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Instructional Clarity in Science Lessons: High-Achieving Students' Motivation to Learn Science and Perception of Science Utility Value

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Annotation. The study deals with the relevance of instructional clarity in science lessons to eighth-grade school students' motivation and perceptions of science utility value. A secondary analysis of data from the Trends in International Mathematics and Science Study (TIMSS) was carried out for countries whose students' science achievement scores were higher than the TIMSS 2019 scale center point. The results revealed that instructional clarity increases high-achieving students' motivation and perception of science utility value.

Keywords: *high-achieving student, instructional clarity in science lessons, motivation to learn science, science education, science utility value.*

Introduction

The 21st century is an age of rapid technological change. Science is at the heart of technology and innovation, and their importance for technological change is unquestionable. In the first decade of the 21st century, scientists pointed to the declining interest in science among the next generation of students. "Yet in recent times, fewer young people seem to be interested in science and technical subjects. Why is this? Does the problem lie in wider socio-cultural changes, and the ways in which young people in developed countries now live and wish to shape their lives? Or is it due to failings within science education itself?" (Osborne & Dillon, 2008, p. 5).

There is strong evidence that school students' interest in science decreases over time (Alexander et al., 2019). Researchers have noticed that this decrease in students' motivation to learn science begins in the upper grades of elementary school (Patrick & Mantzicopoulos, 2015; Shin et al., 2019) and continues into lower secondary school (Osborne et al., 2003; Steidtmann et al., 2022). Increasing school students' motivation to learn science continues to be a big challenge for researchers and educators (Filgona et al., 2020; Höft & Bernholt, 2019; Osborne & Dillon, 2008; Shin et al., 2019; Steidtmann et al., 2022; Zhang & Bae, 2020).

Many correlational motivational studies have described the state of students' motivation at a given time and its relationship with the environment (Fortus & Touitou, 2021). For instance, a longitudinal study about the process of change in students' motivation revealed the main factors influencing the changes in students' motivation (Fortus &Touitou, 2021). According to Fortus and Touitou (2021), teachers were the most influential factor, followed by parents, and school culture played the smallest role. Teachers' instructional clarity is demonstrated by their ability to clearly present learning content, by asking students questions, by responding to student questions to clarify new learning material, and by repeating content seeking to ensure deeper understanding (Brekelmans et al., 2000; Wlodkowski, 1993).

However, internal factors that promote students' academic motivation are no less important. Teachers can increase students' motivation to learn science by helping them understand the subject's utility value and recognize how science can benefit their personal interests (Perez et al., 2019; Shin et al., 2019; Wigfield & Ecceles, 2020). Expectancy-value theory (EVT) emphasizes the importance of subjective task values. According to EVT, students are motivated to learn when they understand the value of what they are learning (Eccles & Wigfield, 2020; Strobach & Karbach, 2016).

Researchers have noticed that there is only limited evidence about the influence of instructional clarity on academic value (Chen et al. 2022; Maulana et al., 2016). Thus, this study aimed to reveal the role of instructional clarity in science education in high-achieving (HA) students' motivation to learn science, considering the mediating effect of students' science utility value.

The following questions guided this study:

1. What is the relationship between instructional clarity in science lessons and HA students' motivation to learn science?
2. What is the relationship between instructional clarity in science education and HA students' science utility value?
3. How is HA students' science utility value associated with students' motivation to learn science?

Theoretical Background

Instructional Clarity and Students' Motivation

Researchers argue that instructional clarity in the classroom manifests in the ability of the teacher to deliver learning instruction comprehensibly and clearly (Chan et al., 2021; Maulana et al., 2016).

Researchers argue that instructional clarity can reduce cognitive load (Bandura, 1997; Bolkan, 2016; Guo et al., 2018). The concept of cognitive load stems from cognitive load theory (CLT). Instructional clarity can improve motivation and ensure active engagement. Studies have shown that students feel more motivated and inclined to actively engage in courses that they perceive as easier and more attractive. (Assor, 2012; Park et al., 2015; Violanti et al., 2018).

There are two approaches to instructional clarity: the constructivist approach and the traditional (i.e., direct instruction) approach (Maulana et al., 2016). The traditional (direct instruction) approaches follow from deductive instructional strategies, the constructivist – from inductive strategies (Ruutmann & Kipper, 2011). Regarding Self-determination theory (SDT) (the constructivist approach), instructional clarity might occur when the teacher supports students' learning autonomy, efficacy for learning (structure), and connectedness with their peers and teacher (Assor, 2012; Maulana et al., 2016; Ryan & Deci, 2020).

