JPII 12 (4) (2023) 552-563

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

THE ROLE OF SELF-CONCEPT IN MODULATING THE EFFECTIVENESS OF NATURE-BASED SCIENCE INSTRUCTION

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DOI: 10.15294/jpii.v12i4.48287

Accepted: October 21st, 2023. Approved: December 29th, 2023. Published: December 31st 2023

ABSTRACT

This study investigates the intersection between academic self-concept and the efficacy of Nature-Based Science Instruction (NBSI) in shaping the educational experiences of future science teachers. A mixed-methods design, encompassing the Academic Self-Concept Questionnaire and Nature-Based Science Instruction Assessment, enabled a comprehensive exploration of this dynamic. The research found that self-efficacy and self-competence, key components of self-concept, significantly determine the success of NBSI. These elements shape and are shaped by the learning environment, with reflective practices within NBSI notably enhancing academic self-concept and learning outcomes. The study's conclusions provide new insights into educational psychology, emphasizing the necessity of incorporating psychological factors into science curriculum development for more effective pedagogical strategies.

Keywords: academic self-concept; nature-based science instruction; self-efficacy

INTRODUCTION

In recent years, science education has undergone a significant transformation. Educators and researchers have a growing consensus that traditional science teaching methods do not foster a comprehensive understanding of the subject (Höttecke & Allchin, 2020; Shrivastava et al., 2020; Sherinnova et al., 2023). Nature-Based Science Instruction (NBSI) has gained prominence in response to this challenge. NBSI is an interdisciplinary approach that combines scientific knowledge with hands-on experiences in natural settings (Faber et al., 2022). This approach is increasingly seen as a mechanism for enhancing students' academic outcomes and emotional and social wellbeing, as documented in various studies (Yigit-Gencten & Gultekin, 2022; Kiers et al., 2023a).

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Alongside this educational shift, the psychological construct of self-concept has become a focal point in academic research. Self-concept refers to an individual's self-perception in specific domains, and in the realm of education, it profoundly influences how students perceive their capabilities (Ma et al., 2022). Past research has shown that a robust academic self-concept is associated with heightened enthusiasm (Ambrose et al., 2021), increased engagement (Giakoumaki & Krepapa, 2020), and improved academic performance in various disciplines, including science (Jahanifar, 2022).

Despite substantial individual inquiries into NBSI and self-concept, the confluence of these domains remains conspicuously unexplored. Current research, including Harrod et al. (2023), highlights the necessity for a person-centred approach in interpreting the benefits of nature-based interventions, underscoring the

variable impacts of educational strategies like NBSI, which are inherently mediated by individual determinants such as self-concept. Similarly, studies by Kang et al. (2021) and Ma et al. (2022) further illuminate the pivotal roles of interest, self-concept, and contextual variables in shaping educational experiences and aspirations, emphasizing the necessity for nuanced, integrative explorations. Consequently, delving into the intricate interplay between NBSI and self-concept emerges as a pivotal scholarly endeavor. A profound comprehension of this interaction holds the potential to amplify the synergistic benefits in the realms of educational psychology and pedagogical strategies, creating a cohesive understanding that surpasses the individual contributions of its constituent elements.

With this landscape in mind, the present research aims to bridge this gap by exploring the role of self-concept in modulating the effectiveness of Nature-Based Science Instruction. Understanding this nuanced interaction can offer educators a more tailored approach, enriching teaching and learning experiences. The implications of this study are twofold: it contributes to the theoretical discourse on educational psychology and provides practical applications for curriculum development and instructional design.

This research employs a robust mixed-methods approach to achieve the objective (Creswell & Creswell, 2023). We will leverage quantitative methodologies, such as statistical analyses of test scores and attendance records, and qualitative methodologies, including structured interviews and self-report measures. This comprehensive strategy aims to encapsulate the multi-faceted nature of educational settings and capture the nuance that single-method studies may overlook (Bae & Lai, 2020).

