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MODERATING ROLE OF SCIENCE SELF-CONCEPT IN ELICITING STATE CURIOSITY WHEN CONFRONTING A VIOLATION OUTCOME

Jihoon Kang

Abstract. *A higher science self-concept may be required to stimulate state curiosity in incongruent situations, but there is limited research on the connection between science self-concept and state curiosity. The purpose of this study is to examine whether science self-concept moderates the process of arousing students' state curiosity when they encounter results that violate their expectations in science learning. To achieve this aim, 410 fifth- and sixth-grade primary school students (194 female) were asked to solve science questions, and students who faced results that deviated from their expectations were classified as the violation outcome group (experimental group), while those who faced results consistent with their expectations were classified as the expected outcome group (comparison group). Then, the moderating effect of science self-concept on the relationship between science curiosity and state curiosity arousal in these two groups was verified using PROCESS macro. Results showed that science curiosity significantly predicted state curiosity in both groups. Notably, science self-concept had a significant moderating effect on the process of arousing state curiosity in the violation outcome group, where higher science self-concept led to a greater increase in state curiosity after confirming the correct answer. However, in the expected outcome group, the moderating effect of science self-concept was not significant. The implications of these findings for science education and potential directions for future research are discussed.*

Keywords: *science self-concept, science curiosity, state curiosity, moderating effect, PROCESS macro*

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Introduction

One of the main goals of science education is to change students' misconceptions into scientific concepts. One of the proposed approaches to effectively guide students' misconceptions into scientific concepts is the strategy of inducing cognitive conflict (Lee et al., 2003; Niaz, 1995). While presenting situations of incongruity alone does not guarantee the occurrence of cognitive conflict, it is imperative to have incongruent situations for cognitive conflict to arise (Kwon et al., 2003). Therefore, in science education, emphasizing the presentation of phenomena or data that are inconsistent with students' preconceptions has been emphasized as a means to rectify their misconceptions (Lee & Kwon, 2001; Lee et al., 2003; Stahl & Feigenson, 2017).

Students tend to become more attentive when they encounter novel and intriguing stimuli that do not align with their expectations during the learning process, and curiosity moderates this process (Day, 1982; Gruber & Ranganath, 2019; Loewenstein, 1994). Students who confront phenomena or results that do not align with their expectations become aware of a knowledge gap, which is a discrepancy between what they currently know and what they want to know, and their curiosity is then aroused to resolve this gap (Berlyne, 1960; Grossnickle, 2016; Loewenstein, 1994; Shin & Kim, 2019). Curiosity in learning has a positive impact on attention, memory, and retention, enabling effective learning, and is also helpful in fostering scientific thinking and science literacy (Bathgate et al., 2014; Gruber & Ranganath, 2019; Gruber et al., 2014; Kang et al., 2009; Marvin & Shohamy, 2016; Murphy et al., 2021). Given that curiosity has a significant influence on academic performance and achievement in science learning (Authors, 2021; Bathgate et al., 2014; Weible & Zimmerman, 2016), it is necessary to induce a high level of curiosity for effective learning.

Given the significant impact of students' curiosity on academic performance, it is crucial to identify their curiosity levels in the learning situation and respond accordingly. At this point, curiosity refers to an individual's emotional state whose level can relatively easily fluctuate depending on the situation, not as a personal innate trait that does not change easily (Loewenstein, 1994). State curiosity, which denotes temporary curiosity in specific learning situations, can be altered in its intensity through appropriate educational interventions. Therefore, it should be given significant attention in the research of science education.

