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TECHNOLOGY-ENHANCED COGNITIVE CONFLICT ON STUDENTS' STRATEGIC COMPETENCE AND PRODUCTIVE DISPOSITION

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ABSTRACT

Technology-Enhanced Cognitive Conflict Learning (TECCL) is an instructional approach that integrates digital tools such as GeoGebra and artificial intelligence (AI) to create cognitive conflict by confronting learners' misconceptions and guiding them toward conceptual understanding. This study determined the effect of TECCL on the strategic competence and productive disposition of Grade 10 learners in Mathematics at Lantapan National High School during the School Year 2025–2026, third quarter. A quasi-experimental research design was employed involving 76 learners, with 38 assigned to the control group (Non-TECCL) and 38 to the experimental group (TECCL). Data were gathered using a 10-item researcher-made problem-solving test and a 23-item adopted survey questionnaire. Descriptive statistics such as mean, frequency, standard deviation, and percentage were used, while Analysis of Covariance (ANCOVA) determined significant differences. Both groups obtained very low strategic competence during the pretest but improved in the posttest and retention test. The TECCL group demonstrated greater improvement, with more learners reaching higher proficiency levels. Significant differences were found in both posttest and retention test results in favor of the TECCL group. In terms of productive disposition, both groups improved after the intervention. The TECCL group showed better results in connectedness and curiosity, while the Non-TECCL group obtained higher results in self-confidence, flexibility, perseverance, and assessment of the application of mathematics. No significant difference was found in reflective thinking. These findings indicate that TECCL effectively improves strategic competence, although its effect on productive disposition varies across indicators. It is recommended that TECCL be utilized in Mathematics instruction to enhance learners' strategic competence.

Keywords: ***strategic competence, productive disposition, technology-enhanced cognitive conflict learning***

1. INTRODUCTION

Mathematics learning is not limited to remembering formulas or performing routine procedures. It also requires learners to formulate problems, select appropriate strategies, represent mathematical situations, and view mathematics as useful and worthwhile. Mathematical proficiency is commonly described through five interrelated strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Groth, 2017). These strands must be developed together because overemphasis on one area may limit students' overall mathematical growth (Elsayed, 2022).

Strategic competence refers to learners' ability to formulate, represent, and solve mathematical problems effectively. It involves recognizing the structure of a problem, selecting suitable strategies, and adjusting one's approach when an initial solution does not work (Darwani et al., 2020). Productive disposition, on the other hand, refers to the tendency to see mathematics as sensible, useful, and worthwhile, together with confidence in one's ability to learn and use mathematics (Kilpatrick et al., 2001). These two strands are closely connected because learners who value mathematics and believe in their ability are more likely to persist and apply appropriate strategies when solving problems (Rahman et al., 2022).

The development of strategic competence and productive disposition remains a major concern in the Philippine mathematics classroom. The Programme for International Student Assessment reported that Filipino learners continue to perform below international standards in mathematics (OECD, 2023). Similarly, the TIMSS 2019 results showed low mathematics achievement among Filipino learners (Mullis et al., 2020). These findings indicate the need for instructional approaches that do not only improve students' mathematical performance but also strengthen their confidence, engagement, perseverance, and appreciation of mathematics (Cordova & Tan, 2018).

One approach that may respond to these concerns is cognitive conflict learning. Cognitive conflict occurs when learners encounter a situation that challenges their existing understanding, creating a need to examine, revise, and reconstruct their ideas (Kang et al., 2018). When properly guided, cognitive conflict can encourage learners to confront misconceptions and develop deeper mathematical understanding. However, cognitive conflict should be supported by appropriate scaffolding to prevent confusion and frustration among learners.

Technology can strengthen cognitive conflict learning by providing multiple representations, interactive tasks, immediate feedback, and opportunities for exploration. Digital tools such as GeoGebra and Nearpod can help learners visualize mathematical concepts, test conjectures, and compare solution strategies (Hegedus et al., 2017; Hillmayr et al., 2020). Artificial intelligence tools may also assist teachers in designing tasks, identifying misconceptions, and providing adaptive support during learning (Holmes et al., 2019; Zawacki-Richter et al., 2019). Although technology-enhanced mathematics instruction has been widely studied (Drijvers et al., 2016), there remains a need to examine its effect on learners' strategic competence and productive disposition, especially in local classroom contexts (Cevikbas & Kaiser, 2023). Thus, this study investigated the effect of Technology-Enhanced Cognitive Conflict Learning on Grade 10 learners' strategic competence and productive disposition in Mathematics.

