Journal of Education Technology
Volume 8, Number 2, 2024, pp. 215-223
P-ISSN: 2549-4856 E-ISSN: 2549-8290
Open Access: https://ejournal.undiksha.ac.id/index.php/JET

Technology-Integrated Formative Assessment and the Predictive Role of Motivational Constructs on Conceptual and Procedural Knowledge in Chemistry

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ARTICLE INFO

Article history:
Received March 10, 2023
Accepted April 12, 2024
Available online May 25, 2024

Kata Kunci:
Konstruksi Motivasi, Teknologi, Pengetahuan Konseptual, Pengetahuan Prosedural

Keywords:
Motivational Constructs, Technology, Conceptual Knowledge, Procedural Knowledge

DOI:
https://doi.org/10.23887/jet.v8i2.49155

ABSTRAK

Di banyak negara, termasuk Ethiopia, upaya untuk menerapkan penilaian formatif diperumit oleh berbagai tantangan yang mengarah pada praktik yang buruk. Teknologi memiliki kemampuan untuk memainkan peran penting dalam metode penilaian formatif yang mendukung pembelajaran. Namun, sebagian besar penelitian penilaian formatif sebelumnya tidak bergantung pada teknologi. Oleh karena itu, tujuan penelitian ini adalah untuk menganalisis perbedaan motivasi yang signifikan antara dua kelompok eksperimen dan satu kelompok pembanding, serta dampak dari lima prediktor motivasi dalam pembelajaran kimia. Untuk mencapai tujuan tersebut, desain quasi-eksperimental pretest-posttest diadopsi. Kuesioner motivasi, konseptual kesetimbangan kimia, dan tes prosedural digunakan untuk mengumpulkan data. ANOVA satu arah dan analisis regresi linier berganda digunakan untuk mengevaluasi data. Dalam hal meningkatkan motivasi siswa untuk memahami kesetimbangan kimia, proses penilaian formatif yang terintegrasi dengan teknologi mengungguli pendekatan konvensional dan strategi penilaian formatif, menurut temuan tersebut. Berdasarkan persamaan regresi signifikan, kelima komponen motivasi penelitian mempunyai pengaruh yang signifikan terhadap nilai tes pengetahuan konseptual dan prosedural. Prediktor individu diselidiki lebih lanjut, dan ditunjukkan bahwa motivasi intrinsik dan motivasi kelas keduanya merupakan prediktor positif dan signifikan terhadap nilai tes konseptual, sedangkan motivasi kelas merupakan prediktor positif dan signifikan terhadap nilai tes pengetahuan prosedural. Prosedur penilaian formatif terintegrasi teknologi terbukti lebih efektif meningkatkan motivasi siswa mempelajari kesetimbangan kimia dibandingkan dua kelompok lainnya.

ABSTRACT

Many countries, including Ethiopia, efforts to employ formative assessment are complicated by a variety of challenges that lead to poor practices. Technology has the ability to play a crucial role in learning-supporting formative assessment methods. However, the bulk of previous formative assessment research did not rely on technology. Therefore, this study aims to analyze the differences in motivation between the two experimental and one comparison groups, as well as the impact of five motivational predictors in learning chemistry. To achieve the purpose, a quasi-experimental pretest-posttest design was adopted. The motivation questionnaire, the chemical equilibrium conceptual and the procedural tests were utilized to collect data. One-way ANOVA and multiple linear regression analysis were used to evaluate the data. In terms of improving students' motivation to understand chemical equilibrium, technology-integrated formative assessment processes outscored conventional approaches and formative assessment strategies on their own, according to the findings. According to a significant regression equation, the five motivating components of research have a significant impact on the conceptual and procedural knowledge test scores. Individual predictors were investigated further, and it was shown that intrinsic motivation and grade motivation were both positive, significant predictors of conceptual test scores, whereas grade motivation was a positive, significant predictor of procedural knowledge test scores. Technology-integrated formative assessment procedures were shown to be more effective at increasing students' motivation to study chemical equilibrium than the other two groups.