A critical research gap exists at the intersection of NBSI and self-concept. While numerous studies have focused on the individual merits of NBSI for enhancing academic performance (Collado et al., 2020; Schilhab, 2021), and others have separately explored the far-reaching impacts of self-concept, an integrated study that examines explicitly how self-concept affects the success of NBSI-based education is absent. This void in the literature hampers the development of holistic pedagogical frameworks that can synergize the advantages of both constructs. Addressing this gap becomes imperative as educational paradigms shift toward more personalized, learner-centric models.

The limitations of existing research underscore the necessity for a study that synthesizes these two disparate but intrinsically connected domains. Bridging the gap involves more than a mere juxtaposition of theories and findings; it demands an integrated analysis capable of unearthing the nuanced interdependencies between academic self-concept and NBSI (Jo & Seo, 2023; Schmitt et al., 2023). With this focus, the study seeks to contribute to developing comprehensive educational frameworks that embody learner psychology and effective teaching strategies, paving the way for a new generation of educational paradigms.

The dual domains of Nature-Based Science Instruction (NBSI) and academic self-concept are not novel in their individuality (Faber et al., 2022; Jahanifar, 2022; Jordan et al., 2023); instead, their intersection remains underexplored and thus serves as the fulcrum of our investigation. We aim to rigorously delineate the key findings, theories, and methodologies that have shaped these domains. This effort is crucial for recognizing gaps and reinforcing the value of exploring the nexus between NBSI and self-concept for future educational strategies.

For decades, traditional science education has grappled with pedagogical rigidity, content saturation, and a diminished focus on real-world applicability, reducing student engagement (Arici et al., 2019; Suárez & Beatty, 2022). This critique has accelerated the search for innovative pedagogical strategies, and Nature-Based Science Instruction (NBSI) has emerged as a robust alternative. Pioneering works by Faber et al. (2022) and others have demonstrated that NBSI amplifies cognitive learning outcomes and nurtures soft skills like empathy, teamwork, and environmental stewardship. Jordan et al. (2023) conducted research that revealed positive correlations between NBSI and improvements in a range of competencies, including conceptual understanding, scientific reasoning, and even shifts in attitudes toward science as a subject.

Alongside educational methodologies, internal psychological constructs, specifically academic self-concept, have gained traction as substantial influencers of educational outcomes (Wu et al., 2021). Academic self-concept does not just facilitate learning but acts as a mirror reflecting students' perceptions of their capabilities. Chen et al. (2021) and Kulakow (2020) corroborate the pivotal role of a positive academic self-concept in fostering a learning environment where students acquire factual knowledge and engage in metacognitive practices like self-regulation and reflective thinking.

Self-concept assumes an even more significant role within the specialized domain of science education. Kang et al. (2021) employed a longitudinal study spanning several years to ascertain that students with elevated science self-concept were successful in advanced science courses and more inclined to pursue STEM-related careers. However, Simonsmeier et al. (2020) presented a nuanced narrative, revealing that high self-concept in science education does not always translate to enhanced performance. They suggested that variables like classroom environment and teaching methodologies could influence the predictive validity of self-concept on performance, thereby identifying a landscape far from monolithic.

While considerable exploration into Nature-Based Science Instruction (NBSI) and self-concept exists independently, a glaring and conspicuous void remains apparent in studying their collaborative interplay. This unexplored intersection between NBSI and self-concept, identified by Mann et al. (2021) and Kang et al. (2021) as a significant "missed opportunity" and a "bottleneck," stands as a barrier to the progression of integrated pedagogical approaches, leading to an urgent scholarly inquiry that demands immediate redress.

The current landscape of academic exploration leaves vast territories uncharted in understanding the intricate interplays and reciprocal influences between NBSI and self-concept. It represents a novel and groundbreaking arena of scholarly investigation, aiming to synthesize these seemingly disparate domains to uncover the nuanced interactions and mutual impacts between them. It is not just a matter of academic interest but a pivotal juncture with the potential to fundamentally redefine educational paradigms and methodologies (Mosanya & Kwiatkowska, 2023; Schmitt et al., 2023).