According to SDT, efficacy for learning (structure) promotes students' academic motivation (Lazarides et al., 2019; Maulana et al., 2016; Ryan & Deci, 2020). Efficacy for learning manifests when teachers adapt educational material to students' experiences and abilities, clearly communicate goals to students, help students understand and solve learning problems, and give students support and feedback during the learning process (Ryan & Deci, 2020). The TIMSS 2019 Instructional Clarity Scale includes the following items regarding efficacy for learning: the teacher explains the teaching material well, gives support and feedback during the learning process and has clear answers to students' questions.

SDT posits that involvement occurs when teachers promote collaboration between students and their peers and between teachers and their students (Kunter et al., 2013; Ryan & Deci, 2020). There is evidence that instructional clarity enhances students' involvement and motivation in learning mathematics and the English language (Bolkan & Griffin, 2018; Mu-Hsuan Chou, 2021; Violanti et al., 2018). Based on CLT and SDT we hypothesised:

H1. Instructional clarity in science education directly predicts HA students' learning motivation to learn science.

Motivation and students' science utility value

Expectancy-value theory (EVT) treats students' motivation as a function of two variables: their expectation of success and subjective task values (Eccles, 1993; Maulana et al., 2016; Rosenzweig et al., 2019). Situated expectancy-value theory digs deeper, stressing the impact of the situation and cultural background of learners' expectancy and subjective task value hierarchies (Eccles & Wigfield, 2020). While expectation of success and task value are separate constructs, they are related to each other (Eccles & Wigfield, 2020; Gaspard et al., 2017; Harackiewicz et al., 2014; Wigfield & Ecceles, 2020).

EVT stresses the importance of subjective task value (Eccles, 1983; Gaspard et al., 2018; Eccles &Wigfield, 2020). According to EVT, there are four subjective task value categories: attainment value (importance of the task for the learner), intrinsic value (task attractiveness or enjoyment), utility value (how useful the task is), and cost (competition with other goals) (Wigfield & Ecceles, 2020). Thus, it follows that students' science task value is a multidimensional construct comprising attainment value, utility value, cost value, and intrinsic value.

Self-determination theory (SDT) asserts that learners are not motivated to act until their fundamental needs for competence, autonomy, and relatedness are met (Ryan & Deci, 2002; 2020). According to SDT, motivation can be divided into three subconstructs: amotivation, extrinsic, and intrinsic (Ryan & Deci, 2000). Intrinsic motivation manifests through learners' satisfaction and engagement and leads students toward learning satisfaction, mastery of learning, and challenging learning tasks. While extrinsic motivation is driven by grades, rewards, competition, instrumental values, obligations, and evaluation by others (Ryan & Deci, 2000). It should be noted that there is a discussion about the overlap of motivational constructs in EVT and SDT. EVT's concepts of the expectation of success and self-conceptualization overlap with SDT's idea of the need for competence (Anderman, 2020; Wigfield & Eccles, 2020), while intrinsic value (according to EVT) corresponds to intrinsic motivation (according to SDT) (Eccles, 2005).

A systematic literature review regarding student motivation to learn science in the Trends in International Mathematics and Science Study (TIMSS) 2011 and TIMSS 2015 datasets revealed that students' motivation was analyzed from the perspective of EVT and SDT (Zhang & Bae, 2020). TIMSS 2019 datasets also consistent in terms of utility value constructs and gave us the opportunity to analyze HA students' science utility value. There is a lack of research on the effect of instructional clarity on high-achievement students' perceptions of science utility value (SUV). This led us to explore the relationship between HA students' science utility value and instructional clarity in science lessons.

Considering EVT and SDT, we formulated the following research hypotheses:

H_2. Instructional clarity in science lessons directly predicts HA students' perceptions of science utility value.

H_3. The HA students' perception of science utility value directly predicts their motivation to learn science.

H_4. The instructional clarity in science lessons indirectly predicts HA students' motivation to learn science.

