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STUDENTS' LEVELS OF AGENTIC ENGAGEMENT IN EXPERIMENTS AND ITS EFFECT ON SCIENTIFIC INQUIRY COMPETENCIES IN TECHNICAL EDUCATION AND TRAINING INSTITUTIONS IN TANZANIA

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Abstract:
This study aimed to assess students' levels of agentic engagement in experiments and its effect on scientific inquiry competencies (SICs) in technical education and training institutions in Tanzania. The study employed a quantitative approach and a cross-sectional survey design. A sample of 337 second- and third-year students studying the laboratory science and technology (LST) program from five technical education and training institutions was drawn using a proportionate stratified sampling technique. Data was collected through the use of the student agentic engagement survey questionnaires as well as the SICs test and analyzed through descriptive statistics (mean, standard deviation and variance), an independent sample t-test and hierarchical multiple regression analysis. The results revealed that LST students had a similar level of agentic engagement despite their differences in gender (male vs. female), grade levels (second vs. third years), and the nature of the institutions (private vs. public) and overall moderate levels of agentic engagement in experiments. The results further revealed that students' agentic engagement in experiments had a significant positive effect on SICs when age, gender, nature of technical institutions and grade levels were controlled. Therefore, we concluded that LST students' gender, grade levels and the nature of the institutions have no effect on students' levels of agentic engagement.

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Notably, students demonstrated moderate levels of agentic engagement in scientific experiments, and agentic engagement found to be an important learning factor for promoting SICs. Thus, we recommended that while instructing scientific experiments in the laboratory, instructors be reminded to involve students as agents as often as possible to improve their SICs.

Keywords: agentic engagement, scientific inquiry competencies, technical education and training institutions, Tanzania

1. Introduction

In 2015, the United Nations (UN) proposed the 2030 Agenda for Sustainable Development by outlining 17 Sustainable Development Goals (SDGs). One of the UN's top agendas in the education sector is to promote quality education, as advocated in the 4th SDG (UN, 2019). Several definitions of quality education have been proposed, however, one of the focuses in education settings is to promote students' acquisition of all fundamental competencies (Wu *et al.*, 2018). In science education, scientific inquiry competencies (SICs) are one of the fundamental and beneficial competencies required to be acquired by students as future scientists (Arnold *et al.*, 2021; Krell *et al.*, 2018; NRC, 2012).

Scientific inquiry competencies are a sequential, logical and systematic set of abilities related to conducting scientific investigations (Arnold *et al.*, 2021; Krell *et al.*, 2018). Thus, SICs emphasise hands-on scientific practices or procedural scientific problem-solving processes (i.e., knowing how) for solving particular scientific problems. Several studies have documented that SICs are fundamental competencies, especially in the current world that requires students to be able to do (practice) rather than just understand science concepts (knowledge) (Arnold *et al.*, 2021).

Scientific inquiry competencies have several benefits for scientist students. For example, SICs enable students to develop an ability to conduct scientific investigations by following systematic procedures for generating scientific knowledge and providing solutions to problems based on scientific evidence (Wu *et al.*, 2018). Also, SICs can assist students in developing the ability to "*analyze, interpret, evaluate, reason, and finally solve scientific problems*" (Wulandari & Shofiyah, 2018, p. 1). In that line, SICs enable students to be able to solve various scientific societal challenges scientifically while also being able to generate scientific knowledge by conducting scientific investigations.

Despite the benefits of SICs, studies focused on assessing students' levels of SICs in different countries within different grade levels reported that students have limited levels of SICs (Jamal, 2017; Kambeyo, 2018; Krell *et al.*, 2018). With such a limited level of SICs, there can be a danger of producing science graduates who are incapable of conducting scientific investigations by following systematic procedures for solving scientific problems. Therefore, it is important to identify and investigate different students' learning factors that seem to be instrumental for enhancing students' learning outcomes, including SICs (Wu *et al.*, 2018).

Literature shows that students' engagement in the learning context is an important learning factor for improving students learning outcomes in terms of performance and achievement (Delfino, 2019; Fredricks *et al.*, 2018). For quite some time, students' engagement was conceptualised as a multi-dimensional construct consisting of behavioural, cognitive, emotional and social engagement (Fredricks *et al.*, 2016, 2018). However, Reeve and Tseng (2011) contended that in the teaching and learning context, students can also be engaged as agents by being particularly given autonomy in the teaching and learning processes. Thus, this led to the establishment of the new construct of engagement known as agentic engagement (Mameli & Passini, 2019; Reeve & Tseng, 2011).