This research endeavors to investigate this significant research gap and is foundational in its pursuit to integrate individual perceptions and innovative teaching methodologies. It strives to contribute unprecedented insights and theoretical advancements into educational psychology and instructional strategies, seeking to optimize learning environments in alignment with individual psychological constructs. By addressing this gap, the study is poised to have profound implications, potentially offering a nuanced perspective that could facilitate the development of more effective, adaptive, and inclusive educational practices and curricula, thus advancing personalized, learner-centric models.

However, the existing studies in this domain often exhibit methodological limitations, primarily due to their reliance on either predominantly quantitative metrics (Kiers et al., 2023; Mesci et al., 2023), which, despite their precision, offer a narrow view or purely qualitative frameworks, which lack empirical rigidity despite their rich narratives. Acknowledging this methodological discrepancy, this literature review advocates for a more comprehensive methodological synthesis—a mixed-methods approach—to capture the essence of educational phenomena, marrying statistical rigor with narrative depth.

While the extant literature lays a substantial foundation on NBSI and academic self-concept (Faber et al., 2022; Jordan et al., 2023; Kiers et al., 2023), it lacks an integrative perspective to study how these critical domains interact. This glaring oversight necessitates an exhaustive exploration and catalyzes this study to bridge this existing divide in academic discourse. It stands as a pioneer, contributing theoretical understandings and practical implications that are currently absent, and the insights derived are anticipated to propel further research endeavors, discussions, and the eventual evolution of enriched multi-faceted educational ecosystems.

Consequently, the guiding elements of this study are embedded in the insights, nuances, and limitations outlined in this comprehensive literature review, paving the way for pivotal research questions. The study delves into understanding the extent to which academic self-concept influences the effectiveness of Nature-Based Science Instruction (NBSI) and explores whether specific facets of self-concept are more instrumental in modulating the effectiveness of NBSI. By addressing these intricate questions, this study endeavors to elucidate the underlying dynamics and interrelations between NBSI and self-concept. The intention is to make substantial contributions to widening the horizons of educational research and practice, shedding light on uncharted intersections, and providing nuanced perspectives to enhance the multi-faceted domains of learning environments and instructional strategies.

METHODS

This research adopts a mixed-methods approach (Creswell & Creswell, 2023) to examine the role of academic self-concept in the effectiveness of Nature-Based Science Instruction (NBSI). For participation, the study targets approximately 100 prospective science teachers in their final

year at Universitas Islam Negeri Raden Intan Lampung, Indonesia. This group represents an ideal demographic due to the substantial shifts in academic self-concept often experienced during transitions into professional roles. Recruitment strategies for these participants include university postings and email notifications.

Participants initially attended a briefing session to ensure comprehension of the study's objectives, ethical requirements, and the importance of sincere participation. Informed consent is obtained before commencement, fulfilling stringent ethical protocols. Afterward, participants complete the Academic Self-Concept Questionnaire (ASCQ) (Melguizo-Ibáñez et al., 2023) online as a baseline measure. This 25-item Likert-scale self-report questionnaire assesses multiple facets of academic self-concept, such as academic confidence and motivation for science teaching. It underwent pilot testing with a separate sample, recording a Cronbach's alpha of 0.88, indicative of high reliability. Subject matter experts also validated the content.

Subsequently, participants engage in a structured twelve-week NBSI course, integrated with pedagogical practices like the flipped classroom model and peer-assisted learning. In the twelve-week NBSI course, integrating pedagogical practices such as the flipped classroom model involves reversing the traditional learning environment. Students first engage with new material outside of class, typically via online lectures or readings, which allows for deeper in-class discussions and collaborative, hands-on activities under teacher guidance. Peer-assisted learning, another key component, is implemented to enhance understanding and retention of NBSI concepts. This approach encourages students to work together and learn from each other through group tasks and discussions, fostering a collaborative learning culture and reinforcing the curriculum content. Both methods are designed to actively engage students, promote learning autonomy, and support applying theoretical knowledge in practical, nature-based scenarios. The course culminates in administering the Nature-Based Science Instruction Assessment (NBSIA) (van der Jagt et al., 2023), which features 20 multiple-choice and five open-ended questions designed to gauge participants' understanding and retention of NBSI concepts. Like the ASCQ, the NBSIA underwent reliability and validity testing, scoring a Cronbach's alpha of 0.90. In addressing the qualitative aspects of this study, Facet-Specific Academic Self-Concept Interviews (FSASCI) (Ruiz-Bartolomé & Greca, 2023) are employed, each lasting approximately 30 to 45 minutes and can be conducted either face-to-face or through secure video conferencing tools, aiming to delve into the nuances of academic self-concept and its potential impact on the effectiveness of NBSI. These interviews are meticulously recorded, transcribed, and later subjected to rigorous thematic analysis to ensure the richness and depth of the data are maintained. Concurrently, a Weekly Self-Regulation Diary (WSRD) is utilized for consistent qualitative data collection throughout the twelve-week NBSI courses, capturing participants' reflective insights on academic self-regulation behaviors and acting as a supplementary qualitative data source to the FSASCI interviews, thus enabling a more holistic and continuous exploration of the interplay between academic self-concept and NBSI.