Materials and Methods

Research Instrument and Sample Size

To achieve the purpose of the research, we chose to examine the data of three TIMSS 2019 scales: the Instructional Clarity in Science Lessons Scale (BSBS 23_n), the Students Like Learning Science Scale (BSBS 22_n) and the Students Value Science Scale (BSBS 25_n). We decided to select countries from the list of eighth-grade students' Average Science Achievement and Scale Score Distributions (Mullis et al., 2020). We selected several countries whose students' science achievement scores were higher than the TIMSS 2019 scale center point. Such a choice was made to find out what the relationships exist between instructional clarity in science lessons (ICSL), science utility value (SUV) and motivation to learn science (MLS) of students with high science achievement. A secondary data analysis of TIMSS 2019 data from five high-performing countries (Singapore, Japan, Korea, Australia, and Israel) was performed (Table 1).

Table 1

Countries and Study Samples

Countries	SGP	JPN	KOR	AUS	ISR	Total
Primary sample	5,546	4,446	4,409	9,060	4,268	27,729
Final sample	5,484	4,342	3,795	8,334	3,792	25,747

Notes. SGP – Singapore; JPN – Japan; KOR – Korea; AUS – Australia, ISR – Israel.

Primary data were downloaded from the TIMSS 2019 database (http://www.timss.org/).

After performing the primary analysis of the data of the three scales mentioned in the selected countries, it became clear that not all questionnaires were filled out. We subsequently removed incomplete questionnaires, which reduced the study sample (Table 1). We created one database of five countries databases and conducted a study with a sample of 25,747 subjects. Considering situated expectancy-value theory; we performed hypothesis testing on the basis of each country's databases separately.

We checked the normality of the data and made sure that the values for asymmetry (skewness and kurtosis) satisfy the condition of normality (Table 2). According to Georg and Mallery (2010), the values of asymmetry between -2 and +2 indicate the data normality.

Table 2

Assessment of Data Normality

Latent variable	BSBS	Item	Skewness	Kurtosis
SUV	25F	It is important to learn about science to get ahead in the world.	.544	-.686
	25E	I would like a job that involves using science.	.006	-.717
	25I	It is important to do well in science.	.999	.448
	25H	My parents think that it is important that I do well in science.	.579	-.637
	25G	Learning science will give me more job opportunities when I am an adult.	.658	-.476
	25A	I think learning science will help me in my daily life.	.738	-.187
	25B	I need science to learn other school subjects.	.233	-.858
	25C	I need to do well in science to get into the university of my choice.	.554	-.678
	25D	I need to do well in science to get the job I want.	.448	-.895
MLS	22I	Science is one of my favorite subjects.	.237	-.868
	22H	I like science experiments.	.961	.159
	22G	Science teaches me how things work.	.674	-.392
	22F	I look forward to learning science in school.	.197	-.913
	22E	I like science.	.472	-.763
	22D	I learn many interesting things in science.	.697	-.392
	22A	I enjoy learning science.	.587	-.469
ICSL	23A	I know what my teacher expects me to do.	.437	-.789
	23B	My teacher is easy to understand.	.704	-.271
	23C	My teacher has clear answers to my questions.	.768	-.108
	23D	My teacher is good at explaining science.	.892	.103
	23E	My teacher does a variety of things to help us.	.799	-.038
	23F	My teacher links new lessons to what I already know.	.631	-.341
	23G	My teacher explains a topic again when we don't understand.	.857	.150

Research Model

This study is a secondary analysis of TIMSS 2019 data, focusing on defining and measuring the direct and indirect role that ICSL plays in HA students' motivation to learn science, considering the mediating effect of students' perceptions of SUV. Our structural model included three latent variables: ICSL, students' MLS, and students' perceptions of SUV (Figure 1).

We performed confirmatory factor analysis (CFA) and structural equation modeling (SEM) with AMOS17.0. CFA extended the possibility of revealing the relationships between the latent variables (ICSL, MLS, & SUV) and the observed variables. SEM helped us reveal the role that ICSL plays in high-achieving students' MLS, considering the mediating role of students' perceptions of SUV.

ICSL comprised seven observed variables representing different aspects of instructional clarity (BSBS 23_n), MLS contained seven observed variables corresponding to its various aspects (BSBS 22_n), and students' SUV contained nine observed variables (BSBS 25_n) (Table 2). It should be noted that all questions of ICSL, MLS and SUV were on a rank scale from 1 (strongly agree) to 4 (strongly disagree).