Agentic engagement is defined as a student's active contribution to the teaching and learning process to make it more supportive for them (Reeve & Jang, 2022). It involves intentional attempts and willingness to express interest, offer constructive inputs and make suggestions about the learning tasks and pedagogical processes during classroom or laboratory instructions (Mameli & Passini, 2019; Reeve & Shin, 2020). Previous studies showed that students' agentic engagement is considered an important learning factor for increasing their motivation, confidence and participation in learning activities (Reeve, Cheon, & Tae Ho, 2020). On the other hand, agentic engagement has been reported to be essential for raising students' motivation to perform learning tasks. This is because students who engage as agents feel valued for being allowed to offer their views, inputs, preferences and interests about the learning task and pedagogical processes (Reeve & Jang, 2022). Likewise, other studies have reported that fostering agentic engagement in classrooms is beneficial for improving students' academic achievement (Reeve, Cheon, & Tae Ho, 2020; Reeve & Tseng, 2011).

Students' cognitive, social, behavioural, and emotional engagements are heavily researched constructs in education settings, while agentic engagement is relatively new and inadequately researched (Freeman, 2019; Reeve & Jang, 2022). Thus, this study focused on agentic engagement. However, to date there is no evidence that agentic engagement has been studied in laboratory settings, particularly in technical education and training institutions. Based on that, it is not even clear whether students have the required levels of agentic engagement while performing scientific experiments and whether such levels differ based on students' gender, the nature of technical institutions and grade levels. Moreover, it is not yet clear whether students' agentic engagement has an effect on their SICs. To solve all those issues, the current study addresses this knowledge gap by investigating students' levels of agentic engagement in experiments and its effect on SICs in technical education and training institutions in Tanzania.

1.1 Purpose of the Study

The general purpose of this study is to investigate students' levels of agentic engagement in experiments and its effect on SICs in technical education and training institutions in Tanzania.

1.2 Objectives of the Study

The study aimed to achieve the following specific objectives:

1. To assess students' levels of agentic engagement in experiments based on gender, nature of technical institutions and grade levels in technical education and training institutions in Tanzania.
2. To ascertain the effects of students' agentic engagement in experiments on SICs in technical education and training institutions in Tanzania when controlling for age, gender, nature of technical institutions and grade levels.

2. Literature Review

2.1 Theoretical Framework

This study was guided by Kahn's Employee Engagement Theory (EET), established by Kahn in the year 1990. The EET theory is a management theory that assumes that the effective performance of employees depends on how much they are emotionally, cognitively and physically engaged (Burch *et al.*, 2015; Kahn, 1990). Similarly, in education settings, cognitive, emotional, and physical engagement are vital for promoting students' good understanding of the lesson and consequently improving their learning outcomes (Fredricks *et al.*, 2016, 2018). Recent studies have confirmed that agentic engagement is among the engagement constructs. Additionally, agentic engagement has been confirmed to be an essential learning factor for raising students' motivation, confidence and participation in learning activities (Freeman, 2019; Mameli & Passini, 2019) and for improving students' academic achievement (Reeve, Cheon, & Jang, 2020; Reeve & Tseng, 2011). Since SICs are among the learning outcomes, we hypothesized that agentic engagement can have significant positive effects on SICs, similar to cognitive, emotional, and physical engagement.

2.2 Scientific Inquiry Competencies Framework

A review of the literature presented several sets of SICs. However, this study covers the ability to formulate scientific questions, generate hypotheses, plan and design experiments, analyse and interpret data and draw scientific conclusions adapted from Krell *et al.* (2020). Such abilities are in line with what has been provided in a guideline for assessment in the technical education and training institutions in Tanzania. The guideline stated that in practice, students should be assessed for their "*proficiency in setting up investigative questions and hypotheses; planning and conducting science experiments; gathering and analysing experimental data; as well as drawing scientific conclusions*" (NACTE, 2015, p. 13). Furthermore, such abilities present a complete set of scientific problem-solving processes (Wulandari & Shofiyah, 2018).

2.3 Students' Levels of Agentic Engagement in Experiments

Understanding students' levels of engagement in teaching and learning settings is important. Because students' levels of engagement provide feedback about student participation in the teaching and learning process (Ardura *et al.*, 2021; Ardura & Pérez-

Bitrián, 2019; Ribeiro *et al.*, 2019) as well as about the teaching approaches and methods used, particularly whether they attract students' engagement or not (Ladino Nocua *et al.*, 2021). Thus, it is important to assess students' levels of engagement in teaching and learning. A study by Dong and Liu (2020) reported a moderate level of agentic engagement after assessing 89 students from a Chinese university in online English lessons. This shows that little is known about students' levels of agentic engagement, particularly paying attention to students' gender, grade levels and the nature of institutions. Furthermore, it is unknown about student levels of agentic engagement, particularly in laboratory settings in technical education and training institutions in Tanzania.