2. METHODOLOGY

2.1. Objectives

This study aimed to determine the effect of Technology-Enhanced Cognitive Conflict Learning (TECCL) on the strategic competence and productive disposition of Grade 10 learners in Mathematics at Lantapan National High School during the third quarter of School Year 2025-2026. Specifically, it sought to:

1. Determine the level of learners' strategic competence in mathematics when exposed to TECCL and Non-TECCL in terms of:
   a. pre-test;
   b. post-test; and
   c. retention test.
2. Identify the level of learners' productive disposition in mathematics when exposed to TECCL and Non-TECCL in terms of:
   a. self-confidence;
   b. connectedness and high curiosity;
   c. flexibility;
   d. perseverance;
   e. reflective thinking; and
   f. assessment of the application of mathematics.
3. Ascertain if there is a significant difference in learners' strategic competence when exposed to TECCL and Non-TECCL in terms of post-test and retention test, using the pre-test as covariate.
4. Find out if there is a significant difference in learners' productive disposition when exposed to TECCL and Non-TECCL, using the pre-test as covariate.

2.2. Research Design

This study employed a quasi-experimental research design. Two intact Grade 10 classes were used as participants. One class served as the experimental group and was exposed to TECCL, while the other class served as the control group and was exposed to Non-TECCL instruction. Both groups were administered a pre-test, post-test, and retention test for strategic competence, and a productive disposition questionnaire before and after the intervention. The design was appropriate because random assignment of individual learners was not feasible in the school setting, but comparison between two instructional groups was necessary to determine the effect of the intervention.

2.3. Locale of the Study

The study was conducted at Talakag National High School (TNHS) in Barangay San Isidro, Talakag, Bukidnon, along the Cagayan de Oro-Dominorog-Camp Kibaritan Road. Located near Sayre Highway and a short ride from the Poblacion proper of Talakag, TNHS is a public school that offers a complete Junior High School curriculum, Open High School, Alternative Learning, and various Senior High School programs, providing access to a wide range of student backgrounds and educational experiences.

Talakag National High School is an appropriate setting for this study because of its diverse student population, and it was discovered that the Grade 11 students in Mathematics classes had poor performance and negative self-efficacy, as evidenced by their overall weighted average of 50.25% last school year 2024-2025 based on the Consolidated Report on Teachers' Report Card (CMSS).

2.4. Respondents of the Study

The participants in the study were the enrolled Grade 11 students of Talakag National High School for the School Year 2025-2026. Grade 11 consisted of eight (8) sections with an average population of thirty-five (35) students per class. Two heterogeneously mixed sections were selected; one section was exposed to the Cover-Copy-Compare (CCC) strategy, which consisted of 10 males and 25 females aged around 16-17 years, while the other section was exposed to the Non-Cover-Copy-Compare (Non-CCC) strategy, which consisted of 12 males and 23 females aged around 16-17 years. The chosen sections received identical lessons, ensuring that both groups received the same educational content.

2.5. Research Instrumentation

This study used two research instruments. One instrument measured the strategic competence of the Grade 10 students covering the third-quarter topics, while the other was a survey questionnaire that measured the students' productive disposition.

The first instrument was a 10-item researcher-made test in Mathematics 10 focusing on permutation and combination. It was based on the lessons included during the implementation of the study. The instrument was validated by local experts prior to its use. It covered topics in permutation and combination. This was pilot tested before the researcher utilized the instrument, with a Cronbach's Alpha of 0.82. Rubrics were used to score the learners' answers and evaluate their performance.

Using the standard set of DepEd Order No. 8 series of 2015, the results will be interpreted using the scale below after the scores are transmuted.

