraw gradually. Knowledge compilation is the fundamental mechanism for learning from just-in-time information. It involves assimilating new information into cognitive rules.

For SPS instruction, an explicit instruction manual was prepared based on a 4C/ID model developed by researchers. The manual contains 12 SPS for instruction: basic SPS (observation, classifying, measuring, and using numbers, making inferences, predicting, and communication) and integrated SPS (defining operationally, identifying and controlling variables, interpreting data, making hypotheses, experimenting, graphing, and modeling). The selected tasks offered practice variability and opportunities, appropriate difficulty levels, and optimal support and guidance. Task classes were sequenced from easy to difficult, with performance objectives set for each task to assess student performance and provide feedback. Supportive and procedural information was designed for each task based on cognitive rules, mental models, and prior knowledge. Finally, part-task practice was used sparingly in learning tasks to enhance performance on routine aspects of the task when a high level of automaticity was desired. The prepared material underwent validation by two science education experts to determine its suitability for training SPS skills. The SPS instruction was provided to pre-service teachers for approximately 12 weeks. One science teacher educator, assigned from Arba Minch Education College, conducted the instruction under the researcher's supervision.

Data collection tool

The students' understanding of science and scientific inquiry scale (SUSSI) questionnaire is used to collect data. SUSSI is an instrument designed with both Likert-scale and open-ended components to provide opportunities for in-depth study of NOS views among pre-service teachers (Liang et al., 2008). The questionnaire considers only six themes or aspects of NOS: observations and inferences; the tentative nature of scientific theories/knowledge; scientific laws and theories; social and cultural influences on science; imagination and creativity in scientific investigations; and methodology in scientific investigations. Each theme consists of four Likert items (covering both the most common naive and informed views, as well as positive and negative items) and one open-ended question. Therefore, the scale comprises 24 items and six open-ended questions. An analysis was made after negative items were scored reversely. The Cronbach's alphas of the subscales are: observations and inferences (0.61); tentative nature of scientific theories (0.56); scientific laws vs. theories (0.48); social and cultural influence on science (0.64); imagination and creativity in scientific investigations (0.89); and methodology in scientific investigations (0.44). The overall Cronbach's alpha for the entire instrument is 0.69. The SUSSI open-ended questions were used for a semi-structured interview.

Data analysis

Quantitative data were analyzed using descriptive and inferential statistics (paired-samples t-test, independent-samples *t*-test, and repeated-measures MANOVA) in the Statistical Package for the Social Sciences (SPSS). Normality assumptions were assessed using skewness and kurtosis, and Levene's test was used to assess homogeneity of variances. The sex comparability of groups was assessed using a chi-square test, while the academic and pre-test comparability was checked using an independent t-test. The effect size indicates the relative magnitude of differences or relationships between groups. Qualitative data from interviews were analyzed using the SUSSI rubrics for open-ended questions (Liang et al., 2009), which classify responses for each NOS theme into: not classifiable, naïve, transitional, and informed. Views reported is not classifiable if: there is no response; they state that they do not know; the response does not address the prompt, naïve if the participant's views did not agree with currently accepted consensus view of that particular aspect of NOS (example: Scientists' observations AND/OR interpretations are the same because scientists are objective), transitional if the participant's views agree with currently accepted consensus view of that particular aspect of NOS, but lacks appropriate explanations, justifications or examples (example: the observations AND/OR inferences may be different) and informed if the participant's views agree with currently accepted consensus view of that particular aspect of NOS and contain appropriate explanations, justifications and examples (example: Scientists' observations and inferences may be different because of their prior knowledge, personal perspective, or beliefs).