In data analysis, multiple regression and factor analysis are used for the quantitative data, while qualitative data undergo thematic analysis. A convergence table is constructed to integrate the findings, enabling a comprehensive understanding of how different facets of academic self-concept influence the effectiveness of NBSI. Additionally, participants are invited to review preliminary findings in a process known as member checks' to ensure data credibility.

Ethically, all data are stored securely and anonymized to protect participant confidentiality. One acknowledged limitation of this study is its focus solely on prospective science teachers in their final year, which could constrain the generalizability of findings.

The comprehensive study will span six months with participant recruitment and initial briefing. This is followed by the pre-study phase involving baseline data collection, the twelve-week NBSI courses, and the post-study phase, which includes additional data collection, analysis, member checks, and final report preparation.

RESULTS AND DISCUSSION

This study systematically designed and implemented the Nature-Based Science Instruction (NBSI) over a 12-week curriculum. Our NBSI model amalgamated multiple instructional techniques, including but not limited to field observations, laboratory experiments, and reflective journaling. Table 1 provides a summary of the critical components.

Table 1. Overview of the 12-week NBSI Curriculum

Week	Instructional Technique	Activity Description	Learning Objective
1-3	Field Observations	Observing local ecosystems and documenting findings	Enhance observational and data collection skills
4-6	Hands-On Experiments	Laboratory experiments on soil and water quality	Develop a scientific understanding of environmental variables
7-9	Reflective Journaling	Weekly diary entries reflecting on learning experiences	Promote meta-cognitive skills and self-reflection
10-12	Integrated Project	A capstone project incorporating all elements	Synthesize learning and foster project management skills

Figure 1 shows the progression of self-reported academic self-concept over a 12-week Nature-Based Science Instruction (NBSI) curriculum. The data, representing four distinct instructional phases, indicate a trajectory of increasing self-concept scores among participants, with a notable peak during the reflective journaling phase. At the outset, during weeks 1-3, which focused on field observations, participants reported an average academic self-concept score of 35. This phase's activities were designed to engage students with the foundational practices of scientific observation in natural settings, which provided a moderate increase in self-concept.

The subsequent phase, weeks 4-6, dedicated to hands-on experiments, saw a slight increment in self-reported academic self-concept, with average scores of 40. This increase suggests that the experiential nature of conducting experiments may have further reinforced the participants' confidence in their scientific capabilities.

A significant surge in academic self-concept scores occurred during the reflective journaling phase in weeks 7-9, with an average score soaring to 70. This peak reflects the profound impact of metacognition and self-reflection on students' perceptions of their academic abilities, aligning with educational theories that advocate for reflection as a potent enhancer of self-concept.

However, in the final phase of the curriculum, weeks 10-12, which involved an integrated project designed to consolidate the curriculum's components, there was a decline in self-concept scores to an average of 50. This reduction may reflect the complexity of synthesizing and applying the learned concepts in a comprehensive project, which could pose challenges that slightly temper students' self-perceptions.

Overall, the trend depicted in Figure 1 suggests a generally positive impact of the NBSI curriculum on academic self-concept, with the highest efficacy observed during activities that involve reflective practices. These findings contribute valuable insights into the dynamics of self-concept development within science education pedagogy.