Score	Descriptive Rating	Interpretation
0 – 24	Beginning	Very Low strategic competence (VLSC)
25 – 29	Developing	Low strategic competence (LSC)
30 – 34	Approaching Proficiency	Average strategic competence (ASC)
35 – 39	Proficient	High strategic competence (HSC)
40 – 50	Advanced	Very High strategic competence (VHSC)

The second instrument was adopted from Bahar et al. (2023) to measure students' productive disposition. The instrument, which was a survey questionnaire, consisted of 23 items and was rated by the participants using a 4-point Likert scale to indicate their levels. The questionnaire consisted of six sub-variables, namely: self-confidence with six (6) items, connectedness and high curiosity with seven (7) items, flexibility with two (2) items, perseverance with two (2) items, reflective with three (3) items, and assessment of the application of mathematics with three (3) items. The questionnaire was used because productive disposition is an affective component of mathematical proficiency. It reflects learners' tendency to view Mathematics as sensible, useful, and worthwhile, as well as their confidence, persistence, curiosity, and willingness to participate in mathematical tasks. Since the study examined not only learners' strategic competence but also their attitudes and dispositions toward Mathematics, the questionnaire was appropriate for measuring changes in learners' affective responses after exposure to TECCL and non-TECCL instruction. Reverse scoring was applied to the negatively stated items in the questionnaire. The instrument was pilot tested before the researcher utilized the instrument, with a Cronbach's Alpha of 0.83. A scale from the same study was used to interpret the collected data, providing a clearer understanding of the learners' productive disposition scores. The scale is presented as follows:

Score Range	Descriptive Level	Interpretation
79–92	Very High Productive Disposition (VPD)	Consistently demonstrates strong confidence, perseverance, value, and engagement
59–78	High Productive Disposition (HPD)	Often demonstrates positive disposition and active participation
39–58	Moderate Productive Disposition (MPD)	Shows some positive attitudes but needs encouragement
23–38	Low Productive Disposition (LPD)	Rarely shows positive disposition; needs targeted support

Data Gathering Procedure

The researcher first secured approval from the university Research Ethics Committee and obtained permission from the Department of Education Division of Bukidnon and the school principal of Lantapan National High School. The purpose, procedures, and importance of the study were explained to the learners, parents, and class advisers during orientation. Informed consent and assent were secured before the conduct of the study.

Before the intervention, a pre-test and productive disposition questionnaire were administered to both groups. The experimental group was then exposed to TECCL, while the control group received Non-TECCL instruction. Both groups covered the same lesson topics and competencies in permutation, combination, and probability. After the intervention, a post-test and the same productive disposition questionnaire were administered. Two weeks after the post-test, the retention test was given to determine learners' retention of strategic competence.

Implementation of Technology-Enhanced Cognitive Conflict Learning (TECCL)

In the TECCL group, the teacher used lesson activities designed to create and resolve cognitive conflict through digital interactive tools. GeoGebra, Nearpod, and artificial intelligence-assisted activities were used to present problem situations, visualize mathematical concepts, facilitate exploration, and provide feedback. Learners encountered tasks that challenged their existing mathematical conceptions, discussed possible solutions with peers, and used digital tools to test and revise their thinking. The teacher provided guidance and scaffolding as learners resolved misconceptions and constructed more accurate mathematical understanding.

Implementation of Non-TECCL Instruction

The control group was exposed to Non-TECCL instruction using the same topics and competencies. The teacher used conventional classroom strategies such as teacher-led discussion, board work, printed materials, worksheets, and paper-and-pencil activities. Learners participated in class discussions and solved mathematical problems without the use of technology-enhanced cognitive conflict activities.

2.7. Ethical Considerations in the Data Collection

Ethical procedures were observed throughout the study. The researcher secured the required ethics clearance and written permissions before data gathering. Participation was voluntary, and learners were informed that they could withdraw from the study at any time without penalty. The identities of the participants were not disclosed in any part of the study. All data were treated with confidentiality, securely stored, and used solely for research purposes.

2.8. Statistical Tool

The study used descriptive statistics such as frequency, percentage, mean, and standard deviation to describe learners' strategic competence and productive disposition. The Shapiro-Wilk test and Levene's test were used to check the assumptions for parametric analysis. Analysis of Covariance (ANCOVA) was used to determine significant differences between the TECCL and Non-TECCL groups using the pre-test scores as covariates. The level of significance was set at 0.05.

