Metacognitive Pedagogy And Prospective Teachers' Science Identity: An Experimental Study

Dr. Azmat Farooq Ahmad Khurram¹, Aqsa Sajjad Hashmi², Rashida Parveen³, Yasirv Ali⁴

¹Assistant Professor, Khwaja Fareed University of Engineering & Technology, Rahimyar Khan, Pakistan.

²M.Phil Scholar, University of Gujrat, Pakistan.

³Ph.D. Scholar, Khwaja Fareed University of Engineering & Technology, Rahimyar Khan, Pakistan.

⁴Lecturer, Khwaja Fareed University of Engineering & Technology, Rahimyar Khan, Pakistan.

ABSTRACT
Metacognitive pedagogies are the classroom instructional strategies facilitating learning. Science identity is a lens for analyzing the motivation and learning of students. Multiple types of research are available on science identity; however, the research on the science identity of prospective teachers' was rarely focused. Therefore, this study was conducted to examine the effect of metacognitive pedagogy on Prospective teachers' science identity. A sample of fifty-eight (58) prospective teachers enrolled in a public sector university participated in this experimental study. The study sample was randomly divided into experimental and control groups based on their previous scientific results. The control group was taught with the traditional teaching method. Further, the treatment group was taught with metacognitive pedagogy using mind maps, small group discussion, and writing reflections for sixteen weeks per the university schedule. Data were collected using a science identity questionnaire. NCSS 2022 was used to analyze the data. The results concluded that metacognitive pedagogy remained significant in the prospective teachers' science identity. It is recommended that prospective teachers be taught metacognitively to enhance their outputs in terms of science identity, which is a significant factor in academic achievements. They may become effective science teachers and build a new generation with a solid scientific background.

Keywords: Metacognitive pedagogy; Science identity; Prospective teachers
INTRODUCTION

Metacognitive pedagogies pertain to classroom instruction that facilitates learning (Lee & Mak, 2018; Sato & Loewen, 2018). Khurram et al. (2021) indicated that metacognitive pedagogies are effective for classrooms. Metacognitive pedagogy comprises multiple strategies like self-directed learning, explicit teacher modeling, reading aloud, reading comprehension, concept or mind mapping, writing reflections, think-pair-share, etc. Metacognitive pedagogy effectively provides helpful feedback (Sato & Loewen, 2018). It improves learners' writing and metacognitive awareness (Teng, 2020) and enhances listening, proficiency, and cognition (Kobayashi, 2018). Therefore, it became imperative to implement metacognitive pedagogy for prospective teachers also. However, this study employed a few metacognitive pedagogies viz: mind maps, small group discussion, and writing reflections for sixteen weeks per the university schedule. Similarly, it is assumed that if metacognitive pedagogy is employed on prospective teachers, it might gear up their science identity.

Prospective teachers are the students enrolled in any teaching course. They are the future of a nation. Therefore, they need proper professional development in pedagogy, curriculum, and implementation. Prospective teachers in science need exclusive training since they have to teach science, which is a key predictor of the national economy (Khurram et al., 2021). Similarly, Khurram, A.F.A. (2020) reported that most Pakistani instructors now lack good teaching practices and demonstrate an inability to apply theory to practice. They must have the most acceptable teaching practices to convey information and comprehension and attain learning goals successfully. They need adequate preservice professional development to reshape them into experts. As a result, prospective teachers' professional development has to be revised.

Shaby and Vedder-Weiss (2020) pointed out that science identity highlights how organizing the environment promotes scientific knowledge and abilities that encourage students' science identities. It is worth mentioning that science identity is socially created via the everyday practice of pupils. Live experiences of students and their social contacts in diverse communities of practice at school, home, or work may help them create and adapt their science identity in a situated-learning framework. Wyatt et al. (2018) cited that focus and exposure to research experience are directly linked with science identity. According to Kang et al. (2019), students' vision of their informed and changed by their practices across time and situations is based on social practice theory.

Shein et al. (2019) reported that scholars in science education programs have grown more interested in the function of identity in science education contexts in recent years, embracing the notion of "science identity" to understand better the nature of science learning within and outside the classroom. Science identity is considered fluid and ever-changing, consisting of four dimensions: recognition, interest, performance, and competence. Todd and Zvoch (2019) indicated that students' science identity is directly associated with their interest in science, attitudes toward science, and perceptions of self-efficacy in science.
Student identity plays an essential role in affecting student success (Bowman & Felix, 2017). It stimulates students’ motivation to participate in learning tasks (Martin et al., 2014). Chen and Wei (2020) explained the terms identity and student identity. According to them, identity is a particular sort of person known in a given situation, either by oneself or others. Similarly, Science identity is characterized by two fundamental aspects: a feeling of oneself as a science person and its acknowledgment in a social setting, particularly by influential persons such as classroom teachers and other stakeholders. Science identity is not static but rather a series of paths that might change throughout time. Therefore, the science identity needs to be observed by prospective teachers. It is an observed fact that STEM and science identity are inextricably linked. The sub-factors influence identity, but they do not constitute the entirety of one’s identity. For example, it has been extensively established that males tended to be overconfident in their scientific ability even when male and female scientists performed comparably. This resulted in a higher conviction in their scientific identity, as opposed to women, who managed to underestimate their scientific aptitude (Chen et al., 2020)