According to Shrestha (2021), composite reliability (CR) and convergent validity (average variance extracted — AVE) coefficients are related to the quality of a measure. We calculated the AVE and CR of the following latent variables: ICSL, MLS, and SUV (Table 3).

Figure 1

Structural Model for SEM. ICSL – Instructional Clarity in Science Lessons, MLS – Motivation for Learning, and SUV – Science Utility Value, BSBS – Question Code

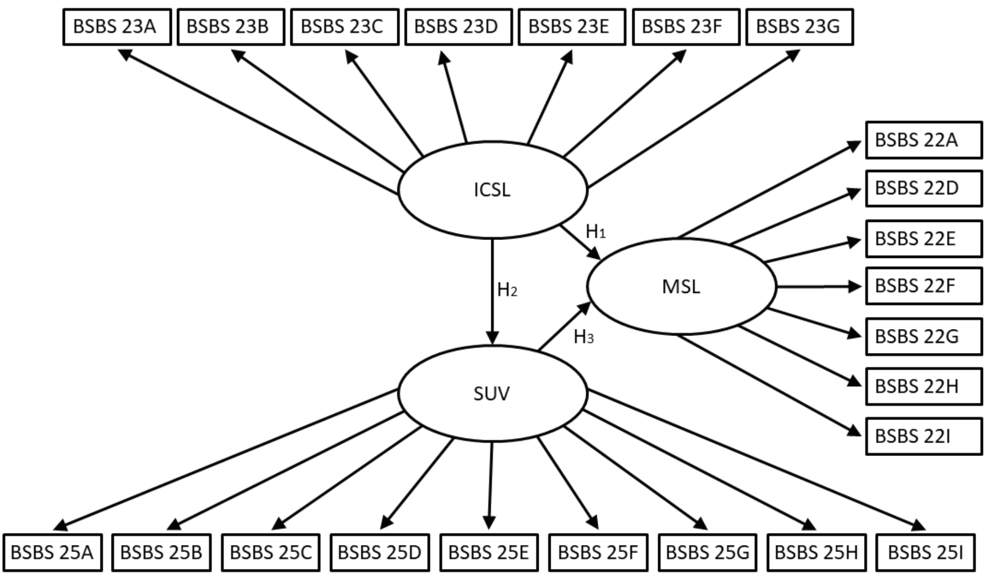

Table 3
Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's Alpha for the Latent Variables (ICSL, MLS, and SUV)

	Average Variance Extracted (AVE)	Composite Reliability (CR)	Cronbach's Alpha
Instructional clarity in science lessons (ICSL)	.825	.886	.921
Students' motivation to learn science (MLS)	.780	.841	.895
Students' science utility value (SUV)	.789	.920	.925

According to Fornell and Larcker (1981), the convergent validity (AVE > .50) and composite reliability (CR > .70) of latent variables (ICLS, SUV, MLS) are suitable (Table 3). The internal consistency of each scale's items was examined using Cronbach's alpha (CA). The results of CA confirm that the latent variables (ICSL, MLS, and SUV) have good internal consistency (> .650) (Table 3).

The structural model consists of exogenous (independent) variables (ICSL) and endogenous dependent variables (MLS and SUV) (Figure 1). The exogenous and endogenous variables were not observed in our model. In reference to model fit, we used the non-normed fit index (Table 4).

Table 4
Fitness of the Items of the Latent Variables (ICSL, MLS, and SUV) and the Structural Model

Model		Absolute Fit Index			Relative Fit Index		
		χ^2/df	RMSEA	GFI	IFI	TLI	CFI
ICSL	Assumed model	3.060	.009	.999	.999	.998	.999
MLS	Assumed model	1.463	.013	.999	.999	.999	1.000
VS	Assumed model	3.323	.025	.999	.999	.996	.999
Structural model	Assumed model	4.743	.054	.953	.969	.956	.969
	Acceptance value	1-5	< .08	> .80	> .90	> .90	> .90

Notes. χ^2 – absolute/predictive fit Chi-square; RMSEA – root mean square error of approximation; GFI – goodness-of-fit index; IFI – incremental fit index; TLI – Tucker–Lewis index; CFI – comparative fit index.

Results

CFA Results: Instructional Clarity in Science Lessons (ICSL)

We performed a CFA on the ICSL latent construct (Table 5). The fitness of the ICSL items indicated an acceptable overall model fit (Table 4).