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To stimulate curiosity, which is a desire for knowledge that an individual does not currently know, they should have the belief and confidence that they can bridge specific knowledge gaps they currently perceive (Deci, 1975; Pekrun, 2019; Peterson & Cohen, 2019). Because moderate levels of perceived knowledge gaps can stimulate high levels of state curiosity (Kang & Kim, 2020; Litman et al., 2005; Loewenstein, 1994), it becomes challenging to arouse state curiosity when individuals face questions perceived as too difficult or when they lack the belief that the gaps can be resolved. Emotions experienced during learning are often influenced by the perceived controllability of the task (Pekrun et al., 2007). If a task is perceived as controllable, state curiosity may be more likely to be instigated. For example, when a student feels capable of dealing with specific tasks, they are more motivated to learn new knowledge and information to solve the task, resulting in a heightened state curiosity. Conversely, when a student holds low expectancy beliefs regarding their ability to succeed in the task, curiosity may remain low or not be stimulated, as they may be less inclined to challenge themselves to acquire new knowledge and information. Therefore, a relatively high level of self-concept may be required to elicit state curiosity in discrepant situations. Self-concept pertains to an individual's subjective judgments, beliefs, and perceptions about themselves, forming a multifaceted and hierarchical construct (Baumeister, 1999; Shavelson et al., 1976). Academic self-concept (e.g., science self-concept), a subcomponent of self-concept, pertains to domain-specific perceptions about oneself in academic-related achievement situations. Therefore, students with a high academic self-concept in a specific field exhibit confidence and a sense of superiority in their competence in that particular subject area (Bong & Skaalvik, 2003; Ferla et al., 2009). Hence, students with a high self-concept in science may be more curious due to their belief that they can comprehend and figure out scientific phenomena, even when those phenomena challenge their preconceptions or expectations. In contrast, students with a low science self-concept lack confidence or belief in resolving knowledge gaps when they encounter unacquainted scientific knowledge or information. Consequently, their curiosity may be low even when they recognize knowledge gaps.

It is challenging to find empirical studies that examine whether state curiosity levels vary depending on the level of the student's science self-concept when state curiosity is aroused by encountering phenomena that contradict their expectations in science learning. If research is conducted on the level of state curiosity aroused depending on the level of self-concept, it can establish a theoretical foundation for understanding the relationship between self-concept and curiosity, which is known to strongly predict academic achievement. This could offer valuable insights to researchers and practitioners in science education, providing them with significant educational implications.

Accordingly, in this study, an attempt is made to ascertain whether science self-concept plays a moderating role in the process of arousing students' state curiosity when they are confronted with scientific phenomena that deviate from their expectations. Through this, implications for science education are aimed to be provided by examining the role of the science self-concept in arousing state curiosity.

Research Question

Does students' science self-concept moderate the relationship between their science curiosity and the arousal of state curiosity when they encounter results that violate their expectations?

Research Methodology

General Background

This research was attempted within the natural setting of a classroom, where education normally transpires, with an effort to minimize artificial intervention or manipulation. As a result, this research was conducted in the research participants' classroom in the context of a general science class. This approach, which observes and measures participant behavior as it naturally unfolds in regular learning environments, guarantees substantial ecological validity (Jirout et al., 2018).

The current study was conducted with primary school students in a major city in South Korea. The students came from families with a socio-economic status deemed as upper middle class. Moreover, the students exhibited an above-average level of academic achievement and displayed a notable interest in their schoolwork.

This study is based on quantitative methods. The hypothesis in this study posits that the relationship between science curiosity and state curiosity would be moderated by science self-concept when students are faced with outcomes deviating from their expectations (see Figure 1). Accordingly, cases where participants encountered

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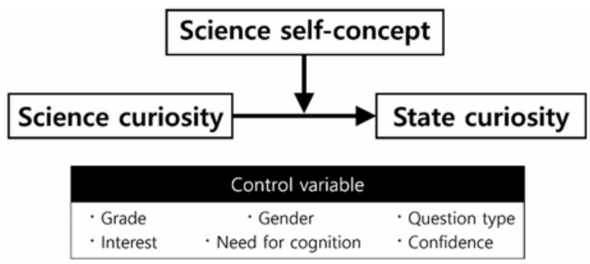
results that contradicted their expectations were classified as the "violation outcome" group, whereas those that did not were classified as the "expected outcome" group. In the conceptual model (Figure 1) designed to test the hypothesis, the independent variable was designated as science curiosity, the dependent variable as state curiosity, and the moderating variable as science self-concept. In this study, curiosity was analyzed by dividing it into two components: science curiosity, which pertains to long-term aspects, and state curiosity, which pertains to short-term aspects (see Ainley, 2019; Grossnickle, 2016). Science curiosity is defined as a relatively stable tendency for individuals to experience curiosity regarding natural phenomena within the realm of scientific knowledge (Kang et al., 2020; Spektor-Levy et al., 2013; Weible & Zimmerman, 2016). This curiosity is distinctive from epistemic curiosity about general knowledge. In contrast, state curiosity is considered as a transient emotional state, characterized by a momentary curiosity evoked in specific situations (Loewenstein, 1994). Grade, gender, question type, interest in the content of questions, need for cognition, and confidence in one's answer, all of which are plausible to affect state curiosity, were held as covariates.