Chen and Wei (2020) reported four factors of science identity viz: performance, competence, recognition, and interest. Similarly, Shein et al. (2019) briefly discussed the dimensions of science identity. He linked science performance to belief in an ability to perform scientific tasks, science competence to understand science, science recognition to the recognition by others or self as a science person, and linked science interest with curiosity to think and learn science. Therefore, the science identity of prospective teachers is measured by science performance, science competence, science recognition, and science interest.
Hernandez-Matias et al. (2020) indicated three factors of science identity, namely competence, performance, and recognition. He explained that the learner's perspective of his research competencies is described as how the learner views what he learns and understands. Similarly, competence in science fields includes vital characteristics such as logical, educational, investigative, intellectual, and recall abilities (Pender et al., 2010).

Students' performance is determined by how they perceive and respond in several critical scientific disciplines such as communal dialogue, conducting experimentations, and utilizing apparatus (Carlone & Johnson, 2007). Science knowledge may assist as a subjective incentive to go deeper with newly discovered abilities and pursue one's goals as a scientist (Hernandez-Matias et al., 2020).

Carlone and Johnson (2007) indicated that recognition from others has a tremendous impact on self-recognition as a scientist. It is also associated with social findings and cultural standards. He further explained that acknowledgment might be considered an indispensable part of identity development; for example, a person's motivation to succeed in school or at work may be motivated by a desire to please their family or an inner goal to achieve self-recognition. In other words, if the student perceives himself as a scientist and believes that he is accepted as such by the scientific community, he will do whatever it takes to maintain that reputation based on his natural views. Similarly, Science interest predicts self-concept and knowledge in science (Leibham et al., 2013). Multiple types of research established the influence of science activities on learners' scientific knowledge in terms of science identity (Pattison & Dierking, 2019).

**OBJECTIVES OF THE STUDY**
The study's objective was whether metacognitive pedagogy is beneficial for the prospective teachers' science identity.

**HYPOTHESES OF THE STUDY**
Following research questions were formulated to achieve the objective of the study.

R1: Is there any difference in prospective teachers' science performance when taught through metacognitive pedagogy and traditional method.
R 2: Is there any difference in prospective teachers' science competence when taught through metacognitive pedagogy and traditional method.
R 3: Is there any difference in prospective teachers' science recognition when taught through metacognitive pedagogy and traditional method.
R 4: Is there any difference in prospective teachers' science interest when taught through metacognitive pedagogy and traditional method.
R 5: Is there any difference in prospective teachers' science identity when taught through metacognitive pedagogy and traditional method.

METHODOLOGY
This study aimed to determine the effectiveness of metacognitive pedagogy on prospective teachers' science identity. The metacognitive teaching strategies were employed on prospective teachers as a type of intervention, and the effects were examined. The study's population included all prospective teachers enrolled in the third semester of B.Ed. (Hons) in a public sector university of Punjab, Pakistan. This university was chosen since the university provided permission to experiment with the current study. It was representative since the curriculum and policies of the Higher Education Commission, Pakistan, were being employed at all stages. Chen and Wei (2020) developed and validated an instrument, namely the Student Science Identity (S.S.I.) questionnaire. This instrument was used to measure prospective teachers' science identity. This questionnaire was developed and validated by Chen and Wei (2020). A similar Chinese version was also used by Luo et al. (2019).

The teaching instruction was an independent variable (IV) in two groups called the experimental group and the control group. Metacognitive pedagogy was used to teach the experimental group, including mind maps, small group discussions, and writing reflections. The control group, on the other hand, received traditional instruction. The science identity of prospective instructors was a dependent variable (DV). Prospective teachers' science identity encompassed four sublevels, i.e., science performance, science competence, science recognition, and science interest.
The science score in the previous class was computed to arrange the prospective teachers in ascending order and was used as a covariate. Based on this last class science score, they were randomly divided into two groups: the experimental and control groups, and the teaching method was an independent variable (IV). In contrast, the quantitative scores on science identity were the dependent variable (DV).

Before and after the intervention, pretest and post-test were administered to measure the science identity of prospective teachers. Science score in the previous class was used as a covariate. Prospective teachers' science identity was calculated with descriptive statistics (Means and Standard Deviations). Independent sample t-tests were applied to test the null hypotheses about prospective teachers' science identity.