3. RESULTS AND DISCUSSION

The results revealed that learners in both the TECCL and Non-TECCL groups initially demonstrated very low strategic competence in mathematics. During the pre-test, all learners from both groups were categorized under the Beginning level, indicating that they had difficulty formulating and applying appropriate strategies in solving mathematical problems. This suggests that both groups were comparable before the intervention and that learners needed instructional support to strengthen their strategic competence. This finding is consistent with studies showing that learners often demonstrate limited problem-solving and strategic abilities before exposure to innovative instructional approaches (Cambaya & Tan, 2022).

After the intervention, both groups improved in strategic competence, but the TECCL group showed greater gains. In the post-test, more learners in the TECCL group reached higher proficiency levels, including Approaching Proficiency, Proficient, and Advanced, while most learners in the Non-TECCL group remained at the Beginning and Developing levels. In the retention test, the Non-TECCL group showed a greater decline, while the TECCL group retained higher performance. These results indicate that TECCL was more effective in enhancing and sustaining learners' strategic competence. The improvement may be attributed to the use of interactive digital tools, visualization, immediate feedback, and cognitive conflict tasks that encouraged learners to revise misconceptions and apply problem-solving strategies (Hillmayr et al., 2020; Kusumaningpuri et al., 2022).

The ANCOVA results confirmed a statistically significant difference in learners' strategic competence in favor of the TECCL group. In the post-test, the TECCL group obtained a higher mean score than the Non-TECCL group, and the group effect was significant. Similarly, in the retention test, the TECCL group maintained a higher mean score, indicating that the approach supported both immediate learning and retention. The use of technology-enhanced representations and cognitive conflict may have helped learners analyze problems, compare strategies, and construct more meaningful mathematical understanding (Hegedus et al., 2017; Drijvers et al., 2016).

In terms of productive disposition, both groups showed improvement after the intervention. However, the TECCL group obtained higher post-test results in self-confidence, connectedness and high curiosity, flexibility, perseverance, and assessment of the application of mathematics. These findings indicate that TECCL supported not only cognitive performance but also learners' affective readiness to participate, communicate, persist, and value mathematics. Productive disposition develops when learners see mathematics as meaningful and when classroom experiences encourage confidence, persistence, and active engagement (Kilpatrick et al., 2001; Haji et al., 2019).

The significant difference in self-confidence in favor of the TECCL group suggests that technology-enhanced activities helped learners become more willing to engage in mathematical tasks. The use of interactive platforms may have allowed learners to receive feedback, attempt solutions, and experience progress during the lesson. This supports the view that affective factors such as confidence, motivation, and attitudes influence learners' participation in mathematics (Hannula, 2020).

The significant difference in connectedness and high curiosity also favored the TECCL group. Since several items under this indicator were negatively stated and reverse-scored, higher post-test scores indicate less anxiety, less hesitation, stronger curiosity, and greater willingness to participate. Cognitive conflict may have increased learners' curiosity by presenting situations that challenged their prior understanding, while digital tools helped them explore and resolve these conflicts. This supports the idea that productive dispositions are shaped by classroom experiences that position learners as active participants in mathematical reasoning (Gresalfi & Cobb, 2016).

Flexibility and perseverance also showed significant differences in favor of the TECCL group. Learners exposed to TECCL became more willing to ask questions, express ideas, adjust strategies, and continue working on mathematical tasks despite difficulty. These results suggest that interactive and feedback-oriented learning experiences strengthened learners' positive engagement and persistence. The presence of cognitive conflict may have encouraged learners to revise their thinking and continue seeking solutions until they reached clearer understanding (Kang et al., 2018; Haji et al., 2019).

For reflective thinking, the ANCOVA result showed no significant difference between the TECCL and Non-TECCL groups. This suggests that although both groups engaged in mathematical activities, the difference between the two instructional approaches was not strong enough to produce a statistically significant effect on reflective thinking. Reflective thinking may require more explicit and sustained activities such as reflection journals, guided self-assessment, and written explanations of solution strategies. Since affective growth develops through repeated experiences that shape learners' beliefs, emotions, and attitudes, longer exposure may be needed to produce measurable differences (Hannula, 2020).