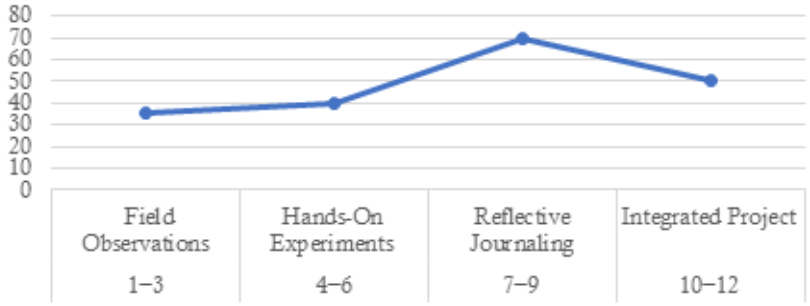

Figure 1. Self-reported Academic Self-concept across the 12-week NBSI Curriculum

To further contextualize the observed trends and delineate the relational dynamics between academic self-concept and the efficacy of NBSI, a correlational analysis was conducted between participants' self-concept scores and a myriad of outcome measures. These included, but were not limited to, academic performance, engagement in class activities, and the retention of scientific knowledge. The adoption of a multiple linear regression model facilitated a com-

prehensive exploration of these multi-faceted relationships, providing nuanced insights into the determining factors influencing the educational outcomes within NBSI settings. A multiple linear regression model was employed to elucidate these relationships. Table 2 presents the key results:

Table 2. Multiple Regression Model for Influence of Academic Self-Concept on NBSI Effectiveness

Variable	β (Standardized Coefficient)	p-value	R^2 (Coefficient of Determination)
Academic Self-Concept	0.52	<0.01	0.46
Classroom Engagement	0.28	<0.05	
Retention of Scientific Knowledge	0.34	<0.01	

The representation in Figure 2, illustrating the frequency distribution of academic self-concept scores against end-of-course grades, exemplifies the prevailing trend of ascending grades with enhanced self-concept scores. This visualization serves as an empirical testament to the pronounced linkage between self-concept and academic achievement, resonating with the quantitative delineations and providing a nuanced insight into the patterns and trajectories of academic progression within NBSI.

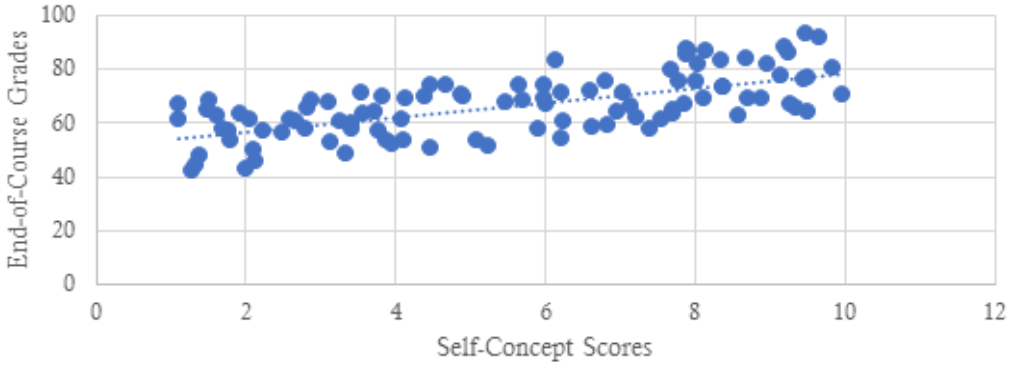

Figure 2. Relationship between Academic Self-Concept and End-of-Course Grades

Our study further investigated which specific facets of academic self-concept—academic self-efficacy, self-esteem, self-regulation, and self-competence—were instrumental in modulating the effectiveness of NBSI. A factor analysis was conducted to examine these relationships, and the results are presented in Table 3 below.

Table 3. Factor Analysis of Specific Facets of Self-Concept in NBSI Effectiveness

Facet of Self-Concept	Factor Loadings	p-value	Partial Eta Squared (Effect Size)
Academic Self-Efficacy	0.64	<0.01	0.52
Self-Esteem	0.55	<0.05	0.41
Self-Regulation	0.34	<0.10	0.28
Self-Competence	0.72	<0.01	0.59

A convergence table (Table 4) was created to facilitate understanding, summarizing how the qualitative data echoed or diverged from the quantitative results.