RESULTS

Prior intervention NOS conceptions

Initial data checks revealed that the distributions of NOS scores for each NOS theme met the assumptions necessary for the analysis of variance. The data for each NOS theme and the overall NOS were found to be normally distributed based on kurtosis and skewness tests. Additionally, Levene's test indicated that the data were homoscedastic. The experimental and control groups were comparable in terms of sex, academic grade point average (GPA), and pre-test scores on four NOS themes (observation and inferences, social and cultural influence on science, imagination and creativity in scientific investigations, and methodology of scientific investigation). For our study sample, the Cronbach's alphas of the pre-test and post-test subscales are as follows: 0.56 and 0.59 for observation and inferences, 0.54 and 0.53 for the tentative nature of scientific theories, 0.47 and 0.61 for scientific laws vs. theories, 0.65 and 0.62 for social and cultural influence on science, 0.73 and 0.66 for imagination and creativity in scientific investigations, and 0.43 and 0.61 for methodology in scientific investigations, respectively. The pre-test and post-test overall Cronbach's alphas for the entire instrument are 0.70 and 0.84, respectively. The low Cronbach's alpha could be attributed to the small sample size and the presence of negative items in each subscale.

The descriptive statistics from the pre-test (Table 1) indicate that the PSSTs exhibited less informed conceptions regarding observation and inferences, the tentativeness of scientific theories, social and cultural influences on science, and imagination and creativity in scientific investigations. Conversely, they held uninformed views regarding laws vs. theories and the methodology of scientific investigation. Generally, the pre-test data indicate that the PSSTs' NOS conception is not at an adequate level across the overall and specific NOS themes.

NOS themes	Pre-tests		Post-test	
	M	*SD*	*M*	*SD*
Observation and inferences	3.27	.86	3.78	0.87
Tentativeness of scientific theories	3.45	.89	4.06	0.72
Scientific Laws Vs. theories	2.91	.67	3.07	0.87
Social and cultural influence on science	3.23	.96	3.62	0.9
Imagination and creativity in scientific investigations	3.43	.98	3.71	0.9
Methodology of scientific investigation	3.04	.75	3.49	0.97
Overall NOS conception	3.22	.47	3.62	0.6

Table 1: Pre-and post-test of all participants (*N* = 69) (Source: own calculation)

Changes in NOS conception

Table 2 displays the descriptive statistics for the pre- and post-tests of the experimental and control groups, along with the interactions between the groups (experimental and control) and the pre- and post-tests. On each NOS theme and overall NOS conception, examined through repeated measures MANOVA. The descriptive statistics reveal a general increase in scores from pre- to post-test for NOS themes in both groups, except for the social and cultural influence on science theme within the control group. Analysis using Wilks's statistic for within-subjects effects indicated significant time and group interactions in the NOS themes: observation and inference ($\Lambda = .89$, F(1,67) = 8.5, $p = 0.005$, $\eta^2 = 0.113$), tentativeness of scientific theories ($\Lambda = .81$, $F(1,67) = 8.84$, $p = 0.00$, $\eta^2 = 0.19$), imagination and creativity in scientific investigations ($\Lambda = .91$, $F(1,67) = 6.93$, $p = 0.01$, $\eta^2 = 0.094$), methodology of scientific investigation ($\Lambda = .89$, $F(1,67) = 8.148$, $p = 0.006$, $\eta^2 = 0.108$), and overall NOS conception ($\Lambda = .83$, $F(6,67) = 13.7$, $p = .00$, $\eta^2 = .17$). This was further supported by paired *t*-tests, indicating a significant increase in observation and inferences ($t(67) = 2.96$, $p = .004$), tentativeness of scientific theories ($t(67) = 3.4$, $p = 0.001$), imagination and creativity in scientific investigations ($t(67) = 2.15$, $p = 0.035$), methodology of scientific investigation ($t(67) = 3.091$, $p = 0.003$), and overall NOS conception ($\Lambda = .83$, $F(1,67) = 13.7$, $p = .00$, $\eta^2 = .17$) within the experimental group (Table 3). However, the effect sizes for the time-by-group interaction were small for each NOS theme and for the overall NOS conception.