**DATA ANALYSIS**

An independent sample t-test was applied through the statistical software NCSS 2022 to compare the effect of metacognitive pedagogy and traditional teaching methods (teaching method) on the science identity of prospective teachers enrolled in science classes. The outcomes obtained by the Independent sample t-test represent a difference between both interventions on prospective teachers' science identity.

<table>
<thead>
<tr>
<th>Area</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t</th>
<th>Sig. value</th>
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<tbody>
<tr>
<td>Mean Gain Score on science identity</td>
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The analysis of table indicates that all the null hypotheses were rejected since the t-value = 3.146 with df = 56 remained significant as p = .000 < α = .01 on the prospective teachers’ science performance. Similarly, the null hypothesis about prospective teachers’ science competence remained significant with t-value = 2.571 for df = 56 on p = .000 < α = .01. The results of the data further concluded that the null hypothesis about prospective teachers’ science recognition remained significant with t-value = 2.421 for df = 56 on p = .000 < α = .01. However, the null hypothesis about prospective teachers’ science interest remained significant also with t-value = 3.524 for df = 56 on p = .000 < α = .01. As a whole, it was evident that all the null hypotheses were rejected because t-value = 7.526 with df = 56 remained significant as p = .000 < α = .01 on the science identity of prospective teachers.

Furthermore, descriptive data demonstrated that prospective teachers who were taught using metacognitive pedagogy exhibited better science performance (M = 15.7, SD = 1.6) than those who were taught traditionally (M = 7.2, SD = 2.5). On the other hand, prospective teachers who were taught using metacognitive pedagogy exhibited better science competence (M = 14.3, SD = 2.6) than those who were taught traditionally (M = 6.9, SD = 3.5). Similarly, prospective teachers who were taught using metacognitive pedagogy exhibited better science recognition (M = 9.7, SD = 1.6) than those who were taught traditionally (M = 5.6, SD = 2.5). However, prospective teachers who were taught using metacognitive pedagogy exhibited better science interest (M = 9.6, SD = 2.6) than those who were taught traditionally (M = 8.4, SD = 3.5). As a whole, prospective teachers who were taught using metacognitive pedagogy exhibited better science identity (M = 11.6, SD = 1.6) than those who were taught traditionally (M = 7.3, SD = 2.5).

The below-mentioned table provides a comparison between the Mean gain Score of all dimensions of Science identity.

<table>
<thead>
<tr>
<th>Science Performance</th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>df</th>
<th>t-value</th>
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<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>7.2</td>
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<td></td>
<td>15.7</td>
<td>1.6</td>
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<td>Science Competence</td>
<td>Control Group</td>
<td>Experimental Group</td>
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<td>t-value</td>
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<td>29</td>
<td>6.9</td>
<td>3.5</td>
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<td></td>
<td>14.3</td>
<td>2.6</td>
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<td>Science Recognition</td>
<td>Control Group</td>
<td>Experimental Group</td>
<td>df</td>
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<td>29</td>
<td>5.6</td>
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<td></td>
<td>9.7</td>
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<tr>
<td>Science Interest</td>
<td>Control Group</td>
<td>Experimental Group</td>
<td>df</td>
<td>t-value</td>
<td>p-value</td>
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<td>29</td>
<td>29</td>
<td>29</td>
<td>8.4</td>
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<tr>
<td>Science Identity</td>
<td>Control Group</td>
<td>Experimental Group</td>
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<td>t-value</td>
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<td>11.6</td>
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* p < .01.
CONCLUSIONS

The study results showed a difference between the two interventions on prospective teachers' science identity. It further represented that metacognitive pedagogy for science prospective teachers remained more effective than the traditional teaching method. Metacognitive pedagogy (M=15.7) remained most effective in the science performance of prospective science teachers as compared to traditional teaching (M=7.2). As a whole, Metacognitive pedagogy for prospective science teachers remained significant in science identity and its sub-areas.

RECOMMENDATIONS

Based on the findings and conclusions, it was recognized that metacognitive pedagogy remained beneficial to science professional development. It is proposed that metacognitive pedagogy may be used as a replacement for traditional teaching approaches. Curriculum developers for professional development may integrate metacognitive pedagogy for prospective science teachers. Metacognitive pedagogy should be included in the course content and training modules at all stages of teacher professional development institutes. As a result, it is proposed that prospective science faculty may be educated using metacognitive pedagogy. More research into metacognitive pedagogy for the teaching-learning process is recommended. University research supervisors may encourage metacognition and encourage their students to investigate various topics. Similarly, during induction and in-service teacher professional development, academics may undertake research on metacognitive engagement to improve teaching.
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REFERENCES