2.4 Students' Agentic Engagement and Scientific Inquiry Competencies

Several research studies have shown the benefits of students' agentic engagement in improving academic performance or achievement (Reeve & Shin, 2020; Reeve & Tseng, 2011). For example, Reeve and Tseng (2011) opined that students' agentic engagement independently explained a 3.1% variance in student achievement in Taiwan. Similarly, in a longitudinal study that spanned for a year and three phases of data collection in Korean secondary school students (beginning, middle and end of the semester), Reeve *et al.* (2020) established that students' agentic engagement predicts their academic progress in each of the phases when gender, grade level and subject matter were controlled.

Contrary to this, Dong and Liu (2020) established an insignificant negative correlation between students' agentic engagement and their average score in weekly online listening courses. Despite the useful information documented by previous studies (e.g., Dong & Liu, 2020; Reeve *et al.*, 2020; Reeve & Tseng, 2011), that provided evidence for the predictive effect of agentic engagement on general academic performances or achievement. These studies were not directly and explicitly associated with learning outcomes such as SICs. Since SICs exist as independent learning outcomes, there is a need to establish the effect of students' agentic engagement in scientific experiments on SICs. Thus, this study aims to address this gap by testing the effects of students' agentic engagement on SICs.

3. Methodology

3.1 Study Design and Data Collection Instruments

This study employed a cross-sectional survey design. A proportionate stratified sampling technique was used to draw 370 second-and third-year students from five technical education and training institutions in Tanzania. Data were collected using a 10 items Likert scale (*1 = never, 2 = rarely, 3 = sometimes, 4 = often* and *5 = always*) student's agentic engagement scale, adapted from Mameli and Passini (2019). All the items for the survey questionnaires were modified to reflect laboratory scientific experiments as the learning context of this study. Some of the items were: (*I let my instructor know what I need and want during laboratory scientific experiments or during laboratory scientific*

experiments, I express my preferences and opinions). Also, the SICs test, adapted from Kambeyo (2018), was used to assess the student level of SICs. Only 23 tasks and 60 items (12 items per competence (i.e., formulating scientific questions, generating hypotheses, planning and designing investigations, analyzing and interpreting data, and drawing conclusions) were selected from a pool of 36 tasks and 100 items originally constructed. The SICs test tasks and items selected covered biology, chemistry and physics disciplines.

3.2 Content Validity of Data Collection Instruments

Before conducting a pilot study, the content and construct validity of agentic engagement survey questionnaires were ensured by being reviewed by three supervisors. Most of the survey questionnaire items were found to measure agentic engagement, except for a few items that were revised based on suggestions given. On the other hand, four experienced science experts from two technical education and training institutions evaluated the relevance of the SICs test tasks and items to the LST curriculum content as well as for clarity. The content validity index (CVI) for relevance and clarity was estimated and found to be .91 and .90 for relevance and clarity, respectively, which were also greater than 0.7. Therefore, this proves the content validity and clarity of the SICs test (Grant & Davis, 1997).

3.3 Pilot Testing

A pilot study was conducted by administering SICs test and students' agentic engagement survey questionnaires to 88 second and third-year LST program students at Arusha Technical College.

3.3.1 Reliability of Survey Questionnaires for the Pilot Data

From pilot data, the estimated reliability for agentic engagement was (α = .73) for the ten items, which was greater than .70, as presented in Table 1 (pilot study). Thus, such reliability value was sufficient to show that the agentic engagement survey questionnaire was reliable and appropriate to be used to collect data for the actual study (Cronbach & Meehl, 1955).

Table 1: Reliability for Student Agentic Engagement in Experiments

	Pilot study		Main Study	
Variable	**Number of items**	**Cronbach's Alpha**	**Number of items retained**	**Cronbach's Alpha**
Agentic Engagement	10	.73	05	.85

3.3.2 Reliability and Psychometric Properties of Scientific Inquiry Competencies Test for the Pilot Data

In a 60-item SICs test, each correct and incorrect response was awarded one (1) and zero (0) marks, respectively. While estimating reliability, five items were deleted to improve reliability; thus, 55 items with 11 items per competence were used in the actual data

collection with an overall reliability of (α = .69), which is the acceptable value (Cronbach & Meehl, 1955). Person reliability, the local independence test (Q3 coefficient), infit and outfit statistics, and the Wright item-person map were further used to assess the quality of the SICs test. All these parameters were obtained by running dichotomous Rasch analysis in Jamovi software. Additionally, all these psychometric parameters were established as a supplement to reliability. This is because "*reliability is a necessary, but insufficient, criterion to assess the quality of measurement*" (Aryadoust *et al.*, 2021, p. 12).