Table 5
CFA Results of the Latent Variable (ICSL)

Question Code-BSBS	Items about instructional clarity in science lessons	R^2	B	S.E.	β	*p*
23A	I know what my teacher expects me to do.	.336	.856	.011	.580	<.001
23B	My teacher is easy to understand.	.768	1.213	.013	.876	<.001
23C	My teacher has clear answers to my questions.	.682	1.122	.011	.826	<.001
23D	My teacher is good at explaining science.	.705	1.136	.011	.840	<.001
23E	My teacher does a variety of things to help us .	.714	1.136	.011	.845	<.001
23F	My teacher links new lessons to what I already know.	.620	1.079	.010	.787	<.001
23G	My teacher explains a topic again when we don't understand.	.574	1.000		.758	<.001

Notes. R^2 – coefficient of determination; B – unstandardised coefficients; SE – standard error for the unstandardised beta; β – standardised beta; p – probability.

The highest unstandardized beta (B) was obtained for the items about the help of teacher (B = 1.136, p < .001) and good explaining science (B = 1.136, p <. 001), and the lowest was obtained for the item about the teacher expectation (B = .856, p < .001) (Table 5). This means that the variable "I know what my teacher expects me to do" shows the weakest prediction of the latent variable (ICSL) (B = .856, p < .001).

The results of the standardized beta (β) showed that all items were positively related to the latent variable (ICSL) (Table 5). We performed hypothesis testing using the coefficient of determination, R-squared (R^2). Our model contains independent variables that are statistically significant with a high R-squared value ($R^2 > .200$) (Table 5).

CFA Results: Students' Motivation to Learn Science (MLS)

The latent construct of students' MLS was examined using CFA. We checked the data's fit to the model (MLS) (Table 4). Unstandardized (B) and standardized (β) coefficients for the observed variables and the latent factor (MLS) were conducted (Table 6).

Table 6

CFA Results of the Latent Variable (MLS)

Question Code-BSBS	Items about motivation for learning science	R^2	B	S.E.	β	*p*
22A	I enjoy learning science.	.766	1.000		.875	<.001
22D	I learn many interesting things in science.	.201	.524	.007	.448	<.001
22E	I like science.	.820	1.080	.005	.905	<.001
22F	I look forward to learning science in school.	.774	1.080	.006	.880	<.001
22G	Science teaches me how things work.	.434	.747	.006	.659	<.001
22H	I like science experiments.	.332	.624	.006	.576	<.001
22I	Science is one of my favorite subjects.	.680	1.076	.006	.825	<.001

Notes. R^2 – coefficient of determination; B – unstandardised coefficients; SE – standard error for the unstandardised beta; β – standardised beta; *p* – probability.

The results revealed that all variables within the latent construct are statistically significant (MLS) (p < .001) (Table 6).

The variables that express students' emotional relationship with science have the strongest correlations with the latent variable (MLS): "I like science" (β = .905, p < .001), "I enjoy learning science" (β = .875, p < .001), and "Science is one of my favorite subjects" (β = .825, p < .001) (Table 6). The results of the R-squared value show that the independent variables explain much of the variability in the dependent variable (MLS) (Table 6).

CFA Results: Students' Perceptions of Science Utility Value (SUV)

We conducted a CFA analysis of the latent construct of students' perceptions of SUV. The CFA results indicated an acceptable overall model fit (Table 4). All variables were statistically significantly related to the latent variable (SUV) (Table 7).

The following variables had the highest unstandardized (B) coefficients: "I would like a job that involves using science" (B = 1.061, p < .001), "Learning science will give me more job opportunities when I am an adult" (B = 1.033, p < .001), and "I need to do well in science to get the job I want" (B = 1.032, p < .001) (Table 7). The lowest unstandardized coefficient among utility value variables was for the variable "I think learning science will help me in my daily life" (B = .832, p < .001). Thus, students realize the value of science for their future work but find the value of science in daily life to be less important. The results of the CFA indicate that the latent variable is correlated with the utility value and attainment value variables and explains much of the variability: R-squared (R^2) varies from .332 to .820.