1. INTRODUCTION

The incorporation of technology into classrooms necessitates good teaching that enhances learning, particularly in the twenty-first century when the route to inspiring and encouraging students to study is built on their desire for technology and digital tools. Since the advent of technology and its role in education, a substantial amount of research has been conducted to investigate the function of technological instructions in the educational process and their influence on enhancing the interactive educational environment (DeJarnette, 2018; Lee et al.,

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2012). A lot of this research has shown that technology has a substantial impact on enhancing teaching and learning approaches.

Researchers recently discovered that technology has the potential to assist formative assessment of learning in a variety of topics at various levels of education (Gikandi & Morrow, 2016; Laborda et al., 2015). With technology-assisted formative assessment, students' participation in assessment activities may be boosted, and timely feedback can be created to advise teachers and students on future teaching and learning directions (Gebre, 2018; Gikandi & Morrow, 2016). In the classroom, using a technology tool to perform formative assessments has a lot of value since it makes the topic more fascinating and allows students to receive particular and personalized feedback. Technology enables for data analysis in addition to delivering quick and thorough feedback. Technology can help with formative assessment. While technology is frequently used to connect students to resources, it may also help with formative evaluation. The difficulties in measuring the success of formative assessments might stem from the manner in which and when they are administered. Previous study discovered, for example, that delayed feedback may not assist student learning or engagement, and that positive feedback may be misinterpreted, negatively impacting learning outcomes (Onojah et al., 2020). As a result, one of the most important teacher and student benefits of adopting the technological tool was immediacy.

Many modern technologies enable teachers to create formative assessments that may be utilized to offer both students and teachers with feedback on their performance. One or both forms of feedback can be provided by applications (verification or elaborative). Students can utilize verification feedback to assist them in achieving their learning objectives, but it only provides half of the information they require. When compared to giving an answer key for students to self-verify later. Previous study discovered that providing verification feedback immediately after each question improved assessment outcomes (Marsh et al., 2012). Similarly, other study discovers that new technologies aimed at assisting with rapid evaluation of student knowledge, timely and focused feedback, interactive learning, and assessment of higher-order abilities integrate a variety of ways to assess student performance (Ng, 2019).

When it comes to employing technology in the classroom, the teacher's involvement is crucial. Meanwhile, a teacher's approach has an impact on the technology's instructional function. In the research of a networked system, indicate that in order to effectively engage students in collaborative learning via digital technology, teachers require clear pedagogical patterns or teaching routines (Teo & Zhou, 2017). Teachers must utilize suitable pedagogical techniques to effectively use technology in learning processes, but an emphasis on strengthening teachers' digital technology abilities while ignoring associated pedagogical consequences appears unlikely to be sufficient (Jacques et al., 2020; Shernoff et al., 2017). Other study indicate that a wide variety of knowledge is necessary to use technology effectively (Elmahdi et al., 2018). Understanding the representation of concepts and pedagogy while utilizing technology, as well as awareness of how technology might solve students' conceptual challenges, are all part of this foundational knowledge. Teachers' knowledge of hardware and software must be complemented with a grasp of formative assessment and associated pedagogies, as advise in the research on technologically enhanced formative assessment (Almalki & Gruba, 2020).

As a result of the increasing attention on formative assessment, teachers and schools sought formative assessment methods that reduced time for teachers, properly assessed students, and offered fast feedback while still aligning with the state's prescribed course of study. Many academics believe that technology can assist teachers in overcoming the challenges of obtaining and analyzing formative data (González-Gómez et al., 2020; Shanks et al., 2017). Rapid assessment, greater access to diagnostic information, more timely feedback to students, interactive learning, easy access to student work, peer feedback and collaboration, efficiency and cost effectiveness, and the ability to capture and assess conceptual and procedural knowledge are some of the key functions of technology identified by previous study support formative assessment processes. This shows that technology can help with formative assessment and contribute to student learning, but it doesn't go into detail on how successful procedures including teachers, students, and technology might improve learning results (Barton et al., 2022; Bosica et al., 2021).