Table 2: Psychometric Properties of the Scientific Inquiry Competencies Test

Psychometric Property	**Acceptable Value**	**Pilot study**	**Main study**	**Interpretation**
The person reliability	≥.70	.677	.652	Acceptable
The Q3 coefficient	≤ |.30|	Most items had ≤ |.30| except few	≤ |.30|	Acceptable
Infit statistics	0.5 to 1.5 logits	0.5 to 1.5 logits	.0955 to 1.055 logits	Acceptable
Outfit statistics	0.5 to 1.5 logits	0.5 to 1.5 logits	.081 to 1.13 logits	Acceptable

The psychometric values obtained are presented in Table 2 (pilot study). Generally, a .677 approximately to .70 person reliability was estimated, which was an acceptable value implying that around 70% of precision the test has managed to estimate and distinguish students according to their ability (Boone *et al.*, 2014). Most of the items demonstrated a respectable degree of local independence since they had Q3 coefficients of < |.30| except for the items that belong to the same SIC, which were expected to have high Q3 coefficient values (Yen, 1984). The infit and outfit statistic values for each item were within the acceptable range of 0.5 to 1.5 logits, implying that items functioned pretty well and were free from confounding issues with the data (Aryadoust *et al.*, 2021). The Wright item-person map showed a fairly good distribution of the test items, hence, it was ideal for the intended population (Boone *et al.*, 2014), as presented in the Figure 1 and hence was used to collect data.

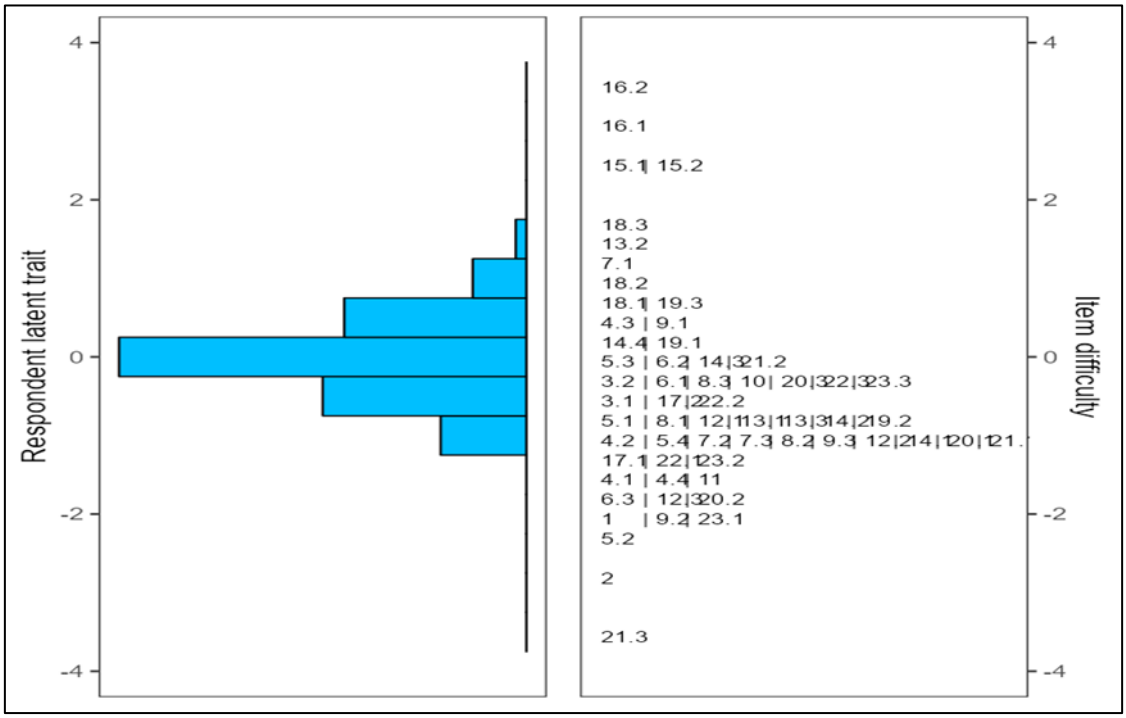

Figure 1: Wright Item-person Map for Scientific Inquiry Competencies Test

3.4 Sample Size, Data Collection and Analysis Procedures

A proportionate sampling technique was used to draw 370 LST program students from five technical education and training institutions in Tanzania. In each institution selected for this study, students were gathered in one room, and they were given important information about the study, seeking voluntary participation as well as data anonymity. Finally, a paper and pencil SICs test and agentic engagement questionnaires were administered, and responses were collected. Students spent approximately 50 minutes completing a SICs test and questionnaires. Before the actual data analysis, data was entered in SPSS and screened for missing values and influential outliers. As a result, 23 respondents were excluded; hence, only 337 LST students were used in the subsequent analysis.