Finally, a significant difference was found in the assessment of the application of mathematics in favor of the TECCL group. This indicates that learners exposed to TECCL developed stronger appreciation of the usefulness and relevance of mathematics. The use of GeoGebra, Nearpod, and interactive tasks may have helped learners visualize mathematical ideas, connect concepts to practical situations, and recognize the value of mathematics beyond routine computation. This supports the view that students' beliefs about the usefulness of mathematics influence their motivation and engagement in mathematical problem solving (Schukajlow et al., 2022).

4. CONCLUSION

Based on the findings of the study, the following conclusions are drawn.

Both the TECCL and Non-TECCL groups began the study with very low strategic competence in mathematics, confirming that learners initially had difficulty formulating, representing, and applying appropriate strategies in solving mathematical problems. After the intervention, both groups improved; however, the TECCL group demonstrated greater improvement in the post-test and stronger retention in the retention test. This establishes that Technology-Enhanced Cognitive Conflict Learning is more effective than Non-TECCL instruction in developing and sustaining learners' strategic competence.

The ANCOVA results further confirmed significant differences in strategic competence in favor of the TECCL group in both the post-test and retention test. This means that the use of technology-enhanced activities, cognitive conflict tasks, visual representations, and feedback contributed meaningfully to learners' ability to analyze problems, select strategies, and apply mathematical concepts in solving tasks.

With respect to productive disposition, the TECCL group showed higher results in self-confidence, connectedness and high curiosity, flexibility, perseverance, and assessment of the application of mathematics. These results indicate that TECCL helped learners become more confident, curious, flexible, persistent, and aware of the usefulness of mathematics. Thus, the approach supported both the cognitive and affective dimensions of mathematics learning.

However, no significant difference was found in reflective thinking between the TECCL and Non-TECCL groups. This indicates that reflective thinking may not be sufficiently developed through technology-enhanced cognitive conflict activities alone within a limited implementation period. It requires more deliberate, explicit, and sustained reflection activities such as guided reflection questions, self-assessment, learning journals, and written explanations of mathematical reasoning.

Overall, the findings establish that TECCL is an effective instructional strategy for enhancing learners' strategic competence and improving most indicators of productive disposition in mathematics. The integration of digital tools and cognitive conflict activities provided learners with opportunities to confront misconceptions, explore mathematical ideas, receive feedback, and apply strategies more meaningfully.

5. RECOMMENDATION

Based on the summary, findings, and conclusions of the study, the following recommendations are given:

In light of the finding that learners exposed to TECCL demonstrated higher and more sustained strategic competence than those exposed to Non-TECCL instruction, mathematics teachers are encouraged to integrate Technology-Enhanced Cognitive Conflict Learning into regular classroom instruction. Teachers may use GeoGebra, Nearpod, artificial intelligence-assisted tasks, and other digital platforms to create problem situations that challenge learners' misconceptions and guide them toward deeper conceptual understanding.

Since TECCL improved most indicators of productive disposition, teachers should design activities that encourage learners to ask questions, express ideas, explore multiple solution paths, and persist in solving mathematical problems. Technology-enhanced activities should be accompanied by clear teacher guidance, feedback, and collaborative discussion so that learners can experience both cognitive support and affective encouragement during mathematical tasks.

Given that reflective thinking did not show a significant difference between the groups, teachers are encouraged to include explicit reflection-based activities in TECCL lessons. These may include reflection journals, exit tickets, guided self-assessment questions, peer discussion prompts, and written explanations of solution strategies. Such activities may help learners monitor their thinking, recognize errors, and evaluate the effectiveness of their problem-solving approaches.

School administrators are encouraged to support the implementation of TECCL by providing adequate technological resources, stable internet access, and teacher training on the use of digital tools in mathematics instruction. Learning action cells and professional learning communities may also be conducted to help teachers share best practices in designing technology-enhanced cognitive conflict activities.

Curriculum developers may consider the integration of TECCL-based activities in mathematics learning materials. These materials may include misconception-based problems, interactive simulations, technology-supported explorations, and real-life mathematical tasks that promote strategic competence and productive disposition.

