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Enhancing Students' Communication and STEM Reasoning Abilities Based on Gender Through Application of IT-based Chemistry Teaching Materials

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Abstract. Among the difficulties faced by instructors in delivering chemistry lessons are lack of information technology (IT)-based teaching materials that would very effectively support e-learning or face-to-face learning especially in effort to enhance students' communication skills and STEM reasoning skills. Digital technology advancement provides the opportunities to help resolve this problem. This study aimed to enhance students' communication skills and STEM reasoning abilities through application of IT-based (bandicame and canva applications) chemistry teaching materials that is integrated to Google Classroom platform and to identify the differences in students' communication skills and STEM reasoning abilities based on genders. The research took samples of 50 students (19 male and 31 female) at an Indonesian senior high school by applying quasi experiment pretest-posttest control group design. Communication skills were measured by means of a questionnaire, while reasoning abilities were gauged using an essay test. The results were then analyzed descriptively focusing on increases in communication skills and STEM reasoning abilities scores and independent sample t-test. Findings of the study show that: (1) Students' communication skills and STEM reasoning abilities can be enhanced through application of GC-integrated IT-based chemistry teaching materials; (2) Significant differences existed in the students' communication skills based on genders, of which highest increase was identified on WCS indicator for females and SCS indicator for males; and (3) significant differences were identified in students' STEM reasoning abilities based on genders with highest increase on RI indicator for females, followed by RD indicator for males, and RA for females.

Keywords: communication skills; stem reasoning abilities; IT-based chemistry teaching materials; gender

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1. Introduction

Application of technology has developed very rapidly and entered all spheres of life, including education. Application of technology in education plays a very important role to support implementation of 21st century learning in the era of industrial revolution 5.0 (Verawati et al., 2022; Pavlova, 2013). Chemistry learning requires media and learning resources that can visualize abstract concepts so that students can easily understand them, one of which is by having chemistry module based on the canva and bandicame applications. However, based on the results of previous studies, it is indicate that the availability of chemistry module based on the canva and bandicame applications is still lacking, resulting in low students' reasoning abilities and communication skills (Fadli & Irwanto, 2020; Kong & Matore, 2022; Irwanto et al., 2023). Moreover, teachers still couldn't develop chemistry module based on the Canva and Bandicame applications in chemistry learning, so learning is still focused on achieving cognitive learning objectives and neglects students' communication and STEM abilities development (Wahyudiati, 2023).

Technology-based learning innovations are very relevant to be used as learning media and resources by teachers and students to develop their 21st century skills, thus becoming individuals with professional competitiveness in the era of industrial revolution 5.0 (Sumardi et al., 2020; Lewin & McNicol, 2015). The 21st century skills that students should develop include problem solving skills, communication skills, collaboration skills, and STEM reasoning abilities (Wahyudiati, 2023). Chemistry learning, in particular, needs learning media and resources that would visualize abstract concepts to be easily understood by the students. So far, technology has been used more as a medium of communication than as a medium of learning (Ramma et al., 2015). For this reason, to make a difference, technology must be used extensively as a pedagogic means in teaching and learning activities as both media and teaching materials (Strayer, 2012).

In the framework of STEM education that is very rapidly developing technology, the new direction of learning worldwide currently is virtual or e-learning system (Estevemon et al., 2022; Krumsvik, 2012). For this reason, educational institutions are encouraged to design chemistry module for e-learning activities in order to stay update with current technological advancements and no longer use conventional media and teaching materials (Castro et al., 2020). These conditions are relevant to E-learning, a pedagogically effective learning design is necessary to help achieve learning objectives that cover cognitive, affective and psychomotor aspects. It includes development of IT-based media and teaching materials, Google Classroom (GC) platform, LMS platform or learning management system that triggers students' active participation in learning activities (Clark & Mayer, 2011).

Students' interactions and participation in STEM-based learning remain a crucial issue (Verawati et al, 2022), especially with regard to training students' reasoning abilities and communication skills (Fadli & Irwanto, 2020; Kong & Matore, 2022). These reasoning abilities are crucial since they constitute the predictors of students' achievements in STEM (Kong & Matore, 2022). In more specific contexts, reasoning is known as critical thinking skills (Ali et al., 2021) with indicators including analysis, inference, evaluation, and problem solving (Ali et al., 2021; Wahyudiati et al., 2019; Wahyudiati et al., 2020). As such, it is very important that students have critical thinking skills or reasoning abilities (Fadli & Irwanto, 2020; Prayogi et al., 2019). However, previous studies show that effective learning designs to train students' 21st century skills have not been established yet, especially in supporting students' STEM abilities and developing their communication skills (Fadli & Irwanto, 2020; Kong & Matore, 2022; Anggraeni & Pentury, 2021). It is especially the case in teaching chemistry concepts with topics requiring high levels of abstraction, such as chemical bonding. This results in students' low reasoning abilities and communication skills due to lack of motivation in learning abstract concepts. In addition, an interview with a chemistry teacher with 12 years of teaching experience disclosed that the teacher faced difficulties in making the students understand abstract concepts, especially the topic of chemical bonding. Likewise, based on the results of preliminary studies that have been carried out by researchers by observing and interviewing activities at school, it was found that students had difficulty understanding chemical bonding material and students' communication and STEM abilities were still low, and there was still a lack of availability of IT-based chemistry module.

This research focused on developing Chemistry teaching materials based on the Canva and Bandicam (CTMBCB) applications are integrated with Google Classroom. Findings of past studies show that sciences teaching using bandicame application through Google Classroom platform in both e-learning and face-to-face learning environments had a positive impact on the students' learning interest and outcomes (Iksan et al., 2011). Likewise, application of canva through Google Classroom platform as learning resources in both e-learning and face-to-face learning environments had a positive effect on students' academic performance, in terms of knowledge, skills and attitude (Christiana & Anwar, 2021; Iksan et al., 2011). Another advantage in the use of canva and bandicame applications is that as a learning medium, making learning more interesting and fun and help solve other learning issues with respect to accessibility (Christiana & Anwar, 2021; Iksan et al., 2011; Erlinawaty & Sellan, 2021).