NOS themes	Experimental group (*n* = 36)				Controlled group (*n* = 33)						
	Pre-test		PostPre-test		retest		Post-test		Time *group interaction		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*P*	Partial η^2
Observation and inferences	3.22	0.93	4.06	0.75	3.32	0.97	3.47	0.89	8.51	0.005	0.11
Tentativeness of scientific theories	3.22	0.87	4.32	0.55	3.69	0.85	3.77	0.77	8.84	0.00	0.19
Scientific Laws Vs. theories	2.78	0.62	2.94	0.98	3.05	0.7	3.2	0.73	0.003	0.95	0.00
Social and cultural influence on science	3.06	0.95	3.64	0.82	3.42	0.95	3.59	0.99	1.81	0.183	0.03
Imagination and creativity in scientific investigations	3.32	0.94	3.93	0.79	3.55	1.03	3.48	0.79	6.93	0.01	0.09
Methodology of scientific investigation	3.01	0.78	3.8	0.81	3.08	0.78	3.13	1.02	8.148	0.006	0.11
Overall NOS conception	3.10	0.44	3.78	0.42	3.35	0.47	3.44	0.71	13.7	0.00	0.17

Table 2: Mean scores and the interaction effects (time of measurement * group) for each NOS theme (Source: own calculation)

Paired-samples *T*-tests were employed to assess the mean differences between pre- and post-scores for each of the six NOS themes and the overall NOS conception in both experimental and control groups. The results indicate significant differences (increases) between pre- and post-scores for all five NOS themes except for Scientific Laws vs. Theories ($p = 0.36$) in the experimental group (Table 3). Similarly, paired-samples *t*-tests on pre- and post-scores for each of the six NOS themes in the control group reveal no significant differences. Following Cohen et al.'s (2018) classification of effect sizes, observation and inferences, the tentativeness of scientific theories, the methodology of scientific investigation, and the overall NOS conception exhibited strong effect sizes, while social and cultural influence on science, and imagination and creativity in scientific investigation, demonstrated moderate effect sizes. Conversely, scientific laws vs. theories displayed a poor effect size in the experimental group (Table 3). All six NOS themes and the overall NOS conception exhibited poor effect sizes in the control group.

NOS themes	Experimental group (N = 36)				Controlled group (N = 33)			
	t	*df*	*Sig.*	Effect size (Cohen's *d*)	*t*	*df*	*Sig.*	Effect size (Cohen's *d*)
Observation and inferences	-5.628	35	.000	1	-.828	32	0.414	0.18
Tentativeness of scientific theories	-6.342	35	.000	1.55	-.432	32	0.669	0.1
Scientific Laws Vs. theories	-.927	35	.360	0.2	-.803	32	0.428	0.21
Social and cultural influence on science	-2.586	35	.014	0.67	-.870	32	0.391	0.17
Imagination and creativity in scientific investigations	-3.401	35	.002	0.7	.400	32	0.692	0.07
Methodology of scientific investigation	-4.337	35	.000	1	-.287	32	0.776	0.08
Overall NOS conception	-6.380	35	.000	1.58	-.749	32	0.459	0.15

Table 3: Paired t-test comparison for Experimental and Controlled groups pre- to post-test means (source: own calculation)

Comparisons of experimental and control group post-tests using independent *t*-tests revealed statistically significant differences between the groups in NOS themes: observation and inferences, tentativeness of scientific theories, imagination and creativity in scientific investigations, methodologies in science, and overall NOS conception (Table 4). For these NOS themes, as per Cohen et al. (2018), the effect sizes were moderate.

NOS themes	*t*	*df*	*Sig.*	Effect size (Cohen's *d*)
Observation and inferences	2.963	67	0.004	0.71
Tentativeness of scientific theories	3.405	67	0.001	0.82
Scientific Laws Vs. theories	-1.239	67	0.220	0.3
Social and cultural influence on science	.220	67	0.827	0.05
Imagination and creativity in scientific investigations	2.148	67	0.035	0.52
Methodology of scientific investigation	3.091	67	0.003	0.75
Overall NOS conception	2.465	67	0.016	0.6

Table 4: Independent *t*-tests for post-test mean comparison of each theme and overall NOS conception (Source: own calculation)

The interview responses corroborated the quantitative findings, demonstrating significant improvements in various aspects of NOS within the experimental group. The existing literature on PSSTs' NOS conception suggests that informed conceptions are characterized by a viewpoint on which scientific agreements are reached and by providing appropriate explanations, justifications, and examples. The following sections delve into the development of participants' specific NOS conceptions, supported by interview data. Sample responses from participants (three from each group) and their corresponding levels of NOS conception are presented in Tables 5 and 6. The interview responses are detailed, including the individual's identifier, their group (experimental or control), the interview phase (pre- or post-interview), and their specific level of NOS conception. For instance, 1E-2: *naïve* refers to the first participant in the experimental group exhibiting a naïve conception during the second interview.