Construct validity for each item in the agentic engagement survey questionnaires in the main study data was ensured by performing exploratory factor analysis (EFA). All items with factor loading greater than .30 were considered to measure the respective construct and hence were taken for further analysis (Hair *et al.*, 2019). Only five items were found to have factor loading greater than .30, and the reliability for the same items was .85 which far greater than .70, as presented in Table 1 (main study). On the other hand, the SICs test overall reliability coefficient for the main study data was .66 for 55 items, which is close to the acceptable value of .70 (Cronbach & Meehl, 1955). Also, the SICs test fairly met all the psychometric properties, as presented in Table 2 (main study). A .652 approximately to .70 person reliability was estimated, which was an acceptable value (Boone *et al.*, 2014). The Q3 coefficients of $< |.30|$ was estimated for most of the items which demonstrated a respectable degree of local independence (Yen,

1984). The infit and outfit statistic values for each item were within the acceptable range of 0.5 to 1.5 logits (Aryadoust *et al.*, 2021).

Prior to the actual data analysis, the underlying statistical assumptions for the independent sample t-test and hierarchical multiple regression analysis were tested and confirmed. Finally, data analysis was conducted using descriptive statistics (mean, standard deviation and variance), independent sample t-tests, and hierarchical multiple regression analysis techniques.

4. Results

4.1 Preliminary Results

4.1.1 Students' Demographic Characteristics

As indicated in Table 3, this study involved 177 (52.5%) female and 160 (47.5%) male students. Also, 168 (49.9%) and 169 (51.1%) were second and third years, respectively. Almost three-quarters of the students in this study, 250 (74.2%), were aged between 21 and 25 years old; 69 (20.5%) were aged between 15 and 25 years old; 13 (3.9%) were aged between 26 and 30 and 5 (1.5%) were aged between 31 and 35 years old.

Table 3: Students' demographic characteristics

Characteristic	Category	Number of respondents	Percent
Gender	Male	160	47.5
	Female	177	52.5
	Total	**337**	**100**
Grade Level	Second year (NTA 05)	168	49.9
	Third year (NTA 06)	169	50.1
	Total	**337**	**100**
Nature of Institution	Private	104	30.9
	Public	233	69.1
	Total	**337**	**100**
Student Age	15-20	69	20.5
	21-25	250	74.2
	26-30	13	3.9
	31-35	5	1.5
	36-40	0	0
	Total	**337**	**100**

This shows that the majority of students who are studying the LST program in Tanzania are between the ages of 21 and 25. Lastly, 233 (69.1%) were drawn from public institutions and 104 (30.9%) were selected from private institutions.

4.1.2 Mean and Correlations between Agentic Engagement and Scientific Inquiry Competencies

The results presented in Table 4 show the mean for agentic engagement was (M = 3.05, SD = 1.06) and the mean for SICs was (M = 34.79, SD = 5.24), which was above the average. Agentic engagement (r = .225, p = .01) was significantly and positively related to SICs.

Table 4: The correlations between agentic engagement and scientific inquiry competencies

		Mean	Standard deviation	1	2
1	Agentic Engagement	3.05	1.06	1	.225**
2	Scientific Inquiry Competencies	34.79	5.24	.225**	1

Notes: *$p < .05$, **$p < .01$.

4.2 Students' Levels of Agentic Engagement in Experiments Based on Gender, Grade Levels and Nature of Technical Institution

In the survey questionnaires, students were asked to respond to items that aimed to assess their level of agentic engagement while conducting scientific experiments in the laboratory. To understand students' levels of agentic engagement based on gender, grade levels and the nature of the technical institution, an independent sample t-test was performed at the 5% significance level (α =.05). The results in Table 5 indicated that there were no significant differences in students' level of agentic engagement based on gender (t(335) =.094, p>.05), grade levels (t(331) =.381, p >.05) and the nature of the technical institutions (t(335) = 1.83, p >.05).