Other studies highlight the attitude aspect in their use (Lewin & McNicol, 2015). However, as far as we are concerned, use of technology (bandicame and canva applications) as the basis for developing chemistry teaching materials (chemical bonding topic) to develop students' communication skills and STEM reasoning abilities in chemistry subject based on genders has never been undertaken (based on previous study). For this reason, this study is very important to be carried out to give positive contribution to STEM-based learning currently being encouraged as a form of learning innovation during industrial revolution 5.0, and to determine if it will increase student communication skill scores and STEM reasoning ability scores after the implementation of CTMBCA applications. Specifically it give answers to the following research questions: 1) Is there a statistically significant improvement in communication skill scores before and after the implementation of CTMBCA applications? and 2) Is there a statistically significant improvement in STEM reasoning ability scores before and after the implementation of CTMBCA applications? Besides that, the objectives of this research purposes: 1) To examine if implementation of CTMBCA applications does have impacts of student communication skills improvement; and 2) To examine implementation of CTMBCA applications does have impacts of students STEM reasoning ability improvement.

2. Review of Literature

Students' communication skills and STEM abilities can be improved by implementation of CTMBCA that are integrated with the Google Classroom platform (e-learning). The findings of previous studies indicate that the use of the bandicame and Canva applications as learning media or teaching materials can enhancing students' critical thinking skills, enhancing students' STEM reasoning abilities, and communication skills (Verawati et al., 2022; Hakim et al., 2022). Likewise, using the Canva application as a learning resource positively affects student academic achievement regarding knowledge, skills, and attitudes (Iksan et al., 2011).

Students' interactions and participation in STEM-based learning remain a crucial issue (Verawati et al., 2022), especially with regard to training students' reasoning abilities and communication skills (Kong & Matore, 2022). These reasoning abilities are crucial since they constitute the predictors of students' achievements in STEM (Kong & Matore, 2022). In more specific contexts, reasoning is known as communication skills and critical thinking skills (Ali et al., 2021) with indicators including analysis, inference, evaluation, and problem solving (Wahyudiati et al., 2019). As such, it is very important that students have communication skills, critical thinking skills or reasoning abilities (Prayogi et al., 2019). However, previous studies show that effective learning designs to train students' 21st century skills have not been established yet, especially in supporting students' STEM abilities and developing their communication skills (Fadli & Irwanto, 2020; Anggraeni & Pentury, 2021).

The 21st century skills that students should develop include problem solving skills, communication skills, collaboration skills, STEM reasoning abilities. Chemistry learning, in particular, needs learning media and resources that would visualize abstract concepts to be easily understood by the students. So far, technology has been used more as a medium of communication than as a medium of learning (Ramma et al., 2015). Communication skills consisting of three indicators that are measured based on three criteria, namely the ability to communicate verbally, the ability to communicate in writing, and the ability to communicate socially. Communication skills as learning outcomes are very important for students to have because they are related to the ability to express what is understood and apply it in everyday life (Iksan et al., 2011).

Application of e-learning system in integration with Google Classroom (GC) platform at schools and their use depend on designer's access approval (some are freely accessible while others are not) and the teacher has full control over the learning system through GC. A new aspect of the study is that it developed chemistry teaching materials on chemical bonding topic using GC platform-integrated canva and bandicame applications to enhance students' communication skills and STEM reasoning abilities as viewed from gender perspective. Many studies show different findings. A study by Iksan et al. (2011) revealed significant differences in students' communication skills based on genders, where male students have better written communication skills in making discussions than their female counterparts (Nurlu, 2017). On the contrary, other studies found no differences in STEM reasoning abilities based on genders, while a study by Spelke (2005) did identify differences in students' STEM reasoning abilities based on genders.

Implementation of CTMBCA can improve students' communication skills and STEM abilities. Previous research proved that using chemistry module positively impacts students' communication and STEM abilities (Fraile et al., 2021). The findings of previous studies indicated that the use of the bandicame and Canva applications as learning media or teaching materials could improve students' digital literacy competencies students STEM reasoning abilities and have a positive impact on improving students' communication skills (Verawati et al., 2022; Hakim et al., 2022). Likewise, using the Canva application as a learning resource positively affects student academic achievement in terms of knowledge, skills, and attitudes (Iksan et al., 2011). Thus, applying IT-based chemistry (bandicame and Canva) through the GC platform expected to improve students' communication and STEM skills in chemistry learning.

3. Method

3.1 Research Design

This study is an experimental study with quasi experiment nonequivalent pretest-posttest control group design. Experimental and control classes were determined randomly. The experimental group was given the CTMBCA treatment via GC, while the control group was given the expository method. Before treatment was given, an observation was carried out on the two groups' communication skills and STEM reasoning abilities (pretest) and another was carried out after treatment (post-test). The research design in its simple form is shown on Table 1 below.

Table 1: The nonequivalent pretest and posttest control group design.

Groups	*Pretest*	*Treatment*	*Posttest*
Experimental	Communication Skills Questionnaire and STEM Reasoning Test	CTMBCA	Communication Skills Questionnaire and STEM Reasoning Test
Control	Communication Skills Questionnaire and STEM Reasoning Test	Face-to-face learning with the expository method	Communication Skills Questionnaire and STEM Reasoning Test

Research was carried out on the two sample groups on the same materials with chemical bonding topics, including covalent bonding, ionic bonding, hydrogen bonding and metallic bonding. The materials were taught to students in 8 sessions to both experimental and control classes. This research was permitted by the school that became the research location as a condition for fulfilling the research code of ethics (permission number: 20/Ma.19.02/PP.00.6/2022).

3.2 Participants

Samples for the research involved 50 students of an Indonesian senior high school. Using cluster random sampling technique, 25 students (9 male students and 16 female students) were designated as the control group and another 25 students (10 male students and 15 female students) as the experimental group with average age of 16-17 years (Table 2). Before the researcher determines the experimental and control classes to ensure that the two groups have homogeneous cognitive abilities, a sample normality test is first carried out. Based on the test results, it showed that both samples had homogeneous abilities (experimental and control classes). The reference for determining the number of samples in this study is in accordance with previous studies that have been carried out using 50 samples consisting of 25 people for the experimental class and 25 for the control class (Wahyudiati et al., 2022). They were taught by a teacher with 7 years of teaching experience. To avoid subjectivity in research activities, the chemistry teacher taught the experimental and control classes at the school where the research was conducted. However, before giving treatment, perceptions were equalized. The training was first conducted as research preparation to obtain the right data to measure students' communication and STEM abilities.