Figure 1
Conceptual Model of the Relationship between Science Curiosity and State Curiosity, and the Moderating Role of Science Self-Concept



Participants

This study was conducted with a total of 410 primary school students (194 female) in the 5th and 6th grades. Given that each student responded to two questions (designated questions A and B), the maximum possible number of study cases is 820. Among them, invalid cases, such as those where participants indicated a lack of comprehension of the question, instances displaying insincere responses (e.g., illegible handwriting), cases marked by unclear labeling, and those containing at least one missing response, were excluded from the analyses. In addition, students who had low confidence in their answers (the level of confidence was less than 3) and did not write down reasons for their answers were excluded because it was judged that their preconceptions regarding the question were not firmly established. As a consequence, a final analysis was conducted on 547 cases. With this sample, there were 293 cases in the violation outcome group (132 female), and 242 cases in the expected outcome group (98 female).

Procedures

The procedure of assessments and treatments in this study is illustrated in Figure 2. First, students were requested to rate their level of science curiosity, interest in the subject matter covered by science questions A and B, need for cognition, and science self-concept. Subsequently, all students were presented with either science question A or question B and were asked to try to answer them. Question A pertains to thermal conductivity according to materials and contact area, and Question B pertains to temperature change according to the amount of solution and temperature difference between two materials. The science questions A and B were descriptive questions that required students to provide the reasons for their chosen answer. For each question, students were asked to select one or more of the provided answers and write down the rationale behind their selection in order to gain a closer understanding of the students' preconceptions. The last option within each question was designed to allow for an "another opinion," giving students the opportunity to express opinions divergent from the provided answers. Students were given sufficient time to peruse the question and formulate their answer. Right after trying to solve the question, the students were asked to rate their confidence level in their answer. Subsequent to these ratings,

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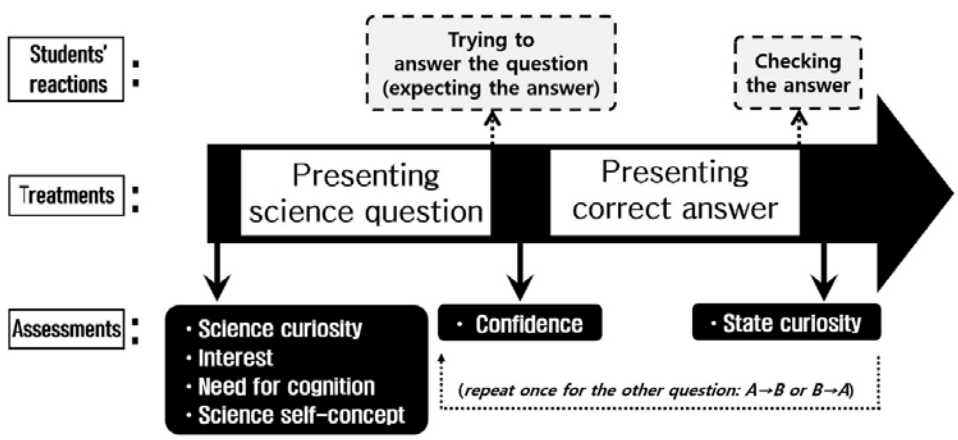
the correct answers were revealed to the students. At this time, students whose answers matched the correct answer were classified into the "expected outcome" group, while students whose answers did not match the correct answer were classified into the "violation outcome" group. Immediately after presenting the correct answer for each question, state curiosity was assessed. The same procedure, from presenting the science question to assessing their state curiosity, was repeated for the other question. Considering that the order of question presentation might influence the outcome, students in six classes were exposed to questions in the order of "question A → question B," while students in another seven classes were exposed to questions in the order of "question B → question A." A 3-minute break was provided between questions to mitigate the cognitive load stemming from question-solving. These procedures were not time-limited and were executed in a manner akin to a standard classroom setting. All procedures were conducted by the author to mitigate the possibility of variation in students' responses and, consequently, in the study results, which could arise due to different teachers carrying out the procedures. After all the treatment was completed, learning materials containing solutions to the questions were provided, allowing participants to learn. Participants were thoroughly briefed on the study's objectives and the significance of their involvement, and all results would be treated anonymously and confidentially.