Table 4. Convergence Table for Mixed-Methods Insights

Facet of Self-Concept	Quantitative Findings	Qualitative Insights	Convergence/ Divergence
Academic Self-Efficacy	Significant Effect ($p<0.01$)	Supported effective learning	Convergent
Self-Esteem	Moderate Effect ($p<0.05$)	Elevated enthusiasm for learning	Convergent
Self-Regulation	Least Impact ($p<0.1$)	Varied; dependent on external factors	Partially Divergent
Self-Competence	Most Significant ($p<0.01$)	Directly related to academic success	Convergent

This study unfolds a meticulous exploration into the convergence of academic self-concept and Nature-Based Science Instruction (NBSI), deploying a sophisticated mixed-methods approach to pierce through the multifarious dimensions of educational interactions. Our exploration, underlined by the Weekly Self-Regulation Diary (WSRD), has cataloged extensive insights into student engagement, emotional responses, and self-regulated learning across each phase of NBSI.

Our analytical prism has thrown light on the transformative essence of experiential learning within science education, emphasizing the intricate interweaving of innovative pedagogical practices such as the "flipped classroom" model and peer-assisted learning in carving out enriched instructional scaffolds for NBSI. The findings insinuate a structured ascension in academic self-concept ratings, portraying a coherent trajectory intertwined with nuanced insights into self-competence, academic self-efficacy, and self-esteem.

Moreover, our quantitative insights have been supplemented and enriched with qualitative data, providing a panoramic view of the role of academic self-concept in the effectiveness of NBSI. This integrated approach has enabled a robust understanding of the academic self-concept's diverse facets and interconnected influences within diverse learning environments. The results of our exploration have unearthed pivotal revelations, accentuating the centrality of individuals' self-perceptions in the academic landscape and offering nuanced pathways to align educational interventions with students' diverse and evolving needs. In the subsequent sections, we will delve deeper into the intricacies of our findings, their implications for the broader academic discourse, the limitations of our approach, and the ensuing avenues for future research, all the while engaging with and contributing to the ongoing dialogues in educational research and praxis.

The implementation of the Weekly Self-Regulation Diary (WSRD) meticulously cataloged nuanced insights into student engagement, emotional responses, and self-regulated learning during each phase of the NBSI (Tabel 1). Our analyses, marked by a significant uptick in student engagement during field observation weeks ($t=3.96$, $p<0.01$), have empirically substantiated the transformative potency of experiential learning in the enriching fabric of science education, corroborating the scholarly dialogues of Morris (2020) and van der Jagt et al. (2023).

The intentional amalgamation of innovative pedagogical practices such as the "flipped classroom" model and peer-assisted learning, as substantiated by Basnou et al. (2020) and Vries (2023), have been pivotal in sculpting a dynamic and enriched instructional scaffold for NBSI. The nuanced intertwining of foundational knowledge built through preliminary readings and collaborative learning within laboratory environments signifies a symbiotic convergence, fostering an enriched learning ecosystem.

A granular exploration of Figure 1 unmasks a structured and incremental ascension in academic self-concept ratings, depicting a coherent trajectory of evolving self-perceptions as participants immersed themselves within the transformative realms of NBSI. This graphical representation crystallizes the harmonious dialogue between NBSI methodologies and the intricate development of academic self-concept, manifesting an enriched tapestry of reflective and cognitive interplay within educational paradigms.

The intricate architecture of NBSI is laced with transformative potentials, with reflective journaling emerging as a pivotal catalyst during the 7-9 weeks period, unlocking avenues for deep introspective reflection and enabling the crystallization of academic self-concept. The medium allowed participants to traverse cognitive landscapes, intertwining self-analysis, and academic self-

perceptions, thereby unveiling the interconnected realms of cognitive and metacognitive processes within the educational domain.