Table 2: Demographic characteristics of the samples

Characteristics		**Experimental Class, n = 25**		**Control Class, n = 25**	
		Quantity	%	**Quantity**	%
Genders	Female	10	40%	9	36%
	Male	15	60%	16	64%
Age (year)	16	11	44%	10	40%
	17	14	56%	15	60%

3.3 Research Instruments

The study employed two instruments, namely communication skill and STEM reasoning ability instruments.

3.3.1 Communication Skill Instrument

The communication skill questionnaire adopted the instrument developed by Iksan et al. (2011), which comprises three indicators, namely verbal communication skills (VCS), written communication skills (WCS) and social communication skills (SCS) with a total of 43 items as shown in Table 3.

Table 3: Communication skills instrument grid (Iksan et al., 2011)

Indicators	**Subindicators**	**Num. of items**
Verbal Communication Skills (VCS)	Presenting ideas verbally	3
	Understanding what was heard	4
	Giving feedback	4
	Presentation	5
Written Communication Skills (WCS)	Presenting ideas in written form	4
	Giving feedback in written form	5
Social Communication Skills	Negotiating to get agreement	4

(SCS)	Communicating to people from different cultures	4
	Communicating in different languages	4
	Communicating humbly	6
Total Number of Items		43

Answer options in the questionnaire refer to five-point likert scale, which includes strongly disagree, disagree, slightly disagree, agree and strongly agree with 5 as the highest score and 1 the least score (applicable for both negative and positive statements). Based on the scoring criteria, the scores were then converted into interval equation (Iksan et al., 2011), and the interval category of communication skills is summarized in Table 4. A mean range of 0-1.67 is classified as low skills; a mean range of 1.68-3.34 is classified as average skills, and a mean range of 2.25-5.00 is classified to have good skills.

Table 4: Communication skills criteria (Iksan et al., 2011)

Communication Skills Criteria	**Mean range**
Low skills	0-1.67
Average skills	1.68-3.34
Good skills	3.35-5.00

3.3.2 STEM Reasoning Ability Instrument

Data on students' STEM reasoning abilities consist of four indicators (Verawati et al., 2022), namely reasoning-analysis (RA), reasoning-inference (RI), reasoning-evaluation (RE), and reasoning-decision (RD), which were collected using an essay test instrument. Each indicator consists of two questions, so that there were a total of eight test questions for STEM reasoning abilities. Reasoning skills were measured based on indicator (RSi) and individual (RSs) parameters (Verawati et al., 2022).

Table 5: STEM reasoning ability criteria based on RSi and RSs parameters

STEM Reasoning Ability Criteria	RSi Score Interval	RSs Score Interval
Very Good	RSi > 3.21	RSs > 25.60
Good	2.40 < RSi ≤ 3.21	19.20 < RSs ≤ 25.60
Fair	1.60 < RSi ≤ 2.40	12.80 < RSs ≤19.20
Poor	0.80 < RSi ≤ 1.60	6.41 < RSs ≤12.80
Bad	RSi ≤ 0.80	RSs ≤ 6.41

As for before being used, the two instruments were validated by four experts (2 experts with Ph.D. degrees and 2 experts with MEd degrees) from the University of Mataram and UIN Mataram, Indonesia. The Cronbach alpha coefficient for the Communication Skill Questionnaire is $\alpha = 0.87$ and the STEM Reasoning Test is $\alpha = 0.86$. This value is above the acceptable limit of 0.70 (Hair et al., 2010) thus both instruments are declared valid.

3.4 Data Analysis

Analysis of data on students' communication skills and STEM reasoning abilities descriptively refers to the criteria in Tables 4 and 5, and score gain (n-gain) refers to Hake formula (Hake, 1999). A statistical analysis (difference test on sample groups) was then carried out to identify differences in the score gains in students' communication skills and STEM reasoning abilities in both samples ($p < 0.05$). This was preceded by normality test ($p > 0.05$) using Shapiro Wilk test (since sample membership ≤ 50). Statistical analysis used SPSS 24.0 program.

3.5 Research Procedures

This research conforms to Helsinki Declaration on studies involving humans. After the researcher explained on research objectives, a consent form was distributed to and signed by each participant prior to intervention. The research comprised of 2 key phases: (1) development of CTMBCA that were integrated to Google Clasroom (GC) platform, and (2) application of CTMBCA in the experimental classes. Bandicame application was used to design a learning interactive video (chemical bonding and molecule forms, & material and changes), while canva application was used to choose interesting features in presenting chemical bonding topic in order to make learning more interesting and fun so that learning would not be boring to students. Application of the CTMBCA used Google Clasroom (GC) platform and held for twelve sessions (April-June 2022) and each session comprised one hundred and sixty minutes. The experiment group was taught with CTMBCA, while the control class had face-to-face learning with expository method.

4. Results

4.1 Communication Skills

Results of descriptive analysis of students' communication skills based on genders are presented in Table 8 with reference to communication skills criteria (Iksan et al., 2011).