However, there are a lot of challenges that make it difficult to implement formative assessment in many countries, including Ethiopia. One of the problems that contributed to poor practices was the time-consuming nature of formative assessment procedures and the time constraints of class sessions, which made it challenging for teachers to integrate these tactics into their lesson plans. Additionally, it might be difficult for teachers to set up formative assessment assignments in a classroom with a large number of students and overloaded curriculum content (Al-Wassia et al., 2015; Shavelson et al., 2008). Numerous studies suggest using technology to develop formative assessments to get around issues like time restrictions, big classrooms with a number of learners, and a wide-ranging curriculum (Guay et al., 2010; Hayat et al., 2020; Vongkulluksn et al., 2018). Many scholars also believe that technology can assist educators in overcoming the challenges associated with collecting and interpreting formative data (Darner, 2014). However, not enough empirical research has been done to determine how technology-integrated formative assessment could help students learn more effectively (Jansen et al., 2015).

This study aims to analyze the impact of technology-integrated planned formative assessment on students' motivation for chemical equilibrium concepts.

2. METHOD

The non-equivalent pretest, multiple treatments, and posttest control group quasi experimental research design was used in this study. One comparison group (CG) and two experimental groups (TG) with pretest and posttest are included in the design. Group 1 received treatment using technology integrated formative assessment (X_1), Group 2 received treatment using formative assessment alone (X_2), and Group 3 received treatment using conventional methods. As a result, the study's research design could be summarized as show in Table 1.

Table 1. The Diagrammatic Representations Of Nonequivalent Comparison Group Research Design

Groups	Pre-test	Treatments	Post-test
Experimental group one	O_1	E_1	O_2
Experimental group two	O_1	E_2	O_2
Comparison group	O_1	X	O_2

To answer the study's research questions, data were collected using a conceptual and procedural knowledge test, as well as a chemistry motivation questionnaire (adapted from the literature) (Özmen, 2008). The Chemical Equilibrium Procedural Test (CEPT) was used to measure students' procedural knowledge learning results. It consists of 15 multiple-choice questions that were adapted and modified for the study. Like the conceptual questions, this exam featured tasks to assess students' general procedural knowledge before and after intervention. All procedural test items had a reliability rating of 0.75 or above for internal consistency (Cheung, 2009; Mensah & Morabe, 2018; Özmen, 2008). The researchers coded and examined the findings acquired from all of the instruments used. Descriptive and inferential statistics were used to analyze the data. Descriptive statistics (mean and standard deviation) were used to describe the results between research variables. To check if there were any statistically significant differences between the means of two treatments and one comparison group, a one-way analysis of variance (ANOVA) was employed (Glynn et al., 2011). The strength of the association between students' motivation and their higher-order cognitive knowledge as dependent variables was determined using multiple linear regressions.

3. RESULT AND DISCUSSION

Result

Intervention Groups Analysis of Pre-Test Results

At the outset of this investigation, it was assumed that the intervention groups that would be employed would be equivalent. As a result, prior to implementing the instruction, the researchers attempted to examine the homogeneity of the intervention groups. On the basis of data obtained from the pre-administration of the pre-conceptual knowledge test, the pre-procedural knowledge test, and the pre-motivation test, the pretest mean scores for the two experimental and one comparison groups were compared using one-way ANOVA. The statistical data of each group were evaluated and provided in Table 2 and Table 3.