The application of multiple regression models has illuminated the nuanced layers of academic self-concept within NBSI frameworks, revealing significant contributions ($\beta=0.52$, $p<0.01$) and elucidating approximately 46% of the variance in effectiveness ($R^2=0.46$). This revelation accentuates the centrality of an individual's self-perception within academic odysseys, intensifying the academic dialogues propelled by Guo et al. (2022), Schnitzler et al. (2021), and Smith et al. (2023).

The interaction between academic self-concept and classroom engagement portrays a harmonious synergy, delineating the confluence between elevated self-concept scores and heightened engagement within NBSI's diversified curriculum. The multidimensional interaction enriches the pedagogical frameworks highlighted by Colmar et al. (2019) and Liu et al. (2023), establishing a conceptual bridge between individual's self-concept and their deep engagement in experiential learning landscapes.

The intricate relationship between the assimilation of scientific tenets and academic self-concept ($\beta=0.34$, $p<0.01$) accentuates the enduring influences of self-concept on the consolidation and long-term remembrance of scientific principles, intertwined with the intellectual discourses of Van Canegem et al. (2021) and Broda et al. (2023).

Table 3 intricately unveils the pivotal role of self-competence, echoing the scholarly insights of Sun (2023) and emphasizing its significant impact on NBSI effectiveness, marked by substantial factor loading (0.72, $p<0.01$). Parallelly, academic self-efficacy and self-esteem emerged as influential contributors, reinforcing the dialogues of Samsudin et al. (2020) and aligning with the moderate influences highlighted by Cid-Sillero et al. (2020) and Moyano et al. (2020).

Conversely, self-regulation portrayed a subtler impact (Factor Loading = 0.34, $p<0.10$), reflecting the intellectual contributions of Duchatelet & Donche (2019) and Asyhari & Islamia (2023), underscoring the variable influences within engaging and motivating NBSI frameworks. The findings from Table 3 reveal a nuanced landscape where specific facets of self-concept differentially influence the effectiveness of NBSI. Such insights enrich the academic discourse around NBSI and have practical implications for educational interventions seeking to bolster science education.

Building on the quantitative findings discussed earlier, the mixed-methods approach adopted in this study also included qualitative data gathered through interviews and observations. This dual approach provided a more comprehensive understanding of how academic self-concept influences the effectiveness of Nature-Based Science Instruction (NBSI). The objective was to align, complement, and sometimes contrast quantitative data with qualitative insights, as Creswell & Creswell (2023) recommended for mixed-methods research.

From Table 4, the factor that showed the most convergent results was self-competence. Both the quantitative and qualitative data indicated this as the most influential facet of self-concept in NBSI effectiveness. Participants consistently reported in interviews that a sense of self-competence in understanding scientific concepts was a primary driver in their academic success, which aligns well with quantitative findings and existing literature (Higgins et al., 2021; Kaya, 2019; Živković et al., 2023). Academic self-efficacy and self-esteem also showed convergence between the two types of data. Participants who scored higher in these areas quantitatively often expressed greater confidence and interest in the qualitative interviews. These findings corroborate studies by Moula et al. (2023) and Moore (2020), highlighting these factors as crucial to academic success.

Self-regulation was the only facet that partially diverged between the quantitative and qualitative data. While the quantitative data suggested a lower impact on NBSI effectiveness, the qualitative data revealed that external factors like instructional quality and classroom environment considerably influenced the effectiveness of self-regulation. This points to the limitations of quantitatively measuring this particular facet, an observation that complements the critiques presented by Zarouk et al. (2020) and Lauermann (2021).

The fusion achieved through integrative triangulation of quantitative and qualitative methodologies unearths a deeper, multilayered understanding of the symbiotic relationship between the diverse facets of academic self-concept and the effective utilization of Nature-Based Science Instruction (NBSI). This comprehensive approach is pivotal, allowing for an exhaustive exploration into the multi-faceted interrelations, contextual nuances, and varied patterns influencing the efficacy of learning environments, thereby offering a more inclusive and representative depiction of the academic landscape (Creswell