Based on these findings, it shows that regardless of students' gender, grade levels and nature of the technical institution, their agentic engagement levels during scientific experiments were, on average, statistically similar. On the other hand, the results in Table 5 showed that the overall mean for students' agentic engagement was 3.05, which is around code 3 on the Likert scale. This indicated that students were moderately (averagely) engaged as agents while performing scientific experiments. Furthermore, the results showed that students had variations in their responses to agentic engagement during scientific experiments, as indicated by the standard deviation (1.06) and variance (1.13).

4.3 Effects of Covariates on Scientific Inquiry Competencies

Four students' demographic characteristics (gender, age, grade level, institution nature) were treated as covariates in this study. Thus, their unique effects on SICs were controlled when estimating the effect of agentic engagement on SICs. To control for such effects, all four students' demographic characteristics were entered as block one variables of the hierarchical multiple regression analysis. The results summarized in Table 6 show that student gender (B = -.1.971, t = -3.489, p =.001), age (B = -1.595, t = -2.910, p =.004), and nature of the technical institution (B = 1.899, t = 3.156, p =.002) had a significant effect on SICs. On the other hand, student grade level (B =.985, t =1.716, p =.087) had no significant effect on SICs.

Thus, this shows that changes in SICs are explained by student age, nature of technical institution, and gender, but not student grade level. The results further show that students' demographic characteristics (age, gender, grade level, and nature of the technical institution) as covariates accounted for 7.8% of the variance in SICs (R^2 =.078). Additionally, the ANOVA test results show that the model for the covariates was statistically significant (F = 7.011, p =.000), indicating a relatively good model fit. Nevertheless, all these variables had no theoretical interest in the present study. Thus, their effects were controlled in order to accurately estimate the effects of agentic engagement on SICs.

4.4 The Effects of Students' Agentic Engagement on Scientific Inquiry Competencies

In order to achieve the second objective, student agentic engagement was entered into hierarchical multiple regression analysis as a second block variable after gender, age, grade level, the nature of the institution as covariates. The hierarchical multiple regression analysis outputs were examined specifically to see whether the effect of agentic engagement was significant or not at the .05 significant level (i.e., $p<.05$) under the condition of controlling for the covariates. The results summarized in Table 5 indicated that students' agentic engagement (B = 1.150, t = 4.520, $p<.05$) had a significant and positive effect on SICs when controlling for the effects of covariates.

Table 5: Students Overall Level of Agentic Engagement and Based on Gender, Grade Level and Nature of Institutions

Overall mean							3.05					
Standard deviation							1.06					
Variance							1.13					
					Levene's Test		**t-test for Equality of Means**					
Demographic feature		**N**	**Mean**	**SD**	**F**	**p**	**t**	**df**	**p**	**Mean Difference**	**95% Confidence Interval of the Difference**	
											Lower	**Upper**
Gender	Male	160	3.06	1.10	1.53	.216	.094	335	.925	.011	-.218	.239
	Female	177	3.04	1.03								
Grade level	2nd year	168	3.07	1.00	7.61	.006	.381	331	.703	.044	-.184	.272
	3rd year	169	3.03	1.12								
NOI	Private	104	3.21	.996	3.45	.064	1.83	335	.068	.229	-.016	.475
	Public	233	2.98	1.09								

Notes: NOI = Nature of technical institution

Table 6: The Effects Agentic Engagement on Scientific Inquiry Competencies

		Coefficients	**Model summary**									
							95% Confidence Interval		**R**	**R^2**	**R^2-Change**	**F-Change**	**Sig.**
Model	**Predictors**	**Path**	**B**	**Std. E.**	**t**	**Sig.**	**Lower**	**Upper**					
Model 1 for covariates	Grade level	Grade → SICs	.985	.574	1.716	.087	-.144	2.115	.279	.078	.078	7.011	.000
	Gender	Gender → SICs	-1.971	.565	-3.489	.001	-3.083	-.860					
	Age	Age → SICs	-1.595	.548	-2.910	.004	-2.673	-.517					
	NOS	NOS→SICs	1.899	.602	3.156	.002	.715	3.083					
Model 2 for AE	Agentic Eng.	AE→SICs	1.150	.254	4.520	.000	.649	1.650	.363	.131	.054	20.429	.000

Notes: AE = Agentic engagement, **Grade levels:** 1 for first year, 2 for second year, 3 for third year. **Gender:** 1 for males and 2 for females. **Age:** 1 for 15-20, 2 for 21-25, 2 for 26-30, 3 for 31-35 and 5 for 36-40. **Nature of institutions:** 1 for private and 2 for public.