Prior to intervention, the observation and inference NOS theme appeared to be more transitional among participants in both groups. However, post-interview findings revealed that the experimental group (1E-2: *Informed*; 2E-2: *Informed*; 3E-2: *Informed*) showed greater improvements in their conception levels for the NOS theme of inference and observation than the control group (1C-2: *Transitional*; 2C-2: *Naïve*; 3C-2: *Informed*). Regarding the tentative nature of NOS scientific theories, participants in both the experimental and control groups held similar conceptions in pre-test interviews. Most of them indicated that scientific theories do not change (1E-1: *Naïve*, 3E-1: *Naïve*, and 2C-1: *Naïve*). However, participants in both groups had informed conceptions of this theme before the interventions (2E-1: *Informed* and 1C-1: *Informed*). Following the intervention, the NOS conceptions of the tentativeness of scientific theories/knowledge among most participants in the experimental group shifted more positively than those in the control group (1E-2: *informed*; 2E-2: *informed*; 3E-2: *informed*).

In both groups, the PSSTs' conception of the scientific theory vs. law NOS theme was predominantly naïve and difficult to classify. Following the intervention, the pre-interview conceptions were largely retained in both groups. Conversely, regarding social and cultural influence, the controlled group exhibited a more positive pre-interview stance (1C-1: *informed*; 3C-1: *informed*) compared to the experimental group (1E-1: *Naive*; 3E-1: *Naive*). While participants in the experimental group (1E-2: *transitional*; 3E-2: *transitional*) showed improvements in conception, most participants in the control group maintained their pre-interview conceptions.

In the pre-interviews of both experimental and control groups, the presence of imagination and creativity was perceived as naïve and transitional. However, qualitative data suggested that positive

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progress was more evident in the experimental group (1E-2: *informed*; 2E-2: *informed*; 3E-2: *informed*) compared to the control group (1C-2: *transitional*; 2C-2: *transitional*; 3C-2: *transitional*) in the post-interview. Most participants in both groups held a naïve conception of the methodology of scientific investigation prior to the interview. Following the intervention, the experimental groups significantly shifted their conception to an informed level, whereas no progress was observed in the control group.