Table 7

CFA Results of the Latent Variable (SUV)

Question Code-BSBS	Items about students' value science	R^2	B	S.E.	β	*p*
25C	I need to do well in science to get into the university of my choice.	.607	1.000		.779	<.001
25A	I think learning science will help me in my life.	.487	.832	.008	.698	<.001
25B	I need science to learn other school subjects.	.522	.906	.007	.723	<.001
25D	I need to do well in science to get the job I want.	.601	1.032	.006	.775	<.001
25E	I would like a job that involves using science.	.820	1.061	.008	.745	<.001
25F	It is important to learn about science to get ahead.	.774	1.000	.008	.782	<.001
25G	Learning science will give me more job opportunities when I am an adult.	.434	1.033	.008	.829	<.001
25H	My parents think that it is important that I do well in science.	.332	.860	.008	.684	<.001
25I	It is important to do well in science.	.680	.834	.008	.752	<.001

Notes. R^2 – coefficient of determination; B – unstandardised coefficients; SE – standard error for the unstandardised beta; β – standardised beta; *p* – probability.

Analysis of the Structural Model: SEM Results

We tested our hypotheses (H_1–H_4) using common data from Singapore, Japan, Korea, Australia, and Israel (25,747 respondents). We found that the SEM results suggested a good model fit (Table 4). From testing the hypotheses (H_1–H_3), we discovered that the exogenous variable (ICSL) predicted the endogenous variables (students' MLS and SUV) in each model (Figure 1). The structural model allowed us to analyze the contribution of the exogenous variables to the endogenous variables. The results indicated that all direct paths from ICSL were statistically significant (Table 8), thus confirming the robustness of H_1 (β = .372, p < .001) and H_2 (β = .520, p < .001). SEM analysis confirmed hypothesis H_3, which states that students' perception of SUV directly predicts their MLS (β = .534, p < .001). In addition, H_4, which states that ICSL indirectly predicts students' MLS, was confirmed (β = .277, p < .001) (Table 8).

Table 8

SEM Results of the Structural Model: ICSL, MLS, and SUV

Hypothesis	Path Analysis	Effect	R^2	B	SE	β	*p*
H_1 confirmed	ICSL→MLS	Direct	.630	.462	.007	.372	< .001
H_2 confirmed	ICSL→ SUV	Direct	.270	.610	.008	.520	< .001
H_3 confirmed	SUV → MLS	Direct	.630	.564	.007	.534	< .001
H_4 confirmed	ICSL→ MLS	Indirect		.344		.277	< .001

Notes. ICLS – instructional clarity in science lessons; MLS – motivation to learn science; SUV – science utility value; R^2 – coefficient of determination; B – unstandardised coefficients; SE – standard error for the unstandardised beta; β – standardised beta; *p* – probability.

We repeated the hypothesis (H_1–H_4) testing on each country's (Singapore, Japan, Korea, Australia, Israel) database separately (Table 9). All hypotheses (H_1–H_4) were confirmed (p < .001) (Table 9). However, the standardized and unstandardized coefficients of the hypothesis testing were found to be different (Table 9).

Table 9

SEM Results of the Structural Model of Different Countries

Country	Hypothesis	Path Analysis	Effect	R^2	B	SE	β	*p*
SGP	H_1	ICLS→MLS	Direct	.536	.470	.020	.365	< .001
	H_2	ICSL→ VS	Direct	.261	.626	.023	.511	< .001
	H_3	VS → MLS	Direct	.536	.498	.015	.475	< .001
	H_4	ICSL→ MLS	Indirect		.312		.243	< .001
JPN	H_1	ICLS→MLS	Direct	.200	.577	.022	.454	< .001
	H_2	ICSL→ VS	Direct	.477	.493	.022	.447	< .001
	H_3	VS → MLS	Direct	.200	.409	.018	.355	< .001
	H_4	ICSL→ MLS	Indirect		.202		.169	< .001
KOR	H_1	ICLS→MLS	Direct	.572	.574	.023	.425	< .001
	H_2	ICSL→ VS	Direct	.326	.721	.025	.571	< .001
	H_3	VS → MLS	Direct	.572	.458	.018	.428	< .001
	H_4	ICSL→ MLS	Indirect		.330		.245	< .001
AUS	H_1	ICLS→MLS	Direct	.582	.483	.013	.402	< .001
	H_2	ICSL→ VS	Direct	.199	.517	.015	.444	< .001
	H_3	VS → MLS	Direct	.582	.509	.011	.494	< .001
	H_4	ICSL→ MLS	Indirect		.263		.219	< .001