The results further show that the inclusion of agentic engagement increased the predictive power from 7.8% to 13.1% of the variance in SICs (R^2 =.131). Examining the change in predictive power, the results imply that student agentic engagement independently contributed about 5.4% to the variance in SICs (R^2 Change =.054). The ANOVA test results indicated in the model summary further confirmed that the agentic engagement model was statistically significant, as indicated by the F-change results (F-Change = 20.429, $p<.05$). This indicates a good model fit for student agentic engagement in predicting SICs (Kenny, 2015). This implies that students who are highly engaged as agents during scientific experiments are likely to have higher SICs.

5. Discussion

The results indicated that there were no significant differences in students' levels of agentic engagement based on gender. This result received support from the study by Reeve (2013), which showed that both male and female students exhibited similar levels of agentic engagement. This is contrary to the previous studies that conceptualized engagement as a single construct and reported that gender had an impact on the level of engagement in favour of female students (Lamote *et al.*, 2013; Wang & Eccles, 2012). Despite the fact that this study did not aim to find the reason for equal levels of agentic engagement across male and female students, this is a positive aspect of the results, which indicate that instructors might be providing an equitable learning environment for both male and female students. This might be attributed to several initiatives that are currently being undertaken by the government of Tanzania towards alleviating gender inequality in educational settings. For example, in the education and training policy of 2014, "*the government of Tanzania, in collaboration with other education stakeholders, shall make sure that equal provision of education and training based on gender is strictly observed*" (MoEVT, 2014, p. 43). These results yield important implications for educational practices, especially in making sure that instructors maintain and sustain an equal agentic engagement level among male and female students by providing an equitable learning environment for both male and female students.

Also, the results showed that there were no significant differences in students' levels of agentic engagement based on grade levels. Contrary to the present study, which focused on specific engagement constructs, Wilcox *et al.* (2016), who compared the general engagement level among primary children and high school students, found that primary school children exhibited higher levels of engagement compared to high school students. Overall, these results have implications for educational practices, particularly with regard to ensuring that teachers uphold and sustain this level of equal agentic engagement by offering a fair learning environment to both second- and third-year students.

Similarly, the results showed that there were no significant differences in students' level of agentic engagement based on the nature of the technical institutions in which they are studying. These results contribute to the existing gap, particularly documenting that the agentic engagement levels of LST students in Tanzania remained

approximately equal regardless of the nature of the technical institution in which they are studying. These findings yield important implications for educational practices, particularly showing that both private and public-owned technical institutions might be providing an equitable learning environment for students during scientific experiments. Therefore, instructors must make sure that they maintain and sustain such spirit to ensure no gap in students' engagement during scientific experiments among the two types of technical institutions (private vs. government-owned).

The study further reported a moderate level of agentic engagement similar to Dong and Liu (2020), who assessed the level of agentic engagement of 89 students from a Chinese university in online English lessons. Furthermore, the results showed that students varied greatly in their responses to agentic engagement during scientific experiments. Agentic engagement is often associated with self-regulatory and directed learning (Bordbar, 2019; Reeve *et al.*, 2004; Reeve & Shin, 2020). Evidence shows that self-regulatory and directed learning depend on the extent to which the curriculum includes meaningful topics that reflect students' personal interests and future career goals (Wang & Eccles, 2013). Based on such evidence, moderate agentic engagement can probably partly be attributed to the curriculum, which includes less meaningful topics that reflect students' personal interests and future career goals. However, due to the fact that finding the reasons for moderate agentic engagement during scientific experiments was not the focus of this study, this calls for further investigation.

Given the fact that the results showed that students were moderately (averagely) engaged as agents while performing scientific experiments, these results provided two key points of discussion. Firstly, such a moderate level of agentic engagement signifies that a significant proportion of students demonstrated a degree of initiative and autonomy while executing their scientific experiments, which is a sign of active involvement and taking ownership of their learning experiences. Secondly, such a moderate level of agentic engagement could alarm the instructors, especially in encouraging and supporting students to take more proactive roles during scientific experiments. Employing student-centered instructional practices such as inquiry-based learning, providing opportunities for independent exploration, and encouraging self-directed inquiries could potentially enhance agentic engagement (Reeve, 2013; Reeve & Shin, 2020).