NOS theme	Pre-interview	Post-interview
Observation and inferences	I think it is the same, because all scientists are critical workers. (1E-1: *Naive*)	It is different. Some scientists may make critical observations while others make shallow ones. This makes them have different information from their observation. Since what they observed differs, their inferences may differ as well. (1E-2: *Informed*)
	It is different. One thing cannot be observed in the same way by different scientists. (2E-1: *Tranistional*)	Not the same. It is different. Individuals' prior knowledge and experience affect their observations. For example, in our laboratory classes, we do not always observe the same thing in the same way. Also, students sometimes make different inferences from the same observation. (2E-2: *Informed*)
	I feel it would be different. I think it may depend on the human. (3E-1: *Transitional*)	They do not make the same observations and inferences. It can be the same for certain events, yet different as well. Observation may depend on the sense organs and instruments used. (3E-2: *Informed*)
Tentativeness of scientific theories/ Knowledge)	Scientific theories do not change. Theories are established after several critical experiments. (1E-1: *Naive*)	Theories change. Theories are formulated based on experimental data. Data from observation and experiments may change when methods change. If the data change, the theory formulated may change. (1E-2: *Informed*)
	Theories change. Example: the theory of spontaneous generation changed in biology. (2E-1: *Informed*)	Scientific theories are exposed to change. Human beings are not inherently objective. Making critical observations with well-sophisticated instruments and the reinterpretation of information may lead to changes in theories. (2E-2: *Informed*)
	No... I think knowledge, like theories, does not change. (3E-1: *Naive*)	Theories change as instruments and methods advance. Earlier, people believed the Earth was flat, but now, we know it is round. Scientific works lack perfection or absoluteness. (3E-2: *Informed*)
Scientific Laws Vs. theories	Theories do not exist without law. Theories change into law. (1E-1: *Naive*)	The law is more accurate. Theories change, but laws do not change. Theories develop after experimentation. Example Atomic theories modified. (1E-2: *Transitional*)
	We learn theory in the classroom. (2E-1: *not classifiable*)	They relate in that laws are superior to theories. (2E-2: *Naive*)
	There are many theories and laws in science. Example. Atomic theories and the law of gravity. (3E-1: *Naive*)	Theories develop from hypotheses after testing. Laws are natural and more perfect than theories. (3E-2: *Transitional*)
Social and cultural influence on science	It is not affected by culture and society. (1E-1: *Naive*)	Society and culture affect science. (1E-2: *Transitional*)
	Scientists are human with their own culture. Their work may be affected by their culture. Scientists doing science are neutral. (2E-1: *Informed*)	Society and culture affect scientific research. I think creationist theory in evolution is formulated by religious people who do not accept the theory of evolution. (2E-2: Informed)
	I believe cultures do not affect scientific work. (3E-1: *Naïve*)	Some societies respect their culture and do not accept ideas that contradict it. (3E-2: *Transitional*)
Imagination and creativity in scientific investigation	I think scientists use creativity and imagination in science. Because creativity and imagination are important for doing science. (1E-1: *Transition*)	Imagination and creativity exist in science. For example, the units and constants in science are determined by human convention. They do not read directly from the natural world. (1E-2: *Informed*)
	Scientists do not use creativity and imagination. These make scientific works have biases. (2E-1: *Naive*)	Yes, scientists use creativity and imagination. They are very important. Scientific activities such as observation, interpretation, prediction, and experimental design require creativity. (2E-2: *Informed*)
	In science work, creativity and imagination are not important. (3E-1: *Naive*)	Scientists usually use their creativity and imagination. Not all things in the world are visible. Scientists need to use their creativity in scientific work to explain hidden things and analyze data. (3E-2: *Informed*)

NOS theme	Pre-interview	Post-interview
Methodology of scientific investigation	I think scientists use a single and universal scientific method. (1E-1: *Naive*)	There is no single and universally accepted way to do science. For example, scientists may use inferences and observations to answer their questions. (1E-2: *Informed*)
	Single scientific method. The method must be the same internationally. (2E-1: *Naive*)	There is no single method. The scientific method is one way to do science. In addition to the scientific method in astronomy, scientists often use observation. (2E-2: *Informed*)
	Single universal scientific method. (3E-1: *Naive*)	No single method. Several methods can be used in science. (3E-2: *Transitional*)

Table 5: Representative pre- and post-intervention experimental group interview organized by NOS themes (Source: own interview)