Table 2. Students' Pre-Test Scores in Conceptual Test, Procedural Test and Motivation among the Three Groups

Dependent variable	Group	N	Mean	Std.deviation
pre-test conceptual knowledge	TIFA group	45	7.87	2.64
	FA group	43	6.95	3.08
	CM group	44	8.27	2.490
	Total	132	7.70	2.78
pre-test procedural knowledge	TIFA group	45	4.09	1.62
	FA group	43	3.40	2.52
	CM group	44	3.84	1.96
	Total	132	3.78	2.07
pre-test motivation	TIFA group	45	59.69	2.56
	FA group	43	60.35	2.58
	CM group	44	60.57	2.82
	Total	132	60.19	2.66

Base on Table 2, the mean score of the groups (M = 7.84, for the TIFA group; M = 6.96, for the FA group; M = 8.27, for the CM group of conceptual test scores; and M = 4.09, for the TIFA group; M = 3.40, for the FA group; M = 3.84, for the CM group of procedural test scores) appears to be somewhat different, according to the descriptive statistics result of the pretest for conceptual test scores and procedural test scores. However, the mean value for chemistry motivation questionnaire was practically almost same for each research group, according to descriptive statistics. Following the analysis of descriptive statistics, one-way ANOVA as show in Table 3.

Table 3. One-Way ANOVA Summary Table On Scores of Pre-Test of Motivation

Dependent variables	Source	SS	Df	MS	F	Sig.
pre-test conceptual knowledge	Between Groups	39.64	2	19.82	2.63	0.076
	Within Groups	971.83	129	7.53		
	Total	1011.48	131			
pre-test procedural knowledge	Between Groups	10.82	2	5.41	1.27	0.283
	Within Groups	547.81	129	4.25		
	Total	558.63	131			
pre-test motivation	Between Groups	18.67	2	9.34	1.32	0.270
	Within Groups	910.21	129	7.06		
	Total	928.88	131			

Table 3 was performed to determine whether there was a significant difference between groups on their three dependent pre-tests. Before analyzing the pre-test results, the ANOVA assumptions of normality and homogeneity of variance were tested. The skewness and kurtosis z-values of the pretest data in the three dependent variables were within acceptable ranges (see in appendix Table 2). This shows that the data was dispersed normally. The Levene test was used to check the other ANOVA assumptions, such as homogeneity of variance, which was not significant for all dependent variables, pre-conceptual knowledge, pre-procedural knowledge, and pre-motivation tests. This means that the variation of results on each measure is the same for the whole population of groups. As a result, the ANOVA assumptions were not violated. $F(2,129) = 2.63$, $p = .076$ for the conceptual test, $F(2,129) = 1.27$, $p = .283$ for the procedural test, and $F(2,129) = 1.32$, $p = .270$ for their motivation questionnaire, implying that the groups were similar in terms of conceptual test, procedural test, and motivation questionnaire scores.This suggests that previous to adopting the technology-integrated planned formative assessment approach, there was no significant difference in learning conceptual, procedural, or motivation across the three groups.

Treatment Effects on Students' Chemistry Motivation

To assess if treatment had an effect on the students' motivation to learn chemistry as a subject, the researcher performed a one-way ANOVA to compare the students' mean post-test scores in the three groups. The results of this investigation are presented in Table 4, Table 5, and Table 6.

Table 4. Means and Standard Deviation on Scores of Students' Motivation towards Learning Chemistry among Groups

Groups	Motivation Scores		
	N	M	SD
TIFA group	45	72.60	16.71
FA group	43	63.84	17.37
CM group	44	54.73	16.76
Total	**132**	**63.79**	**18.36**

Table 5. One-Way ANOVA Summary Table on Scores of Students' Motivation towards Learning Chemistry among Groups

Source	SS	Df	MS	F	Sig	η^2
Between Groups	7106.673	2	3553.336	12.375	0.000	0.16
Within Groups	37039.39	129	287.127			
Total	**44146.06**	**131**				

Table 6. Multiple Comparisons of TIFA, FA and CM Groups on Students Motivation Scores Scheffé

(I) Group of Students	(J) Group of Students	Mean Difference (I-J)	SE	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TIFA group	FA group	8.76*	3.61	0.044	0.19	17.33
	CM group	17.87*	3.59	0.000	9.35	26.39
FA group	TIFA group	-8.76*	3.61	0.044	-17.33	-0.19
	CM group	9.11*	3.63	0.036	0.49	17.73
CM group	TIFA group	-17.87*	3.59	0.000	-26.39	-9.35
	FA group	-9.11*	3.63	0.036	-17.73	-0.49

*. The mean difference is significant at the 0.05 level.