Furthermore, to support students' agentic engagement, instructors can design curriculum with experimental activities that are directly linked to their interests and future career goals (Wang & Eccles, 2013). Additionally, instructors can encourage students to ask questions, design their experiments, and make autonomous decisions as part of the efforts to raise students' agentic engagement in the teaching and learning process. Apart from that, Reeve, Cheon and Tae Ho (2020), in the intervention study, confirmed that teachers' adaptation of autonomy-supportive strategies during teaching and learning is quite beneficial for increasing students' agentic engagement in the classrooms. The autonomy-supportive strategies include incorporating and meeting students' needs throughout learning activities, offering explanations, using inviting language, recognizing and accepting negative affective responses, and exercising

patience (Reeve, Cheon, & Tae Ho, 2020). Based on this, instructors who teach LST programs in technical education and training can consider employing autonomy-supportive strategies so that they can raise student's agentic engagement in experiments.

The results, which showed a positive and significant effect of students' agentic engagement on SICs, receive direct support from the results of Reeve and Tseng (2011), which informed that agentic engagement had a significant and positive effect on students' achievement measured in terms of grades for the semester in an urban high school in Taipei City, Taiwan. Similarly, the results complement to those of Reeve *et al.* (2020) in Korean middle-and high-class secondary school students. The study reported that agentic engagement has significant positive effects on course achievement when gender, grade level and subject matter (social science, math, and English) are controlled. However, Reeve and Tseng (2011) further revealed that agentic engagement independently explained about 3.1% of the variance in students' achievement, while Reeve *et al.* (2020) found out that students' agentic engagement contributes to about 1.8% of the variance in academic progress. All these predictive powers of students' agentic engagement were low compared to 5.4% of the variance in SICs accounted for by agentic engagement in scientific experiments in this study.

Such differences might be attributed to several factors, including the context of the two studies (Taiwan and Korea versus Tanzania), students' grade levels (high schools and middle and high versus technical education and training institutions), and student learning outcomes (grades for the semesters versus SICs). Additionally, such differences might be due to the different control variables used in the three studies, in which age, gender, grade level, and nature of technical institution were controlled in the present study while gender and grade level were controlled in the Reeve and Tseng (2011) study as well as gender, grade level and subject matter in the Reeve *et al.* (2020) study. This shows that the increase in the number of control variables might be the reason for the increased variance of agentic engagement on SICs from 3.1% and 1.8% to 5.4%. Similarly, differences in learning outcomes (grades for the semesters in the previous studies versus SICs in this study) might be the reason for the high contribution of agentic engagement to the variance of SICs. On the other hand, this study's results do not mirror those of Dong and Liu (2020), who established that students' agentic engagement had an insignificant negative correlation with their average score in weekly online English listening courses.

The results of this study contributed to Kahn's EET theory, as justified below. Generally, Kahn's EET emphasizes three types of engagement: emotional, cognitive, and behavioral. The present study results supported the positive effects of agentic engagement on SICs. Therefore, this offers an expansion of the EET theory by giving a broader framework for student engagement, including agentic engagement and its positive effect on students' learning outcomes. The present study results showed that only a small part (5.4%), which is less than 100%) of the variation in SICs was explained by agentic engagement. This suggests that students' SICs could be affected by learning factors other than the ones this study looked at. Perhaps future studies can consider

including more students' learning factors in order to find out whether the percentage of the variance in SICs can be increased. In a nutshell, these results had useful implications for teaching and learning practices, particularly alerting instructors to allow students to proactively make suggestions and contributions to the flow of laboratory instructions as essential elements of agentic engagement (Bordbar, 2019; Mameli & Passini, 2019; Reeve & Shin, 2020). Such actions increase student participation in the learning activities and are beneficial for improving their SICs.

6. Conclusion

Through this study, we established that LST students in technical education and training institutions in Tanzania had a similar level of agentic engagement despite their differences in gender (male versus female), grade levels (second versus third years) and the nature of the technical institutions (private versus public). Also, students demonstrated moderate levels of agentic engagement in experiments. On the other hand, students' agentic engagement in experiments had a significant positive effect on SICs when age, gender, nature of technical institutions and grade levels were controlled. Therefore, it is important for instructors to encourage students' active participation in the teaching and learning of laboratory tasks. This can be done by allowing and encouraging students to intentionally and willingly express interest and offer constructive input and suggestions about the learning tasks and pedagogical processes during laboratory instructions. By doing so, students are likely to improve their SICs. In this study, a cross-sectional survey design was used; perhaps the longitudinal study might provide a richer understanding of how student agentic engagement and SICs can develop and relate over time.

Data Availability

The data used for this study formed a component of a larger PhD project that will be submitted at Moi University-Kenya.

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Conflicts of Interest Statement

The authors declare that they have no financial or personal interests that could influence the results of this paper.

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