Table 6: Results of measurement of students' communication skills based on genders for each indicator

Groups	Score	Genders	Communication skill indicators			Mean range	Category
			VCS	WCS	SCS		
Experimental	Pretest	Male	2.4	2.6	2.5	2.5	Average skills
		Female	2.12	2.4	2.16	2.23	Average skills
	Posttest	Male	4.22	4.3	4.23	4.25	Good skills
		Female	4.14	4.3	4.2	4.21	Good skills
	N-gain	Male	0.7	0.71	0.69	0.7	high
		Female	0.7	0.73	0.72	0.72	high
Control	Pretest	Male	2.2	2.13	2.15	2.16	Average skills
		Female	2.14	2.16	2.17	2.16	Average skills
	Posttest	Male	2.8	2.9	2.7	2.8	Average skills
		Female	2.92	2.95	2.98	2.95	Average skills
	N-gain	Male	0.16	0.2	0.14	0.17	Low
		Female	0.2	0.21	0.21	0.21	Low

Table 6 above shows that there was an increase in communication skills from pretest scores to posttest scores based on genders for the two treatment groups. The highest increase for the experimental group occurs on WCS indicator for females, followed by SCS indicator for females, and the lowest score on SCS indicator for males. Average increase of N-gain score for experimental class for males was 0.70 and for females of 0.72 with high criteria. Increase in communication skills with low criteria was identified on the control group with N-gain of 0.14 for SCS indicator in males. Meanwhile, the control class records highest score increase on written communication skills (WCS) and social communication skills (SCS) indicators for females with a score of 0.21. Average increase of N-gain score for control class for males was 0.17 and for females 0.21 with low criteria (Figures 1 and 2).

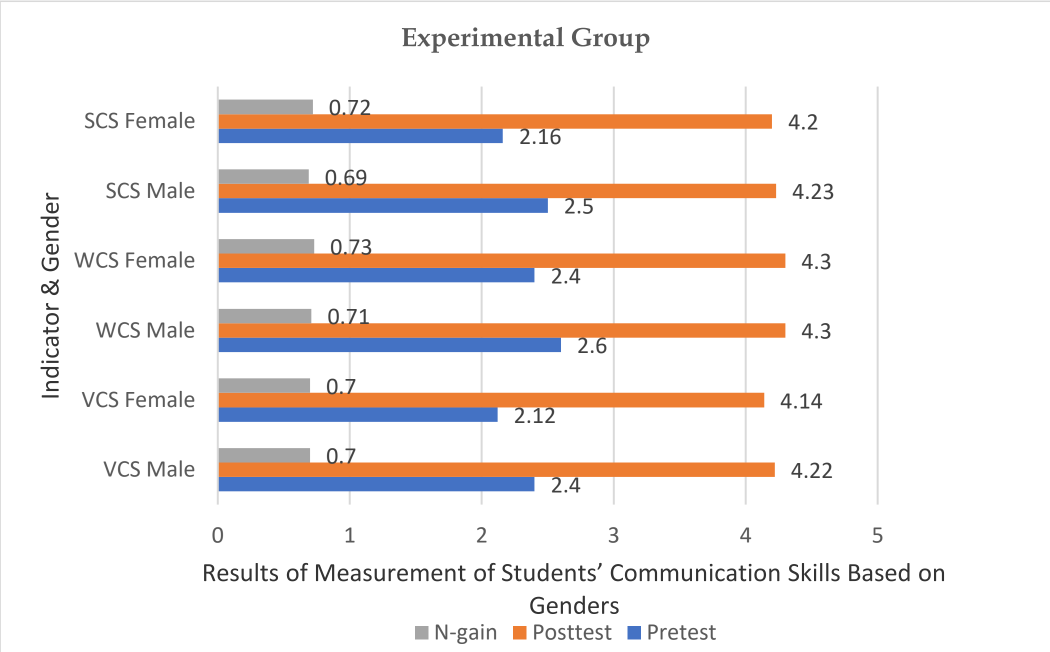

Figure 1: Students' Communication Skills Based on Gender in the Experimental Group

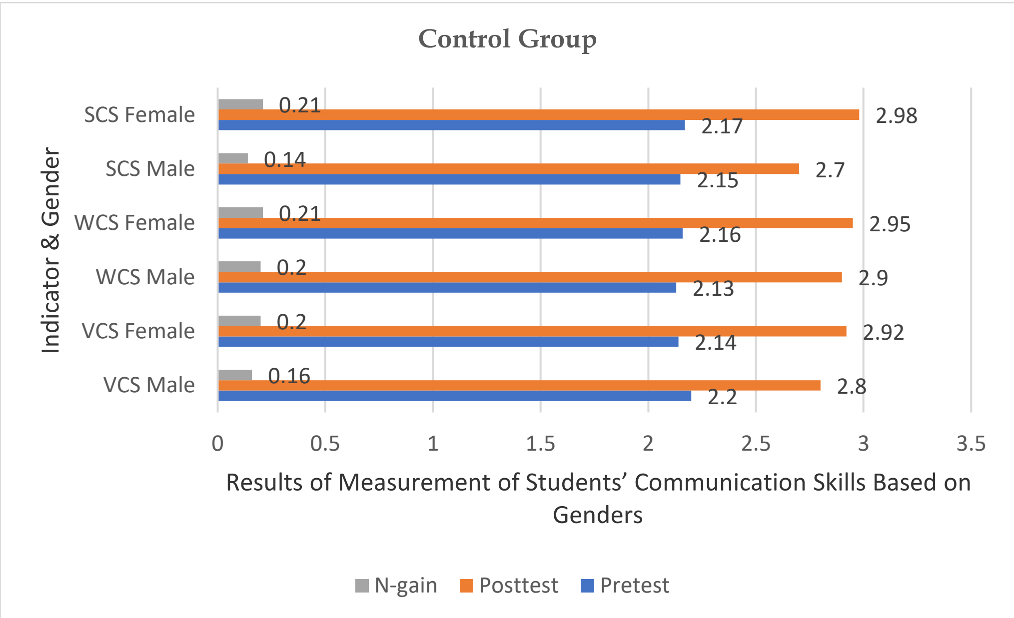

Figure 2: Students' Communication Skills Based on Genders at Control Class

Data on Figures 1 and 2 clearly show the difference in students' communication skills for both treatment groups. Results of before and after treatment show that students' communication skills in the treatment class show an increase from average skills category to good skills category. On the contrary, the control group did not record any increase and remained at the average skills category. Furthermore, differences in the increase in the scores of the two groups were tested statistically by first carrying out homogeneity and normality tests in both groups. The homogeneity value obtained a significance value of p> 0.05, namely 0.22 in the control class and 0.26 in the experimental class and the normality values obtained are shown in Table 7.