Figure 2
Procedure of Assessments and Treatments



Instrument

A total of six variables were measured: interest, need for cognition, and confidence as control variables; science curiosity as the independent variable; state curiosity as the dependent variable; and science self-concept as the moderating variable. When modifying certain items, consultation was conducted with five experts and scholars in their field. Additionally, pilot tests were conducted with 5th to 6th-grade primary school students to confirm if any issues arose in comprehending and responding to the modified items. All items on the measures in this study were designed to be responded to using a 5-point Likert scale ranging from *not agree at all* to *strongly agree*.

Control Variables Measures

The interest questionnaire consisted of items asking how interested students are in the content of questions A and B. Interest in the content of each question was assessed by three items, with a sample item being "How does heat transfer?" Cronbach's α was .880 for question A and .886 for question B. The measurement of the need for cognition utilized Lee's (2004) version of the Need for Cognition Scale, originally developed for college students by Cacioppo et al. (1984), which was adapted to be comprehensible for primary school students. Sample items are "I enjoy problems that require a lot of thinking," and "I like to think seriously for a long time." Cronbach's α for the total 18 items was .891. The confidence questionnaire comprised two items assessing students' confidence in

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their answers after solving questions A or B, with one example being, "I believe the answer I chose will be correct." Cronbach's α in this study was .759.

Science Curiosity Measure

The Epistemic Curiosity Scale developed by Litman and Spielberger (2003) was used by modifying certain item content to make it a questionnaire of epistemic curiosity about science suitable for primary school students. An example of a modified item is as follows: "When I learn new scientific content, I would like to find out more about it." The measurement of science curiosity in this study consisted of 5 items measuring diversive curiosity and 5 items measuring specific curiosity. Cronbach's α for the total 10 items was .943.

Science Self-Concept Measure

To assess science self-concept, the items used to measure academic self-concept were adapted from the self-concept measurement developed by Kim (1984). These items were modified to gauge self-concept within the academic discipline of science (i.e., science self-concept), and subsequently utilized in this study. The questionnaire consists of 11 items measuring competence and 9 items measuring incompetence. Sample items for this measurement included "I can do better science than other students if I set my mind to it" and "I feel like I'm not good at science" (reverse coded). Cronbach's α for the total 20 items was .950.

State Curiosity Measure

The Science State Curiosity and Anxiety Scale (SSCAS), developed by Kang et al. (2020), was used to assess students' state curiosity when they check the correct answers to science questions after solving them. The SSCAS is appropriately designed for young adolescents and is user-friendly both in administration and scoring. It classifies science learning into three phases: "confronting science questions," "checking the answer," and "learning science concepts," offering the advantage of assessing state curiosity and state anxiety in each phase. It comprises three sets of self-report measures, each comprising 10 items. Within each of the three phases, there are 5 items designed to assess science state curiosity and another 5 items measuring science state anxiety. Among them, 5 items measuring science state curiosity were used in "checking the answer" phase, such as "I want to know why this result came out." Cronbach's α for the 5 items was .90 for question A and 0.880 for question B.

Data Analysis

The data collected for this study was analyzed as follows. First, descriptive statistics such as means and standard deviations (*SD*s) were computed to confirm the levels of the variables used in the analysis. Furthermore, correlation analysis was conducted to confirm the relationships between the variables. In order to test the hypothesis that the relationship between science curiosity and state curiosity would be moderated by science self-concept when faced with an outcome violating expectations, a moderation analysis was conducted using Model 1 of the PROCESS macro for SPSS (Hayes, 2013). To operationalize this, the participants were classified into two distinct groups based on their encountered outcomes: the violation outcome group (experimental group), which encountered the outcome that deviated from their expectations, and the expected outcome group (comparison group), which encountered the outcome that was consistent with their expectations. Control variables were grade, gender, question type, interest, need for cognition, and confidence in one's answer. The PROCESS macro model offers the advantage of automatically providing mean centering for both the independent and moderating variables, thus mitigating multicollinearity. Additionally, it allows for a detailed verification of the significance of the simple slope—i.e., the effect of the independent variable on the dependent variable according to the moderating variable (Hayes et al., 2017). When the moderating effect was significant, each conditional effect was confirmed based on the mean value + 1 *SD* (high level), the mean value (medium level), and the mean value – 1 *SD* (low level) of the moderating variable. Furthermore, the Johnson-Neyman technique identified the range of values for the moderating variable that exhibited a significant moderating effect and visualized it as a graph. All statistical analyses were performed using SPSS 22.0 and PROCESS macro-3.5.3.