Country	Hypothesis	Path Analysis	Effect	R^2	B	SE	β	*p*
ISR	H_1	ICLS→MLS	Direct	.616	.573	.022	.446	< .001
	H_2	ICSL→ VS	Direct	.251	.611	.025	.501	< .001
	H_3	VS → MLS	Direct	.616	.486	.016	.460	< .001
	H_4	ICSL→ MLS	Indirect		.296		.231	< .001

Notes. ICLS – instructional clarity in science lessons; MLS – motivation to learn science; VS – value science; R^2 – coefficient of determination; B – unstandardised coefficients; SE – standard error for the unstandardised beta; β – standardised beta; *p* – probability; SGP – Singapore; JPN – Japan; KOR – Korea; AUS – Australia, ISR – Israel.

Discussion and Conclusions

In this study, we tested three hypotheses based on the measurement and structural model of the TIMSS 2019 data. The CFA results of the ICSL measurement model revealed that science teachers' activities to help students learn and to clearly explain new science content were the strongest predictors of ICSL (Table 5). Teacher support in the learning process reduces the complexity of learning material and, at the same time, creates better conditions for improving students' competencies, autonomy, and social relatedness (Lazonder & Harmsen, 2016; Steidtmann et al., 2022). Scholars discus about two types of student support: cognitive and emotional (Kleickmann et al., 2020; Steidtmann, 2022). The TIMSS 2019 Instructional Clarity in Science Education Scale provided the opportunity to analyze only science teachers' cognitive support. Our research based on TIMSS 2019 data confirmed the positive role of cognitive support in ICSL in lower secondary schools.

We performed a CFA of the MLS latent variable and revealed that the variables that expressed HA students' engagement in science had the strongest correlations with their MLS (Table 6). According to EVT, emotional engagement in science ("I like science," "I enjoy learning science", and "Science is one of my favorite subjects") corresponds to intrinsic value (Eccles, 1983; Wigfield & Eccles, 2020). Similarly, according to SDT, emotional engagement corresponds to intrinsic motivation (Ryan & Deci, 2000; 2020) and personal interest (Renninger &Hidi, 2016). Hence, the results of our study on HA students' intrinsic motivation to learn science are in line with the key ideas of SDT and EVT.

The results of the SUV latent variable revealed that the variables corresponding to personal utility value in a future career ("I would like a job that involves using science", "Learning science will give me more job opportunities when I am an adult," and "I need to do well in science to get the job I want") were the highest predictors of HA students' perceived SUV in learning (Table 7). Our results complement previously conducted studies on the link between SUV and careers (DeWitt & Archer, 2015; Gaspard et al., 2015; Gaspard et al., 2017; Gaspard et al., 2018; Sahin, 2015; Shin et al., 2019).

We found that the personal utility value variable ("I think learning science will help me in my daily life") was the weakest predictor of students' perceived SUV (Table 7). Therefore, lower secondary school students realize the value of science for their future careers. However, the value of science in daily life is less important for these students. Thus, science teachers should apply learning strategies that can help students understand SUV in daily life.

The results of the first hypothesis test revealed that ICSL influences HA students' perceptions of SUV. This result is in line with the results of other researchers regarding the relationships between instructional clarity and students' perceptions of academic value (Gaspard et al., 2015; Gaspard et al., 2017; Gaspard et al., 2018; Maulana et al., 2016).

Consistent with our second hypothesis, we found that HA students' perceptions of SUV had a direct and statistically significant effect on their MLS. A large body of research has confirmed that EVT is applicable to educational contexts, emphasizing the importance of utility value in promoting students' MLS (Gaspard et al., 2015; Harackiewicz et al., 2014; Huleman et al., 2017; Shin et al., 2019; Wigfield et al., 2017). The results from our third hypothesis test support EVT: Students' perceptions of SUV are important predictors of their MLS.

By testing the fourth hypothesis, we found that HA students' perceptions of SUV play an important mediating role in the relationship between ICSL and students' MLS. This finding corresponds to the results of a study that used TIMSS 2019 data to explore the of students' mathematics value in the relationship between students' academic enjoyment and instructional clarity (Chen & Lu, 2022). Chen and Lu (2022) analyzed the TIMSS 2019 data of two countries and revealed that instructional clarity was positively related to students' perceived mathematics value in the Hong Kong group and the English group. Likewise, mathematics value was positively related with enjoyment in the Hong Kong group and English group. We analyzed TIMSS 2019 data from five countries (Singapore, Japan, Korea, Australia, and Israel) in one dataset, revealing that ICSL was positively related to students' perception of SUV ($\beta = 0.520$, $p < .001$) and that SUV was positively related with students' MLS ($\beta = 0.534$, $p < .001$). The magnitudes of standardized coefficients (β) are higher in our study compared to Chen and Lu (2022) study results.