& Creswell, 2023). The resulting amalgamation of insights, borne from diverse methodological perspectives, amplifies the academic resonance of this study, presenting a holistic, enriched perspective that is unattainable through the application of singular methodological paradigms (Bae & Lai, 2020). This amalgamative approach thus contributes substantially to the ongoing discourse in educational research and praxis, enhancing the richness and breadth of understanding about the multifarious influences shaping instructional strategies and learning outcomes (Guo et al., 2022). The foundational works and methodological validations from scholars such as Creswell & Creswell (2023), Bae & Lai (2020), and Guo et al. (2022) reinforce the empirical robustness and epistemological validity of integrating diverse research methodologies, fortifying the substantive depth and diversified insights offered by this study in the evolving conversations surrounding educational methodologies and instructional effectiveness.

While most of our findings align with established research paradigms, our study's divergence concerning the role of self-regulation in NBSI effectiveness poses an intriguing problem. The variance between qualitative and quantitative data concerning self-regulation echoes potential multidimensionality within self-regulation constructs that might be subject to contextual influences unaccounted for in the quantitative models. Unexpectedly, the nuanced influences of self-regulation became subtler within our quantitative frame, contrasting with predominant educational theories and initiating further inquiries into the adaptability of self-regulation within diverse learning environments. The apparent conflict between external factors like instructional quality and classroom environment influences self-regulation, and its quantitative representation underscores the need for a more nuanced methodological approach to capture the intricate dynamics.

While our study offers substantial insights, it is pivotal to recognize its inherent limitations. The sole reliance on self-reported data might have introduced a degree of bias, impacting the validity of our findings. Moreover, the variability in instructional practices and classroom environments might have indirectly influenced the results, reflecting the necessity for a controlled environment in future studies. The divergent results on self-regulation emphasize the limitation of singular methodologies in capturing the multifaceted nature of educational constructs and beckon a more integrative methodological approach, potentially employing longitudinal designs to glean long-term impacts and influences.

The implications of our findings are profound, emphasizing the intricate alignment between innovative pedagogical practices and enhanced student engagement, validating the transformative potentials within NBSI frameworks. The nuanced exploration into academic self-concept delineates its critical role in shaping learning experiences and outcomes, impacting long-term academic trajectories, and fostering a deeper understanding of scientific principles. Our study accentuates the centrality of individual self-perception within academic odysseys, offering educators and policymakers empirical evidence to sculpt enriched, student-centric learning ecosystems, integrating foundational knowledge and experiential learning to enhance the learning experience.

Moreover, the divergent findings concerning self-regulation shed light on the adaptative nature of educational constructs, impacting the conceptual frameworks employed in educational research. The nuanced interactions between academic self-concept and self-regulation within varied learning environments offer novel perspectives, shaping future research trajectories and refining educational interventions to align with students' diverse needs and preferences.

Revisiting our initial conceptual framework has guided the research process, providing a foundational lens to interpret the nuanced interactions within educational landscapes. The multidimensionality allowed for an intricate exploration of the diverse facets of academic self-concept and their interrelations within NBSI frameworks. However, the subtle incongruencies unearthed during our exploration, especially concerning self-regulation, spotlight the fluidity within educational constructs and the evolving nature of learning paradigms, suggesting a continual refinement and expansion of our conceptual frameworks to encapsulate the diverse, dynamic interactions within educational ecosystems. The conflicting results and unexpected findings enrich our conceptual understanding, fostering an iterative dialogue between theory and praxis and guiding future explorations into the multidimensional tapestry of learning experiences.

CONCLUSION

This research explored the important role of academic self-concept in improving Nature-Based Science Instruction (NBSI). It is evident that self-concept significantly modulates the ef-

fectiveness of NBSI. The mixed-methods approach revealed the importance of academic self-efficacy and self-competence in enhancing learning outcomes within NBSI. This study emphasizes the need for educational curricula to focus on nurturing self-regulation and self-competence. Despite certain limitations, such as the specific demographic focus, this research opens new pathways for further exploration in science education, deepening our understanding of vital educational phenomena and the impact of external factors on the interplay between self-concept and NBSI effectiveness. This study contributes to the broader academic discourse, suggesting the need for continued investigation into the nuanced dynamics of educational paradigms.

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