Table 7: Results of normality test of experimental and control groups

Groups	*Shapiro-Wilk*		
	Statistic	**df**	**Sig.**
Control	0.637	50	0.540
Experimental	0.734	50	0.630

Table 7 shows that the two data groups are distributed normally. As such, a difference test on the two data groups using parametric statistic test (sample independent test t-test) comes with test results (Table 8). Results of t-test sample independent test show p > 0.05, meaning a significant difference exists in the communication skills based (CSB) on genders of the two treatment groups.

Table 8: Results of t-test independent test

Scores	**CSB**	**t-test**		
		t	df	Sig 2 tailed
Standard N-Gain	Equal variances assumed	12.069	48	0.000
	Equal variances not assumed	12.069	29.045	0.000

4.2 STEM Reasoning Abilities

Results of a descriptive analysis of STEM reasoning abilities based on genders is provided in Table 9, which refers to each treatment group's reasoning ability criteria.

Table 9: Results of measurement of students' STEM reasoning abilities based on genders for each indicator

Groups	*n*	*Score*	*Genders*	*Reasoning skill indicators*				*RSi average*	*Category*
				RA	RI	RE	RD		
Experimental	25	Pretest	Male	1.10	1.12	1.70	1.50	1.35	less
			Female	1.12	1.13	1.16	1.15	1.14	less
		Posttest	Male	3.22	3.28	3.23	3.24	3.24	good
			Female	3.14	3.30	3.20	3.21	3.21	good
		N-gain	Male	0.73	0.75	0.67	0.70	0.71	high
			Female	0.70	0.76	0.72	0.72	0.72	high
Control	25	Pretest	Male	1.13	1.13	1.12	1.14	1.13	less
			Female	1.12	1.15	1.13	1.12	1.13	less
		Posttest	Male	1.42	1.43	1.45	1.48	1.45	less
			Female	1.38	1.48	1.47	1.40	1.43	less
		N-gain	Male	0.10	0.10	0.11	0.12	0.11	Low
			Female	0.09	0.12	0.12	0.10	0.10	Low

Table 9 shows an increase from pretest scores to posttest scores based on genders according to reasoning skills were measured based on criteria for both treatment groups. The highest increases in treatment groups occur on reasoning inference (RI) indicator for females and reasoning decision (RD) for males, followed by reasoning evaluation (RE) indicator for males, while the lowest score was RA indicator for females. Average increase of RSi N-gain score for treatment class for males was 0.71 and for females 0.72 with high criteria. Enhancing in RSi with low criteria was identified on the class is not given treatment with N-gain of 0.09. For the class is not given treatment, the highest score increase was for RD indicator for males and RI indicator for females, while the lowest score was for Ra indicator for females. Visualization of students' STEM Reasoning skills based on gender differences with reference to RSi parameters (Figures 3 and 4).

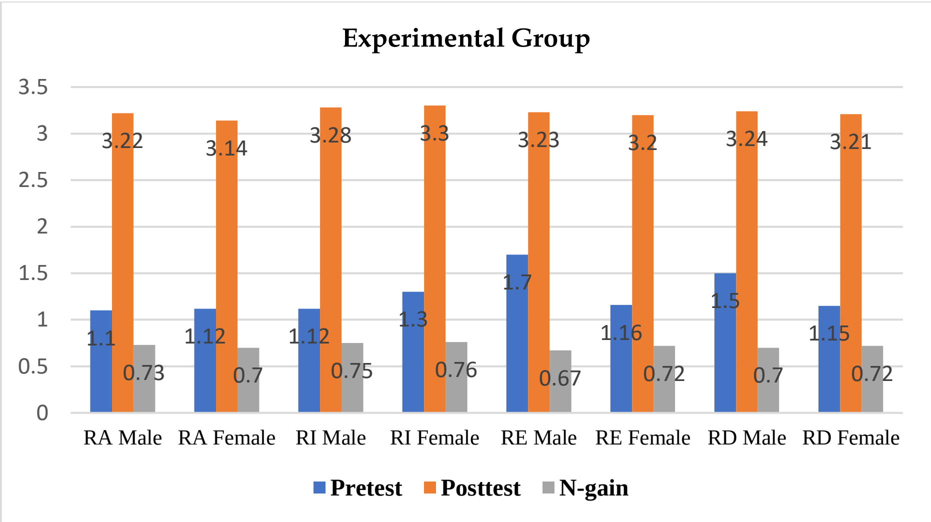

Figure 3: Students' STEM Reasoning Abilities Based on Gender in the Experimental Group

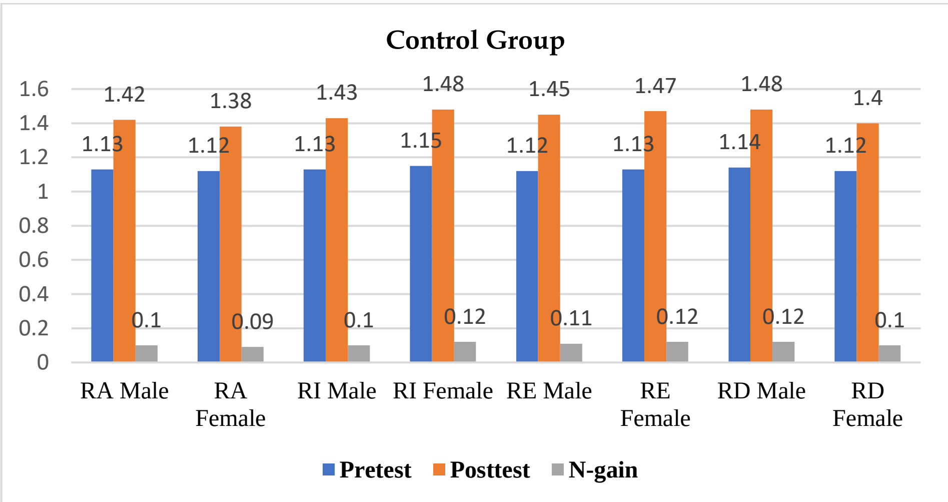

Figure 4: Students' STEM Reasoning Abilities Based on Gender in the Control Group

A summary of each treatment group's STEM reasoning ability performance based on genders with Reasoning skills were measured based on individual (RSs) parameters. RSs parameters is shown on Table 10.