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Research Results

Descriptive Statistics and Correlation Analysis

The results of analyzing the means, *SD*s, and correlations between the variables for the group facing the violation outcome and the group facing the expected outcome are presented in Table 1. In terms of the independent variable, science curiosity, the violation outcome group had a mean of 33.64 (*SD* = 10.16), and the expected outcome group had a mean of 35.43 (*SD* = 8.82). Regarding the moderating variable, science self-concept, the violation outcome group had a mean of 67.28 (*SD* = 16.53), and the expected outcome group had a mean of 69.82 (*SD* = 14.98). In addition, for the dependent variable, state curiosity, the violation outcome group had a mean of 13.41 (*SD* = 4.31), and the expected outcome group had a mean of 12.40 (*SD* = 4.48).

In both groups, correlation analysis revealed moderate to high positive associations between science curiosity and science self-concept (*r*violatioin = .710, $p < .01$; *r*expected = .647, $p < .01$), science self-concept and state curiosity (*r*violatioin = .518, $p < .01$; *r*expected = .401, $p < .01$), as well as science curiosity and state curiosity (*r*violatioin = .664, $p < .01$; *r*expected = .524, $p < .01$). In addition, significant positive correlations were observed between interest and state curiosity (*r*violatioin = .628, $p < .01$; *r*expected = .517, $p < .01$), as well as between need for cognition and state curiosity (*r*violatioin = .503, $p < .01$; *r*expected = .541, $p < .01$).

Table 1
Means, Standard Deviations, and Correlations between Variables

Variable	Mean (*SD*)		Scale range	Correlation (lower diagonal: violation; upper diagonal: expected)								
	Violation (*N = 242*)	Expected (*N = 242*)		1	2	3	4	5	6	7	8	9
1. Grade	5.54(5.00)	5.48(0.50)	.		-.144*	.100	.055	.034	.158*	.059	-.068	.102
2. Gender	0.45(0.50)	0.40(0.49)	0-1	.004		.030	-.195*	-.120	-.251**	-.314**	-.180**	-.083
3. Question type	0.53(0.50)	0.40(0.49)	0-1	-.008	.010		.089	-.044	-.077	.015	.028	.124
4. Interest	6.71(2.85)	7.38(2.81)	0-12	-.091	-.181**	-.063		.463**	.337**	.566**	.485**	.517**
5. Need for cognition	60.32(13.14)	62.56(12.14)	1-90	-.114	-.102	.082	.534**		.392**	.638**	.597**	.541**
6. Confidence	5.45(1.24)	5.86(1.30)	0-8	.068	-.258**	-.018	.233**	.212**		.411**	.403**	.384**
7. Science curiosity	33.64(10.16)	35.43(8.82)	1-50	-.136*	-.271**	.005	.610**	.730**	.236**		.647**	.524**
8. Science self-concept	67.82(16.53)	69.82(14.98)	1-100	-.056	-.175**	.026	.490**	.673**	.343**	.710**		.401**
9. State curiosity	13.41(4.31)	12.40(4.48)	0-20	-.009	-.221**	.022	.628**	.503**	.309**	.664**	.518**	

Note. *$p < .05$, **$p < .01$

Moderating Role of Science Self-Concept in the Relationship between Science Curiosity and State Curiosity when Facing the Violation Outcome

To verify the moderating effect of science self-concept on the relationship between science curiosity and state curiosity, data were analyzed using the PROCESS macro (Model 1) for SPSS, as proposed by Hayes (2013). Verification was conducted using bootstrapping with a 95% confidence interval and a sample size of 5000. As shown in Table 2, the model accounted for 59.4% of the variance in the dependent variable, state curiosity ($R^2 = .594$), indicating a good model fit ($F = 45.984$, $p < .001$). Science curiosity as an independent variable was found to have a positive significant effect on state curiosity ($B = .192$, $p < .001$). The interaction term between science curiosity and science self-concept had a positive significant effect on state curiosity ($B = .005$, $p < .001$), and the confidence interval of bootstrap [0.003, 0.006] did not include zero. It can be seen that science self-concept moderated the relationship between science curiosity and state curiosity ($\triangle R^2 = .051$, $p < .001$).