NOS themes	Pre-interview	Post-interview
Observation and inferences	I think it is not the same but different because they use the same instrument. (1C-1: *Transitional*)	It is different because. (1C-2: *Transitional*)
	The same, if different, they do not find the same result. (2C-1: *Naive*)	I think they will make the same observations and draw the same inferences. (2C-2: Naive)
	Scientists observe and infer the same phenomena in different ways because they are brilliant in scientific work. (3C-1:Transitional)	I hope it will be different because they are different people with different backgrounds and abilities. (3C-2: *Informed*)
Tentativeness of scientific theories	Theories change. For instance, in biological science, theories of abiogenesis are changing. (1C-1: *Informed*)	Theories change. The theory of abiogenesis changed in biology. (1C-2: *Informed*)
	Theories do not change. This is because they are constructed based on accurate experiments. (2C-1: *Naive*)	Theories must not change. Scientific knowledge must be accurate. I believe they are tested for certainty. (2C-2: *Naive*)
	I know knowledge changes. Thus, scientific theories might change. (3C-1:*Transitional*)	Scientific theories change. (3C-2:Transitional)
Scientific Laws Vs. theories	I am not able to differentiate these two terms (1C-1:Not classifiable)	Ok… theory means not well tested, but law is tested. (1C-2: *Naive*)
	Laws are more truthful than theories. (2C-1: *Naive*)	Theory and law possess a hierarchical structure. Theory becomes law with sufficient evidence. (2C-2: *Naive*)
	Theories and laws are scientific knowledge. Laws are more realistic. (3C-1: *Naive*)	Theories are constructed, but Laws are discovered. (3C-2: *Transitional*)
Social and cultural influence on science	Sure, culture and society influence. Scientists may have a hidden interest in promoting their religion, culture, and politics through science. (1C-1: *Informed*)	Culture and society affect science. They affect science by affecting scientists' work and explanations. (1C-2: *Informed*)
	Science is not free from the influence of society and culture. (2C-1: *Transitional*)	No, they do not influence science, because science is about nature. (2C-2:Naive)
	Societal culture affects scientific research. Society may distort scientists' work to serve its own interests. (3C-1: *Informed*)	Yes, it affects. Cultural values and religions affect the acceptance of scientific works. For example, religious people do not accept evolutionary theory. (3C-2: *Informed*)
Imagination and creativity in scientific investigations	I know scientists must be creative. This must be used in science. (1C-1:*Transitional*)	They must be used. Creativity and imagination are important for scientific investigation. (1C-2: *Transitional*)
	Creativity and imagination are human elements. They must not be used by scientists. (2C-1: *Naive*)	I think creativity and imagination are important for science, and they must be used. (2C-2: *Transitional*)
	Scientists should not need to use creativity and imagination. These events make scientists biased. (3C-1: *Naive*)	Using creativity and imagination should be practiced in science. (3C-2: *Transitional*)
Methodology of scientific investigation	Single scientific method. It helps to avoid biases. (1C-1: *Naive*)	Single scientific method. The method must be the same internationally. (1C-2: *Naive*)
	Single scientific method. In different science subjects, I learned the scientific method to do science (2C-1: *Naive*)	Single Universal scientific method. To find reliable results, the scientific method must be used. (2C-2: *Naive*)
	Single scientific method. A common method of doing science. (3C-1: *Naive*)	Scientists may use different types of methods. (3C-2: *Transitional*)

Table 6: Representative pre- and post-intervention control group interview organized by NOS themes (Source: own interview)

DISCUSSION

An informed understanding of NOS is vital for scientific literacy and a focal point in most science education reform documents (Abell & Lederman, 2007). Additionally, science educators are reminded that grasping NOS concepts is crucial and forms part of their teaching competencies. Herman and Clough (2016) emphasized the necessity for science teachers to possess a deep understanding of both scientific content and NOS to effectively teach science. Thus, nurturing NOS understanding among PSSTs requires attention and collaborative strategies. This study evaluated the impact of explicit SPS instruction on NOS understanding. Our findings from prior intervention assessment of NOS in indicated NOS conception in PSSTS are not at an adequate level in the overall and specific themes of NOS as presented in various previous literatures (Abd-El-Khalick & Akerson, 2004; Liang et al., 2009; Cofre et al., 2019; Mesci, 2020; Zion et al., 2020; Wang et al., 2023). They held less informed conceptions in observation and inference, the tentativeness of scientific theories, social and cultural influences on science, imagination and creativity in scientific investigations, uninformed conceptions of laws vs. theories, and the methodology of scientific investigation. In line with our findings, laws vs. theories and methodologies in scientific investigation were also reported as naïve NOS themes in PSSTs by different researchers (Miller et al., 2010; Cofre et al., 2019; Gizaw et al., 2024 (in press)).

The prevailing perspective on the NOS holds that inferences and observations differ, and that two scientists may not perceive or interpret the same object or phenomenon in identical ways (Liang et al., 2008). This disparity is largely attributed to the subjective nature of scientists and variations in their prior knowledge and perspectives. However, many students and teachers hold the misconception that scientists maintain objectivity and perceive and interpret phenomena uniformly (Jaina et al., 2013). In this study, exposing PSSTs to explicit instruction on Science SPS facilitated the development of a scientifically accepted view regarding observation and inference within NOS themes. Both observation and inference are fundamental components of both SPS and NOS. The observed enhancements in the NOS theme of observation and inference may be attributed to the PSSTs' clear comprehension of these skills through explicit SPS instruction. During explicit SPS skill instruction, several PSSTs were encouraged to observe and infer the same phenomena and share their observations and inferences with their peers. It is expected that the disparities encountered when comparing their observations and inferences with those of their peers contributed to their improved understanding of this NOS theme.