The number of intervention groups was used as the independent variable in a one-way between-subject ANOVA, while student motivation was used as the dependent variable. Using Levene's test, $F(2, 129) = .028$, $p = .972$, the assumptions of homogeneity of variances were evaluated and found to be tenable, and the result variable was nearly normally distributed. There was a significant difference in motivation across the three groups ($F(2, 129) = 12.375$, $p < .001$). Following the discovery that there was a significant difference in motivation between students taught the concept of chemical equilibrium using TIFA, FA, and those taught using CM, it was necessary to conduct additional tests to determine where the difference occurred. Scheffé post-hoc analysis tests of multiple comparisons were used to accomplish this. The CM group's motivation to study chemistry ($M = 54.73$, $SD = 16.76$, $p < .001$) was significantly lower than the TIFA group's ($M = 72.60$, $SD = 16.71$, $p = .044$) and the FA group's ($M = 8.10$, $SD = 1.69$, $p = .036$), according to post-hoc analyses using Scheffé. Cohen's effect size number also suggested that the influence had a high practical relevance.

Motivational Construct's Influence on Conceptual and Procedural Knowledge

To answer the final research questions, a multiple linear regression was applied. In specifically, the relationship between the predictor variable (motivational constructs) and the learning outcome (conceptual and procedural knowledge test scores) was investigated. Intrinsic motivation, self-efficacy, self-determination, grade/extrinsic motivation, and career motivation are the five subscales that make up the predictor variable. The dependent variable is the students' posttest exam results on conceptual and procedural knowledge. Conventional Pearson's correlation coefficients and accompanying p-values were produced to investigate this association. The assumptions of normality, linearity, homoscedasticity, residual independence, and sample size have all been confirmed. According to a scatterplot of standardized predicted values against standardized residuals, the data met the conditions of homogeneity of variance and linearity, and the residuals were almost normally distributed. The model description, ANOVA results, and coefficients of multiple linear regressions for conceptual and procedural test scores are shown in Table 7.

Table 7. Presents the Regression Coefficient of Motivation as a Predictor of Conceptual Knowledge Test Scores

		Conceptual knowledge			
		Model summary			
1		Multiple R = 0.670		$R^2 = 0.448$	
		ANOVA Table			
Model	**SS**	**Df**	**MS**	**F**	**Sig.**
1 Regression	1310.190	5	262.038	18.538	0.000
Residual	1611.401	126	14.135		
Total	**2921.592**	**131**			
Predictor variables			**Coefficients**		
Model	**B**	**SE**	**Β**	**T**	**Sig.**
1 (Intercept)	13.63	1.31		10.40	0.001
Intrinsic Motivation (IM)	1.12	0.24	0.45	4.96	0.000
Self-efficacy (SE)	0.10	0.30	0.03	0.34	0.732
Self-determination(SD)	0.27	0.30	0.08	0.90	0.369
Grade Motivation(GM)	0.96	0.27	0.29	3.49	0.001
Career Motivation (CM)	-0.07	0.37	-0.02	-0.20	0.846

Base on Table 7, the conceptual knowledge test score was regressed on the predicting variables of intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation. It indicates that the five factors under study have a significant impact on conceptual knowledge test scores. Moreover, the $R^2 = .448$

indicates that the model explains 44.8% of the variance in the conceptual knowledge test score. Individual predictors were investigated further, revealing that intrinsic motivation (β =.45, t = 4.96, p<.001) and grade motivation (β =.29, t = 3.49, p =0.001) were both positively significant predictors in the model. However, self-determination (β =0.081, t =0.90, p =0.369), self-efficacy (β =0.03, t =0.34, p =0.732), and career motivation (β = -0.02, t = -0.20, p =0.846) were not statically predictors that influenced students' conceptual knowledge test scores. The final prediction model for the conceptual knowledge test score was equal to 13.63 + 1.12 (IM) +0.10 (SE) +0.27 (SD) +0.96 (GM) -0.07 (CM) per one unit increase in each construct of motivation.