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Table 2
Moderating Effect of Science Self-Concept on the Relationship between Science Curiosity and State Curiosity in Violation Outcome Group (N = 293)

		B	*SE*	*F*	R^2 ($\triangle R^2$)
Control variables	Grade	.651	.332	45.984***	.594 (.051***)
	Gender	.123	.354		
	Question type	.256	.331		
	Interest	.490***	.074		
	Need for cognition	.006	.020		
	Confidence	.170	.150		
Science curiosity (A)		.192***	.029		
Science self-concept (B)		.026	.016		
A X B		.005***	.001		

Note. *$p < .05$, **$p < .01$, ***$p < .001$

The conditional effect of science curiosity on state curiosity according to the level of science self-concept was analyzed, and the results are presented in Table 3. The conditional effect was found to be significant for all three conditions: science self-concept smaller than average (*M* - 1*SD*), average (*M*), and larger than average (*M* + 1*SD*). The conditional effect was the strongest for high values (+ 1*SD*) of science self-concept, it was still significant for medium values (*M*) and low values (- 1*SD*) of science self-concept (B_{M+1SD} = .272, p < .001; B_M = .192, *p* < .001; B_{M-1SD} = .113, *p* < .001). This implies that the higher the science self-concept, the stronger the effect of science curiosity on state curiosity.

Table 3
Conditional Effects of Science Curiosity at Values of Science Self-Concept in Violation Outcome Group (N = 293)

Science self-concept	Effect	*SE*	95% CI	
			LLCI	ULCI
M - 1SD	.113***	.032	.051	.175
M	.192***	.029	.136	.249
M + 1SD	.272***	.032	.210	.335

Note. ***$p < .001$; *M* = mean; *SD* = standard deviation; LLCI = lower limit confidence interval; ULCI = upper limit confidence interval

Specifically, the significance region of the conditional effect of science curiosity was identified through the Johnson-Neyman technique. The conditional effect was significant when the science self-concept was higher than 41.82. 91.468% of all cases had a science self-concept level of 41.82 or higher. Consequently, the moderating effect of science self-concept was significant in 91.468% of all cases when science curiosity predicted state curiosity.

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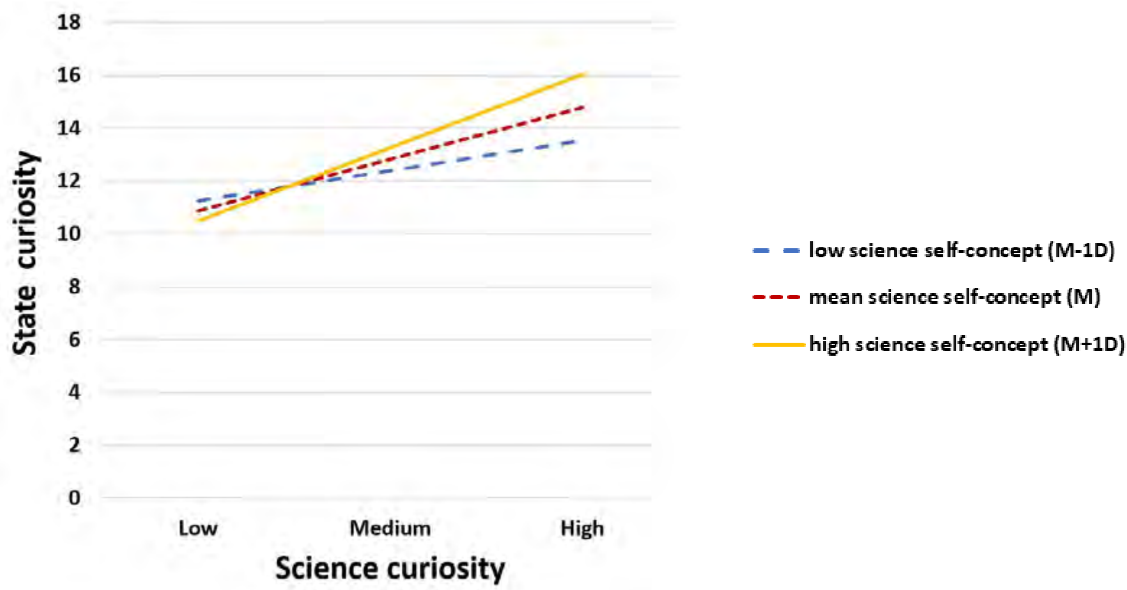
Figure 3
Relationship between Science Curiosity and State Curiosity at Different Levels of Science Self-Concept



The interaction effect can be plotted using values one standard deviation above and below the mean (Aiken & West, 1991). The result of visualizing the relationship between science curiosity and state curiosity according to different levels of science self-concept (mean score, and ± 1 *SD*) is shown in Figure 3. In all three levels, when science curiosity increased, state curiosity also increased. However, it was found that the higher the science self-concept, the steeper the slope of the increase in state curiosity as science curiosity increased. In other words, it can be seen that even if the level of science curiosity was the same, state curiosity further increased when science self-concept was high. For the cases with science self-concept scores 1 *SD* below the mean, the association between science curiosity and state curiosity is more attenuated compared to cases with science self-concept scores 1 *SD* above the mean. This implies that the effect of science curiosity on state curiosity is weaker for individuals who have lower levels of science self-concept compared to those who have higher levels.