Table 10: Results of measurement of students' STEM reasoning abilities based on genders

Groups	N	Genders	STEM Reasoning Abilities score and criteria				N-gain	Category
			Pretest	Category	Posttest	Category		
Experimental	25	Male	9.50	less	25.28	good	0.70	High
		Female	9.00	less	25.60	good	0.72	High
Control	25	Male	9.50	less	12.00	less	0.11	Low
		Female	9.15	less	11.50	less	0.10	Low

A summary of students' STEM reasoning abilities based on genders in Table 9 shows students' STEM reasoning abilities in the experimental class is classified in good category, while the control class in less category. Likewise, N-gain scores show that the enhancing STEM reasoning abilities in the treatment class was in high category, while that in the control class in low category. Visualization of students' STEM Reasoning abilities based on gender differences with reference to RSi parameters for experimental and control classes is shown in Figure 5.

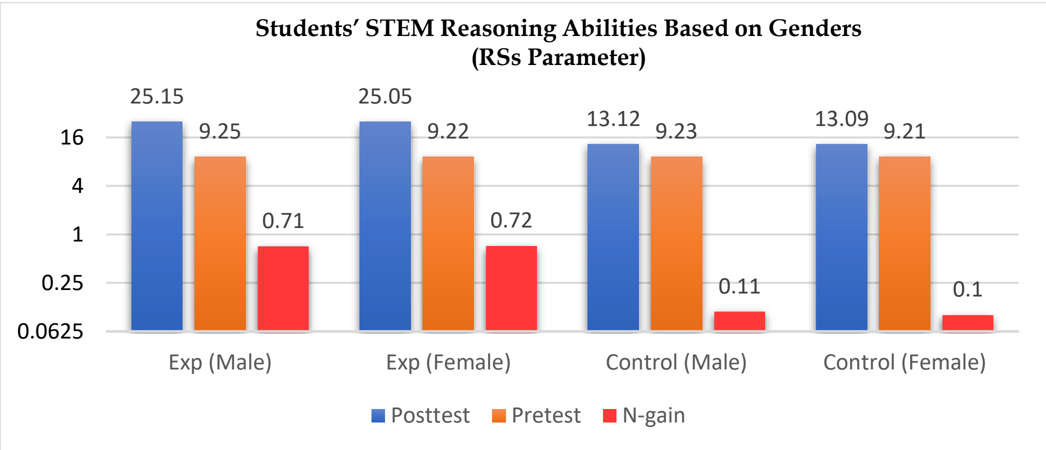

Figure 5: Students' STEM Reasoning Abilities Based on Genders for Experimental and Control Classes

Figure 5 above clearly shows the distinction STEM reasoning abilities in the two treatment groups. Results of before and after treatment show that students' communication skills in the experimental class show an increase from less category to good category. On the contrary, the control group did not record any increase and remained at the less category. Furthermore, differences in the increase in the scores of the two groups were tested statistically by first carrying out homogeneity and normality tests in both groups. The homogeneity value obtained a significance value of $p > 0.05$, namely 0.32 in the control class and 0.36 in the experimental class and the normality values obtained are shown in Table 11.

Table 11: Results of Normality Test of Experimental and Control Groups

Groups	Shapiro-Wilk		
	Statistic	df	Sig.
Control	0.638	50	0.530
Experimental	0.688	50	0.580

Table 10 show that the two data groups to be compared are distributed normally. As such, a distinction test on the two data groups using t-test sample independent test comes with test results as shown in Table 12. Results of t-test independent test show sig. < p (0.05), meaning a significant difference exists in the STEM reasoning abilities based on genders of the two treatment groups in favor of the experimental group. This means that the intervention given which is the application CTMBCA in teaching enhance the reasoning skills of the students than those students who wer exposed to face-to-face expository method.

Table 12: Results of t-test independent test, p < 0.05

Scores	STEM Reasoning Abilities	Score		
		t	df	Sig 2 tailed
Standard N-Gain	Equal variances assumed	13.312	48	0.000
	Equal variances not assumed	13.312	24.265	0.000

5. Discussions

5.1 Communication Skills

Data analysis shows that students' communication skills using IT-based (bandicame and canva applications) chemistry teaching materials integrated to Google Classroom platform are better than that of face-to-face learning using expository method. Findings of this study are consistent with previous studies that IT-based visual media utilization may develop students' digital literacy competencies and communication skills (Hakim et al., 2022). Similarly, utilization of IT-based chemistry module has positive impacts on the students' communication skills (Fraile et al., 2021) and there is a significant difference in students' communication skills based on genders (Yoon et al., 2021; Almuzakir & Qamariah, 2019). Research findings also show that female students' communication skills are higher than that of their male counterparts in both experimental and control groups. These findings are strongly consistent with previous studies that report that female students' communication skills are better than male students' (Hariyanto et al., 2019). This is because women are more motivated to interact in a group work, are more active in verbal presentation session, and are active in giving feedback and suggestions such that their communication skills develop better than their male counterparts (Qazi et al., 2022).

The fact that female students' communication skills are higher than that of male students is shown by the highest score on written communication skills (WCS) indicator by female, followed by social communication skills (SCS) indicator by female, and lowest score being SCS indicator for male. This research finding is strongly consistent with previous studies that show women have better verbal and written communication skills than men (Hariyanto et al., 2019; Pajk, et al., 2021). In addition, this research finding is corroborated by other research findings that prove female students' verbal competencies are more accurate and detailed, while male students are more critical with different interpretations. As such, women excel in language and writing, while men excel in mathematical calculation and logical thinking.

Another interesting finding of the study is the significant difference in the students' communication skills based on genders. The experimental group showed an increase in communication abilities from average skills category to good skills category. On the contrary, the control group did not show any increase and remained at the average skills category. The increase in the communication skills of the students in the experimental group was thanks to the advantage of the CTMBCA that were developed by integrating bandicame and canva applications that were run by means of GC platform. This necessitated the students to actively take part in the discussion, record important information, actively raise questions and respond to other students' questions so that they were able to develop their verbal communication skills (VCS), written communication skills (WCS), and social communication skills (SCS). In addition, the application of the CTMBCA enabled the students to train their visual representation abilities during the learning process, train their skills to actively take part in communicating ideas and giving oral presentation that result in an increase in their verbal and social (Fraile et al., 2021), and train their analysis skills and written communication skills (Cleland et al., 2005, Iksan et al., 2011).