Then multiple linear regression was also used to see if the construct of motivation might predict participants' procedural knowledge exam scores in a meaningful way, the result is show in Table 8.

Table 8. Presents the Regression Coefficient of Motivation as a Predictor of Procedural Test Scores

Procedural knowledge					
Model summary					
1	Multiple R = .49		R^2 = .242		
ANOVA Table					
Model	**SS**	**Df**	**MS**	**F**	**Sig.**
Regression	89.26	5	17.85	8.03	0.000
Residual	280.04	126	2.22		
Total	369.30	131			
Predictor variables			**Coefficients**		
Model	**B**	**SE**	**B**	**T**	**Sig.**
1 (Intercept)	6.77	0.61		11.12	0.000
Intrinsic Motivation (IM)	0.07	0.04	0.20	1.80	0.075
Self-efficacy (SE)	0.02	0.05	0.05	0.39	0.700
Self-determination(SD)	0.07	0.04	0.18	1.64	0.103
Grade Motivation(GM)	0.14	0.05	0.28	2.94	0.004
Career Motivation (CM)	0.07	0.04	0.20	1.80	0.075

Base on Table 8, the five motivating elements under investigation have a substantial influence on the procedural knowledge test score (F (5,126) =8.03, p<.001), indicating that the five motivational factors under study have a significant impact on the procedural knowledge test score. The predictors explained 24.2 percent of the variation in the procedural knowledge test result, according to the R^2 value of 0.242. Grade motivation was revealed to be a significant predictor of procedural knowledge exam score (β =0.28, t = 2.94, p =0.004). Intrinsic motivation (β =0.20, t = 1.8, p =0.075), self-efficacy (β =0.05, t =0.39, p =0.700), self-determination (β =0.18, t = 1.64, p =0.103), and career motivation (β =0.15, t = -1.36, p =0.177) were all non-significant predictors of students' procedural knowledge. The predicted model for the final participants' procedural knowledge test score was 6.77+0.07 (IM) +0.02 (SE) +0.07 (SD) +0.14 (GM) +0.07 (CM) per one unit increase in each construct of motivation.

Discussion

Based on the Self-Determination Theory of motivation, the current study provides a framework for building technology-supported formative assessment activities to boost student motivation to learn chemistry in general and chemical equilibrium in particular. The researcher compared the students' mean post-test scores in the three groups using a one-way ANOVA to examine if the interventions had an effect on their motivation to learn chemistry. In terms of motivation, the three groups were very different (Table 8). According to post-hoc analysis (Table 9), students in the CM group were less interested in studying chemistry than those in the TIFA or FA groups. The effect size value calculated by Cohen also revealed a high practical importance (Table 8). This indicates that, in comparison to the comparison method group, the experimental method group outperforms the comparison method group.

The results back with previous study on computerized assessments, which revealed that students preferred computer-based instruction to paper-based testing (González-Gómez et al., 2020; Lee et al., 2012; Lin et al., 2017). Furthermore, review research on the motivating impact of technology on student learning motivation (Nikou & Economides, 2021; Sung et al., 2016) support the conclusions of this study. Previous study showed that technology-assisted formative assessment significantly increased secondary school students' motivation to learn in a similar study (Goldin et al., 2017). This finding is similar to other study who found that students improved their performance and exhibited higher motivation after engaging with technology-enhanced and non-technology learning materials (González-Gómez et al., 2020). Overall, the outcomes of the study imply that technology may be used to boost learning motivation through formative evaluation in a range of fields. Despite the fact that technology has been used to provide access to and engagement with learning resources, there is no doubt that it can also be used to promote formative assessment.