Moderating Role of Science Self-Concept in the Relationship between Science Curiosity and State Curiosity When Facing the Expected Outcome

The model accounted for 43.7% of the variance in the dependent variable, state curiosity ($R^2 = .437$), and its fit was confirmed ($F = 20.019$, $p < .001$). While students who encountered the expected outcome demonstrated that science curiosity had a positive significant effect on state curiosity ($B = .097$, $p < .05$), the moderating effect of science self-concept on the process of arousing state curiosity was not significant ($p = .489$).

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Table 4
Moderating Effect of Science Self-Concept on the Relationship between Science Curiosity and State Curiosity in Expected Outcome Group (N = 242)

		B	*SE*	*F*	R^2 ($\triangle R^2$)
Control variables	Grade	.353	.460	20.019***	.437 (.001)
	Gender	.831	.486		
	Question type	1.056*	.461		
	Interest	.404***	.100		
	Need for cognition	.112***	.026		
	Confidence	.558**	.201		
Science curiosity (A)		.097*	.040		
Science self-concept (B)		-.022	.021		
A X B		-.001	.002		

Note. *$p < .05$, **$p < .01$, ***$p < .001$

Discussion

As suggested in several previous studies (Grossnickle, 2016; Kang & Kim, 2021a; Loewenstein, 1994), science curiosity as a stable aspect was found to have a positive effect on inducing state curiosity. In addition, the results of this study suggest that science self-concept moderates the pathway from science curiosity to state curiosity, especially when students are confronted with outcomes that deviate from their expectations, as indicated by a significant interaction term between science curiosity and science self-concept. State curiosity, as an urgent desire to close knowledge gaps, may require a certain degree of perceived competence about oneself in the pertinent academic fields, because its primary goal is to reduce knowledge gaps and acquire specific knowledge (Loewenstein, 1994; Shin & Kim, 2019). Therefore, in the process of evoking state curiosity among students who encountered the violation outcome, it is judged that those with a higher science self-concept tend to experience heightened levels of state curiosity. Promoting curiosity can play a crucial role in providing support for science education (Jirout, 2020). Given that higher levels of state curiosity induced during learning have been shown to positively influence academic performance and achievement (Gruber & Ranganath, 2019; Gruber et al., 2014; Kang et al., 2009; Kang & Kim, 2021b), it is important for science educators to acknowledge the significance of cultivating and augmenting students' science self-concept.

The results may provide support for existing theories pertaining to individuals' motivational processes. As indicated by the result that science self-concept significantly moderated the relationship between science curiosity and state curiosity, students need to have the belief or confidence that they can address their knowledge gaps to generate a high level of state curiosity (Deci, 1975; Pekrun, 2019; Peterson & Cohen, 2019). Therefore, the results of this study can be explained by the expectancy-value theory, which posits that a student's expectancy beliefs in their ability to bridge knowledge gaps, that is, completing specific tasks in a particular domain, affect their subsequent academic performance and goal attainment (Atkinson, 1964; Wigfield & Eccles, 2000). In addition, emotions in learning can be influenced by proximal factors in a student, such as situational perceptions and cognitive appraisals (Pekrun et al., 2007). In order for emotions like state curiosity to be triggered in learning, appraisals of controllability are necessary, and the intensity of emotions increases with higher perceived controllability (Pekrun et al., 2007). This control-value theory is premised on the idea that appraisals of control play a crucial role in the arousal of emotions experienced during learning (Pekrun, 2006). As the appraisal of controllability relies on student's subjective judgments, it is highly probable that characteristics or qualities specific to individual students will be influenced in the appraisal. Therefore, students with a higher science self-

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concept are more likely to have a stronger belief in their ability to control knowledge gaps in specific situations, such as when facing a violation outcome. This, in turn, is presumed to lead to a higher level of curiosity aroused to resolve such knowledge gaps.