Findings of previous studies also vindicate that the use of bandicame and canva applications as learning media or teaching materials may enhance students' digital literacy competencies, increase students' STEM reasoning abilities, and have positive impacts in enhancing students' communication skills (Verawati et al., 2022; Hakim et al., 2022). Likewise, the use of canva application as learning resources has positive effect on the students' academic performance, in terms of knowledge, skills, and attitudes (Iksan et al., 2011). Moreover, use of canva and bandicame applications really helped making learning more meaningful, interesting and fun (El Kharki et al., 2021; Erlinawaty & Selan, 2021; Pajk et al., 2021). As such, application of IT-based (bandicame and canva) chemistry through GC platform may be an alternative to enhance students' communication skills and make learning more meaningful and contextual, so that learning objectives may be achieved optimally.

5.2 STEM Reasoning Abilities

Other research findings also show that there is an increase in students' STEM reasoning abilities through the application of CTMBCA. Based on the research findings, it is explicitly proven that STEM reasoning abilities using IT-based (bandicame and canva applications) chemistry teaching materials integrated to GC platform are better than those of learning using expository method. Findings of this research are consistent with the previous studies that virtual simulation may enhance students' reasoning abilities (Verawati et al., 2022) and that a distinction exists in students' STEM reasoning abilities based on genders (Valanides 1997).

Findings of this research also reveal an interesting fact that distinction were identified STEM reasoning abilities based on gender, with the highest increase on the RI indicator for females, followed by the RD indicator for males, and RA for females. The highest increase in the RI indicator for women was due to women having better systematic reasoning abilities than men. Hence, students' RI abilities experienced the highest increase after being taught using IT-based chemical teaching materials. This study's findings agree with previous studies' results, which prove that women have better STEM reasoning abilities than male students in analytical reasoning and mathematical reasoning and have higher self-confidence (Zhang, 2019; Wahyudiati et al., 2019). However, male students have better decision-making reasoning and evaluation reasoning abilities than that of female students. These findings are strongly consistent with Spelke's study (2004) that reports male students' abilities in developing and applying theories are better than that of female students. Similarly, a study by Valanides (1997) corroborates that men's performance in probabilistic reasoning far surpass women. However, different findings show that female students have better STEM reasoning abilities than male students in analytical reasoning, mathematical calculation and self-efficacy (Zhang, 2019).

Another interesting finding from this study was that there were differences in STEM reasoning skills based on gender between the class that was given the treatment and the class that was not given the treatment. The treatment class shows an increase in students' STEM abilities prior to treatment from less category into high category, while the control class also shows an increase from less category into low category. The enhancing in the STEM abilities of the experimental group was thanks to the application of CTMBCA that enabled students to develop visual representations during learning processes, train their independence to construct knowledge from abstract into more concrete form that further increases their' critical reasoning, and train their reasoning, analytical, and problem-solving abilities (Wahyudiati, 2023). Another advantage of the CTMBCA that were developed in integration with bandicame and canva applications as visual media applied through GC platform (e-learning) was that it made learning more meaningful, interesting and fun. Findings of previous studies also show that use of bandicame and canva applications as visual media was a means that was potential to provide students with opportunities to actively take part in learning processes, enhance students' digital literacy competencies, even enhance high level thinking skills and more effective communication skills (Iksan et al., 2011; Chan & Nagatomo, 2022). Previous studies also show that students' acceptance of virtual simulation application in the class was very good and had positive impacts on learning domains in terms of knowledge, skills, and attitudes (Verawati et al., 2022; Havola et al., 2021).

This study has met expectations on the fulfillment of students' accessibility in understanding chemical bonding concepts beyond the constraint of space and time. Compared to face-to-face learning with expository method, students' STEM reasoning performance is much better used the CTMBCA. The advantage of CTMBCA was appropriate to help enhancing communication abilities and help solve other problems in learning related to accessibility (Iksan et al., 2011; Fraenkel et al., 2012). Finally, for sustainable learning process we recommend use of CTMBCA with diverse application options, especially in teaching abstract concepts in sciences. This certainly requires professionalism and serious efforts on the part of the stakeholders to achieve better learning objectives and outcomes ahead of industrial revolution 5.0.

However, there are limitations to the applied IT-based chemistry teaching materials, such as the applications used are limited to the Canva and Bandicame applications integrated with the Google Classroom platform. The weakness of using the Canva and Bandicame applications is that designing an interactive video takes quite a long time. It also requires a stable internet connection, so implementing it in class requires adequate internet facilities. Likewise, the results of previous research also revealed the weaknesses of the Canva and Bandicame applications that it takes quite a long time to make, and students must have adequate multimedia facilities to be able to support the effectiveness of using the Canva and Bandicame applications during learning activities (Hakim et al., 2022). Thus, it is suggested for further research to use a variety of other applications, such as augmented reality or visual laboratories, in chemistry learning as a form of implementing CTMBCA that can improve students' communication skills and STEM abilities to support achieving chemistry learning goals.

6. Conclusions

Based on findings of the study, the following conclusions are drawn: (1) Students' communication skills and STEM reasoning abilities may be enhanced through application of GC-integrated IT based (bandicame and canva applications) chemistry teaching materials; (2) Significant differences were noted in students' communication skills based on genders, of which highest increase was identified on WCS indicator for females, followed by SCS indicator for females, and lowest score in SCS indicator for males; and (3) significant differences were identified in students' STEM reasoning abilities based on genders with highest increase on RI indicator for females and RD for males, followed by RE for males, and lowest score for RA indicator for females. We recommend the application of GC platform-integrated IT-based (bandicame and canva applications) as one of the best solutions to enhance students' 21st century skills not only for chemistry learning, but also for science learning in the broadest sense. We recommend implementing an integrated IT-based GC platform (bandicame and canva applications) in chemistry learning as one of the best solutions to improve 21st century skills, and can support the effectiveness of e-learning based chemistry learning.