Multiple linear regressions were also investigated to evaluate the relationship between the predictor variable (constructs of motivation) and learning outcomes (conceptual and procedural test scores). These constructs included intrinsic motivation, self-efficacy, self-determination, grade/extrinsic motivation, and career motivation. The independent variables significantly predict the conceptual knowledge test scores, which indicate that the five factors under study have a significant impact on the conceptual knowledge test scores. Besides, the findings reveal that 44.8% of the conceptual knowledge test scores can be explained by the five motivational factors. The individual predictors were examined further and indicated that intrinsic motivation and grade motivation were positively significant predictors in the model. However, self-determination, self-efficacy, and career motivation were not statistical predictors that influenced students' conceptual knowledge test scores. Among the five motivational factors involved in this study, only intrinsic and grade motivation are the best predictors of conceptual knowledge test scores (Table 10).

A significant regression equation was also discovered, indicating that the five motivating factors under investigation had a substantial influence on the procedural knowledge test result. In addition, the predictor's model accounted for 24.2 percent of the variation in the procedural knowledge test result. The finding demonstrates that grade motivation was a positively significant predictor of procedural knowledge exam score when the individual contributions of the variables were taken into account. The other four motivating factors, on the other hand, were shown to be insignificant predictors of students' procedural knowledge test scores (Table 11). This finding was consistent with studies that highlighted the importance of motivation as a factor that facilitates individual learning outcomes (Kesavan & Palappallil, 2018; Wolters & Benzon, 2013). Previous study argued that learning outcomes and effectiveness may vary depending on motivators such as interest, desire, and need (Teo & Zhou, 2017). Although there are studies that show a positive relationship between intrinsic motivation and learning outcomes, there are other studies that suggest intrinsic and grade motivation should be combined to motivate an individual to take action toward a goal (Hayat et al., 2020; Sung et al., 2016).

In addition to significant factors, the current investigation also yielded non-significant results. Self-efficacy, self-determination, and career drive were found to have no impact on the conceptual and procedural knowledge exam results of 11th grade students. Despite some discrepancies that contradicted the present study, self-efficacy was positively and substantially associated to, as well as predicted, students' learning outcomes, as most studies suggested, despite some inconsistencies that contradicted the current study (Nabizadeh et al., 2019; Nie et al., 2011).

The results of this study have practical implications for both chemistry teachers and students. This study's findings may help chemistry teachers in developing and implementing better teaching interventions to improve students' thinking, particularly in the area of integrating higher-order thinking skills into the instruction of chemistry in general and chemical equilibrium in particular by motivating students towards the subject. This study also intends to give insight into how technology-integrated formative assessment may be utilized effectively in science education in general and chemistry education in particular. The study also provides further resources for researchers and educators to adopt and/or create acceptable formative assessment procedures in their own classrooms.

The quasi-experimental research study design used in this study has a lot of weaknesses of which validity is the most concerning one. Despite the fact that the researcher attempted to select similar schools and teachers from various perspectives, provided training on instructional methods and techniques of implementation, the intervention may be influenced by the teachers and the schools because it is difficult to control all variables. The other limitation was due to the study's design, which was limited due to the small sample size. As a result, it's possible that the conclusions of this study won't apply to the overall population of grade 11 natural science students. In addition, this study did not consider all of a student's knowledge domains..

4. CONCLUSION

Overall, this research explicitly demonstrated how each motivational construct was related to students' learning outcomes of conceptual and procedural exam scores. The study found that students' motivation will be favorably improved when teachers are dedicated to implementing technology-supported formative classroom assessment with a timely feedback system. We can conclude that the motivation construct has a significant correlation with learning outcomes in chemistry in general and chemical equilibrium in particular. The strength and direction of the relationship among variables were also indicated to provide insights for future work.

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