Liang et al. (2008) highlight the inherent tentativeness in scientific theories and knowledge, stemming from advances in data collection and analysis tools, the introduction of new techniques, and the reinterpretation of existing data. Despite this scientific understanding, many teachers and students maintain contradictory beliefs. Research indicates a prevalent belief that science offers definitive explanations supported by facts and evidence, leading to a deep-seated conviction among students and teachers (Jaina et al., 2013). In our study, the tentative nature of scientific theories and knowledge emerged as a significant strength of the NOS. Through explicit SPS instruction, PSSTs engaged in various scientific activities, such as observing the same event or object with different instruments (e.g., naked eye, hand lenses, compound microscope), analyzing identical data independently, and repeatedly drawing conclusions or interpretations. PSSTs were encouraged to discuss the origins and implications of inconsistencies among their findings. It is anticipated that the discrepancies and dynamic nature observed in their work contributed to an enhanced understanding of the tentativeness of scientific theory or knowledge within the NOS theme. Observation serves as a means to gather information, data, or evidence in the process of scientific knowledge production. Changes in observation methods can sometimes alter evidence or data, potentially challenging well-established knowledge. Our study demonstrates that these scientific phenomena can be effectively conveyed to PSSTs through explicit SPS instruction.

According to proponents of the consensus view of the NOS, such as Kampourakis (2016), both theories and laws constitute bodies of knowledge. Laws are discovered while theories are invented; both are subject to change, with neither being inherently superior to the other, and theories often elucidate laws. However, PSSTs struggle to grasp these distinctions and similarities between theories and laws. One prevalent misconception among PSSTs, as established by Cofre et al. (2019), is the belief in a hierarchical structure where theories are deemed superior to laws, and theories evolve into laws with sufficient evidence. This misconception was evident in our study samples, with many PSSTs failing to clearly differentiate between these two bodies of knowledge. Moreover, the distinction between law and theory constitutes a challenging aspect of the NOS for our PSSTs, as evidenced by their lack of understanding and limited improvement following SPS instruction. Our findings align with previous research indicating the difficulty of altering PSSTs' conceptions regarding the NOS law-versus-theory theme. For example, Mesci and Schwartz (2017) found that, despite enrolling in NOS and scientific inquiry courses delivered through explicit and reflective approaches, several PSSTs still struggled to distinguish between scientific theory and law. However, contrary to our findings, Cofre et al. (2019) reported, based on a review of seven studies focused on changing PSSTs' NOS conceptions, that the law-versus-theory aspect was the most improved in four studies.

As a human endeavor, science is influenced by the society and culture in which it is practiced (Liang et al., 2008). Cultural values, political systems, and expectations shape how and what science is conducted and how it is accepted. Contrary to this, there are views among some PSSTs that science is free from political, social, cultural, and religious influences (Cofre et al., 2019). Regarding this theme, most of our PSSTs held a more transitional view. Improvements in PSSTS cultural and societal influences on NOS occurred after intervention through explicit SPS instruction, but these were not significant. Consistently, Mesci and Schwartz (2017) found that PSSTS struggle to improve their culture and society's influence on NOS themes after enrolling in an explicit, reflective-based NOS and scientific inquiry course. Moreover, Cofre et al. (2019) outlined the social and cultural embeddedness of science as one of the difficult aspects of NOS for change. Contrary to our finding, studies generally indicate that explicit-reflective and context-based instructions improve NOS conception of PSSTs, including cultural and societal influences on science. For instance, Bell et al. (2011) found that elementary PSSTs' NOS understanding improved when NOS instruction was grounded in a global climate change context and in a stand-alone topic.