7. Limitations and Recommendations

The limitation of this research is that the applications used are limited to the Canva and Bandicame applications which are integrated with the Google Classroom platform so that further research is suggested to use other applications such as augmented reality or visual laboratories and their effects on chemistry learning. In addition, to gain a deeper understanding of the impact of implementing CTMBCA on communication skills and STEM reasoning abilities, further research needs to use qualitative data. Thus, to develop communication skills and STEM reasoning abilities of high school students, researchers suggest that chemistry learning needs to be designed using IT-based teaching materials combined with chemistry concepts that are relevant to students' daily experiences to achieve maximum chemistry learning goals. We recommend implementing an integrated IT-based GC platform (bandicame and canva applications) in chemistry learning as one of the best solutions to improve 21st century skills, and can support the effectiveness of e-learning based chemistry learning.

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STEM Abilities Instrument

No	Indicator	Questions
1	Reasoning-Analysis (RA)	1. In everyday life we often use the following compounds: a. Water b. Sugar c. Salt d. Vinegar Analyze the exact chemical bonds formed in these compounds! 2. In everyday life we often use the compounds HCl, HF, $CaCO_3$ and $NaHCO_3$. Analyze the chemical bonds formed from these compounds!
2	Reasoning-Inference (RI)	1. A person makes a sugar solution by dissolving sugar in a water solvent. However, the solution obtained contains floating particles. Try suggesting how to get rid of these impurities! 2. In everyday life, we often use salt (NaCl) as a cooking spice. State your reasons why the NaCl compound is classified as an ionic bond?
3	Reasoning-Evaluation (RE)	1. The first beaker contains 100 ml of 0.1 M CH_3COOH solution. The second beaker contains 100 ml of 0.1 M NaOH solution. If Ka $CH_3COOH = 10^{-5}$. Predict accurately the PH of the solution in beakers 1 and 2, as well as the PH formed when the solutions in beakers 1 and 2 are mixed! 2. The first beaker contains 150 ml of 0.1 M CH_3COOH solution. The second beaker contains 150 ml of 0.1 M NaOH solution. If Ka $CH_3COOH = 10^{-5}$. Predict accurately the PH of the solution in beakers 1 and 2!
4	Reasoning-Decision (RD)	1. Draw conclusions regarding the most likely chemical bonds between the following elements! a. Oxygen with carbon b. Oxygen with sulfur c. Carbon with fluor 2. Draw conclusions regarding the most likely chemical bonds between the following elements! a. Hydrogen with nitrogen b. Hydrogen with fluor c. Hydrogen with oxygen

Communication Skills Instrument

Indicators	Subindicators	Num. of items	Statement
Verbal Communication Skills (VCS)	Presenting ideas verbally	3	1. I express my opinion using clear and easy-to-understand language. 2. I am used to expressing opinions directly during class discussions. 3. When conveying ideas verbally, I try to use the right intonation and sentences so they are easy to understand.
	Understanding what was heard	4	1. When the teacher gave an explanation, I tried to listen carefully so that I understood what was being said. 2. When my friend conveyed his opinion directly, I tried to understand what was conveyed by examining every concept presented. 3. When the teacher gave an explanation, I was less interested in listening to the explanation of the concepts presented. 4. When my friend expresses his opinion directly, I try to understand by asking questions.
	Giving feedback	4	1. When the teacher gave an explanation, I tried to understand the concepts conveyed by asking questions that were relevant to everyday life. 2. When the teacher gave an explanation, I did not try to understand the concepts conveyed by asking questions that were relevant to everyday life. 3. When my friends share their opinions, I try to understand by providing feedback. 4. When my friends share their opinions, I am less interested in giving feedback.
	Presentation	5	1. I always actively ask questions during class presentations. 2. I try to be a presenter during class presentations. 3. I am always willing if asked to be a presenter during presentation activities. 4. I am less active in asking questions during class presentations. 5. I am not willing to be asked to be a presenter during a presentation.

Written Communication Skills (WCS)	Presenting ideas in written form	4	1. I am more interested in expressing my opinion in writing than in expressing my opinion orally. 2. I try to understand the teacher's explanation by asking questions in writing. 3. I am always willing when asked to express opinions in writing during learning activities. 4. I am not willing to be asked to express my opinion in writing during learning activities.
	Giving feedback in written form	5	1. When the teacher gave an explanation, I tried to understand the concepts conveyed by asking questions in writing. 2. When the teacher gave an explanation, I didn't try to understand the concept conveyed by asking questions in writing. 3. When my friends express their opinion, I try to understand by providing feedback in writing. 4. When my friends express opinions, I am less interested in providing feedback in writing. 5. I am more confident in giving written feedback during class discussion activities.
Social Communication Skills (SCS)	Negotiating to get agreement	4	1. I always try to negotiate when I have differences of opinion with friends or teachers. 2. when conducting negotiation activities, I present arguments clearly and easily understood. 3. I don't try to negotiate if I have differences of opinion with friends or teachers. 4. when negotiating, I tend to force my will so that my argument is accepted.
	Communicating to people from different cultures	4	1. I always try to communicate with all my friends regardless of ethnicity or regional origin. 2. When communicating, I tend to choose friends who come from the same area. 3. When communicating, I tend to choose friends who come from the same area.

			4. I am more interested in having discussions with friends who have the same cultural background.
	Communicating in different languages	4	1. I always try to communicate with all my friends using various languages. 2. When communicating, I tend to choose to use my local language. 3. I am more interested in conducting discussions using various languages. 4. I am not interested in conducting discussions using various languages.
	Communicating humbly	6	1. I always try to communicate with all friends using polite language. 2. When conducting discussion activities, I tend to use language that is polite and easy to understand. 3. When asking questions to the teacher, I always use polite language. 4. I don't try to communicate with all friends using polite language. 5. When conducting discussion activities, I tend to use language that is impolite and not easy to understand. 6. When I asked questions to the teacher, I did not use polite language.
Total Number of Items		**43**	