Meanwhile, the moderating effect of science self-concept was not observed in situations where students were confronted with outcomes that aligned with their expectations. This is in contrast to the results in which the science self-concept served as a moderating variable when confronted with violation outcomes. For students who encountered expected outcomes, the result of the question (i.e., the correct answer) may not have posed a challenging task requiring a new understanding. Consequently, there may be no significant moderating effect observed between their state curiosity and science self-concept.

Science self-concept is a key factor for predicting academic achievement in science (Bouchey & Harter, 2005; Jansen et al., 2014; Zhang et al., 2022). Meaningful learning in science education involves changing students' existing knowledge structures, which may include misconceptions, into a more accurate understanding of scientific concepts (Chi, 2008). In order to grasp new scientific concepts that students are unfamiliar with, they should experience curiosity, which is characterized as an individual's inclination to learn, explore, and comprehend novel information (Kashdan & Steger, 2007). The temporary state curiosity experienced at these moments can be influenced by the learner's more stable science curiosity (Loewenstein, 1994). Students' curiosity can motivate them to seek new information in anomalous situations, offering support in overcoming learning challenges and taking intellectual risks (Engel, 2011; Jirout & Klahr, 2012). The role of academic self-concept might also be involved in this process. Therefore, as the results of this study indicated, the moderating effect of science self-concept was confirmed in the relationship between science curiosity and state curiosity._

Limitations

The results of the study require cautious interpretation due to several limitations. First, the results were derived from data collected from 5th and 6th-grade students in a Korean primary school. To generalize these findings to a wider range of ages or regional contexts, further studies are needed. Second, as presented in the results of the Johnson-Neyman technique, the moderating effect of science self-concept was observed only among students whose science self-concept was not extremely low when facing a violation outcome. Consequently, generalizing the results of this study to students with significantly low levels of science self-concept is challenging. Third, these results may not be applicable to students with low confidence in their answers, as they were not included in the analysis. Nevertheless, the applicability of these findings to related studies can be contemplated in light of the general consensus that a higher self-concept within a particular discipline can positively influence the acquisition of novel or unfamiliar knowledge.

Conclusions and Implications

This study explores the moderating effect of science self-concept on eliciting state curiosity in science learning for 5th and 6th-grade primary school students, with potential applications in diverse educational settings. The study claimed that science self-concept can promote students' state curiosity when they are confronted with a violation outcome. The results of the study provide empirical evidence that the higher the science self-concept, the greater the positive effect of science curiosity in stimulating state curiosity. Additionally, they offer insights into how students' self-concept in science can influence their engagement and curiosity when encountering unexpected results, a phenomenon relevant to students from various cultural and educational backgrounds. Considering that presenting scientific phenomena or outcomes that contradict students' preconceptions in teaching scientific concepts is often necessary, and given that state curiosity triggered during the learning has a positive impact on academic achievement, it is important for educators and parents to make efforts to develop students' science self-concept. Meanwhile, the moderating effect of science self-concept was not significant when no violation outcomes were confronted. Future studies should therefore examine a broader range of conditions or situations under which science self-concept can influence the elicitation of state curiosity, beyond instances of encountering the violation outcome.

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Many studies on strategies to arouse state curiosity in learning thus far have focused on external factors (situations or stimuli) that can elicit state curiosity, rather than on students themselves who experience state curiosity. However, this study focused on students' self-concept as the subjects experiencing state curiosity, rather than on external situations or stimuli that trigger state curiosity. In particular, the analysis focused on whether the level of state curiosity experienced by students when they encountered violation outcomes varies depending on their science self-concept levels. The findings are meaningful in that they empirically revealed the moderating role of science self-concept in eliciting state curiosity, in light of the theoretical definition of science self-concept as one's perceived competence in science disciplines.

Students with positive academic self-concept are more likely to enjoy and participate in challenging yet attainable tasks. Therefore, the findings that science self-concept positively moderates the arousal of state curiosity can be applied not only in the context of encountering violation outcomes but also in situations involving challenging tasks. This presents a direction for future research.

Although curiosity and academic self-concept are known to have a positive effect on stimulating learning and are related to persistence in learning, limited empirical research exists on the relationship between state curiosity and academic self-concept. The present study may be an initial step toward empirically understanding the role of science self-concept in arousing state curiosity, which has implications for educational practices worldwide. The findings of this study contribute to revealing the role of science self-concept in the fundamental mechanism of inducing state curiosity and open the door to future avenues for research on the relationship between state curiosity and science self-concept in science learning.

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