Situated expectancy-value theory stresses the impact of situational and cultural backgrounds on students' development of expectancy and value hierarchies (Ecceles & Wigfield, 2020). Scholars argue that culture plays an important role in shaping motivation and that it influences the personal and contextual determinants of motivation (Filgona et al., 2020). We tested the hypotheses (H_1–H_4) separately using each country's databases: Singapore, Japan, Korea, Australia, and Israel (Table 9). The results of the hypothesis testing showed that all hypotheses were confirmed, but the magnitudes of the standardized and standardized coefficients differed among the various countries (Table 9).

The first limitation follows from the fact that we tested the model based on TIMSS 2019 data obtained using three scales: the Instructional Clarity in Science Lessons Scale, the Students Like Learning Science Scale, and the Students Value Science Scale. Zhang and Bae (2020) argued that the items drawn from the TIMSS 2011 and TIMSS 2015 datasets were consistent in terms of utility value constructs. We performed a content analysis of the TIMSS 2019 Students' Value Science Scale items, ensuring that the items were consistent in terms of utility value constructs. However, we suggest retesting our structural model using specialized and frequently used scales for instructional clarity, MLS, and SUV.

Second, according to SDT, instructional clarity occurs when a teacher supports their students' learning autonomy, efficacy for learning (structure), and connectedness with peers and teachers. The TIMSS 2019 Instructional Clarity in Science Lessons Scale allowed us to analyze efficacy for learning (structure). In future studies, we suggest analyzing ICSL using learning autonomy and connectedness with peers and teachers.

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Mokymo aiškumas gamtamokslinių dalykų pamokose: labai gerų gamtamokslinių rezultatų pasiekusių mokinių mokymosi motyvacija ir gamtamokslinių dalykų vertingumo suvokimas

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Santrauka

Tyrime nagrinėjama mokymo aiškumo gamtamokslinių dalykų pamokose reikšmė aštuntos klasės mokinių gamtamokslinei motyvacijai ir gamtos mokslų naudingumo suvokimui. Buvo atlikta antrinė 2019 m. tarptautinio matematikos ir gamtos mokslų tyrimo TIMSS duomenų analizė. Naudoti trijų TIMSS 2019 skalių duomenys: mokymo aiškumo gamtamokslinių dalykų pamokose (angl. *Instructional Clarity in Science Lessons Scale*), gamtamokslinės motyvacijos (angl. *Students Like Learning Science Scale*) ir gamtos mokslų naudingumo (angl. *Students Value Science Scale*). Analizuotos penkių šalių (Singapūro, Japonijos, Korėjos, Australijos ir Izraelio) duomenų bazės. Šių šalių mokinių gamtos mokslų pasiekimai buvo aukštesni už TIMSS 2019 pasiekimų skalės vidurkį. Toks šalių pasirinkimas buvo sąlygotas siekimo išsiaiškinti, kokių sąsajų esama tarp mokymo aiškumo, gamtos mokslų naudingumo suvokimo ir labai gerų gamtamokslinių rezultatų pasiekusių šalių mokinių gamtamokslinės motyvacijos. Šiam tyrimui atlikti naudota patvirtinamoji faktorinė analizė ir struktūrinių lygčių modeliavimas. Nustatyta, kad mokymo aiškumas turi statistiškai reikšmingą, teigiamą poveikį mokinių gamtamokslinei motyvacijai. Tyrimo rezultatai atskleidė, kad mokymo aiškumas gamtamokslinių dalykų pamokose gali padidinti labai gerų gamtamokslinių rezultatų pasiekusių mokinių gamtamokslinę motyvaciją ir gamtos mokslų naudingumo vertės suvokimą.

Esminiai žodžiai: *gamtamokslinių dalykų mokymosi motyvacija, gamtamokslinis ugdymas, gamtamokslinių dalykų vertingumo suvokimas, mokymo aiškumas gamtamokslinių dalykų pamokose, labai gerų mokymosi rezultatų pasiekęs mokinys.*

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