Scholars contend that scientists employ their creativity and imagination in formulating hypotheses, crafting theories to elucidate natural phenomena, and making predictions during their scientific inquiries (Erduran & Dagher, 2014). However, many studies show that many teachers and students hold the belief that there are no human elements, such as creativity and imagination, in science (Abd-El-Khalick & Akerson, 2004; Liang et al., 2009; Mesci, 2020; Zion et al., 2020; Wang et al., 2023). Although the majority of our participants acknowledge the presence of human elements in science, some maintain an alternative viewpoint, denying their existence. Our intervention, implemented through explicit SPS instruction, led to significant changes among PSSTs in our sample regarding the recognition of imagination and creativity in scientific investigation. During the intervention, students engaged in activities such as object classification based on criteria, data collection through measurements, and data analysis and interpretation. The impact of these SPS was evident in the post-interview responses, in which participants in the experimental group provided justifications and examples. For instance, two participants from the experimental group responded as follows: "*For example, measuring units and constants in science come from human creativity through convention. They do not read directly from the natural world (1E-2: Informed)", "All things in the world are not visible. Scientists need to use their creativity in science work to explain hidden things and analyze data (3E2- Informed).*" Cofre et al. (2019) highlighted in their review that imagination and creativity in scientific investigation are among the aspects of the NOS that are easily influenced by educational interventions.

Scientists employ various methods such as observation, classification, mathematical deduction and induction, inference, speculation, and experimentation to address inquiries and amass scientific knowledge (Erduran & Kaya, 2018). Consequently, there is no single, universally accepted, step-by-step, one-way to do science. However, prior research has revealed a misconception among PSSTs that scientists strictly adhere to a singular, universal, step-by-step scientific method (Cofre et al., 2019; Zion et al., 2020). This misconception was also prevalent among the participants in our study. Both qualitative and quantitative data from our study indicate that the PSSTs in our sample harbored naive conceptions regarding the methodology of scientific investigation within the NOS theme. However, after participating in the intervention, the experimental group demonstrated a significant improvement in their understanding of the methodology of the scientific investigation NOS theme. This improvement might be attributed to the fact that most SPS can serve as methodologies for scientific investigation. The intervention provided students with opportunities to practice accumulating scientific knowledge without strictly adhering to step-by-step scientific methods, simply by making observations, inferences, and predictions. According to Cofre et al. (2019), the methodology of scientific investigation is among the most challenging NOS themes to change in PSSTs. However, in our study, this theme showed significant improvement due to the intervention.

CONCLUSION

Improving PSSTs' understanding of NOS is essential for effectively imparting science content and NOS concepts to their students. In our study, we examined the level of NOS conception and the impact of explicit SPS instruction on various NOS themes among PSSTs. Our findings revealed that NOS themes, such as observation and inference, the tentative nature of scientific theory and knowledge, the role of creativity and imagination in scientific investigations, and methodologies in scientific investigation, were significantly enhanced through intervention via explicit SPS instruction. SPS and NOS themes are intricately linked; they share associations and overlap. It is anticipated that these connections facilitate the transfer of knowledge and skills acquired by PSSTs through explicit SPS instruction to NOS conception themes. Our study demonstrated that explicit SPS instruction can provide a more effective framework for context-based NOS instruction. Therefore, by incorporating explicit NOS instruction into the PSST curriculum, there is potential to foster both the development of SPS and understanding of certain NOS themes among PSSTs. The NOS themes of law vs. theory and of cultural and social influences on science did not show significant change as a result of our intervention. It indicates that interventions aimed at improving NOS themes need to create tailored opportunities that directly address specific NOS themes. A single strategy may not be sufficient for all NOS themes. Therefore, we recommend that strategies utilized for enhancing NOS understanding should encompass all NOS conception themes to be effective.

DECLARATIONS AND STATEMENTS

Data availability statement

The original raw data used to draw the conclusions of the investigation are available from the corresponding author upon request, without undue reservation.

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Ethical approval

All Procedures performed in studies involving human participants were in accordance with the ethical standards of the institution's research committee and with the 1964 Helsinki Declaration and its later amendments. Participants of the study were informed before enrollment about the objectives and the usage of the information they provided. Moreover, the data analysis was conducted in accordance with research ethics.

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Author contributions

Corresponding author involved in the conceptualization, selecting methodology, making analysis, producing visualization, and writing the original draft preparation. All other authors read the original drafts and gave constructive comments.

Conflict of interest

The authors declare the study was undertaken without any authoring, commercial, or financial relationships that could raise a potential conflict of interest.

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