Future researchers may conduct similar studies using a longer implementation period, larger sample size, different grade levels, and other mathematics topics. Further studies may also examine the long-term effects of TECCL on reflective thinking, mathematical reasoning, motivation, and other strands of mathematical proficiency. Comparative studies between TECCL and other instructional approaches may provide additional evidence on effective strategies for improving mathematics learning.

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REFERENCES

[1] Abdullah, M. I., Inayati, D., & Karyawati, N. N. (2022). Nearpod use as a learning platform to improve student learning motivation in an elementary school. Journal of Education and Learning (EduLearn), 16(1), 121-129. https://doi.org/10.11591/edulearn.v16i1.20421

[2] Bahar, R., Hidayat, O., Syadiah, A. N., & Sutardi, B. (2023). Finding a mathematical disposition instrument of junior high school students in Indonesia. Psychology, Evaluation, and Technology in Educational Research, 5(2), 66-78. https://doi.org/10.33292/petier.v5i2.145

[3] Cambaya, R. J., & Tan, D. A. (2022). Enhancing learners' problem-solving skills and engagement in mathematics learning through contextualized instruction. Science International (Lahore), 34(2), 101-109.

[4] Cevikbas, M., & Kaiser, G. (2023). Can flipped classroom pedagogy offer promising perspectives for mathematics education on pandemic-related issues? A systematic literature review. ZDM Mathematics Education, 55(1), 177-191. https://doi.org/10.1007/s11858-022-01388-w

[5] Cordova, C. C., & Tan, D. A. (2018). Attitude towards mathematics and achievement among secondary students in mathematics education. Science International (Lahore), 30(2), 319-323.

[6] Darwani, Zubainur, C. M., & Saminan. (2020). Adaptive reasoning and strategic competence through problem based learning model in middle school. Journal of Physics: Conference Series, 1460, Article 012019. https://doi.org/10.1088/1742-6596/1460/1/012019

[7] Drijvers, P., Ball, L., Barzel, B., Heid, M. K., Cao, Y., & Maschietto, M. (2016). Uses of technology in lower secondary mathematics education. Springer. https://doi.org/10.1007/978-3-319-33666-4

[8] Elsayed, S. A. M. (2022). The effectiveness of learning mathematics according to the STEM approach in developing the mathematical proficiency of second graders of the intermediate school. Education Research International, 2022, Article 5206476. https://doi.org/10.1155/2022/5206476

[9] Gresalfi, M. S., & Cobb, P. (2016). Cultivating students' discipline-specific dispositions as a critical goal for pedagogy and equity: Response to Engle, Conant, and Greeno. Cognition and Instruction, 25(2-3), 250-266. https://doi.org/10.1080/07370008.2007.9651851

[10] Groth, R. E. (2017). Classroom data analysis with the five strands of mathematical proficiency. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 90(3), 103-109.

[11] Haji, S., Abdullah, M. I., Maizora, S., & Yumiati. (2019). Developing students' productive disposition: The case of a mathematical modelling class. Journal of Physics: Conference Series, 1315, Article 012011. https://doi.org/10.1088/1742-6596/1315/1/012011

[12] Hannula, M. S. (2020). Affect in mathematics education. In S. Lerman (Ed.), Encyclopedia of

mathematics education (pp. 32-36). Springer. https://doi.org/10.1007/978-3-030-15789-0_174

[13] Hegedus, S., Laborde, C., Brady, C., Dalton, S., Siller, H.-S., Tabach, M., Trgalova, J., & Moreno-Armella, L. (2017). Uses of technology in upper secondary mathematics education. Springer. https://doi.org/10.1007/978-3-319-42611-2

[14] Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. Computers & Education, 153, Article 103897. https://doi.org/10.1016/j.compedu.2020.103897

[15] Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign.

[16] Juandi, D., Kusumah, Y. S., Tamur, M., Perbowo, K. S., & Wijaya, T. T. (2021). A meta-analysis of GeoGebra software decade of assisted mathematics learning: What to learn and where to go? Heliyon, 7(5), Article e06953. https://doi.org/10.1016/j.heliyon.2021.e06953

[17] Kang, H., Scharmann, L. C., & Noh, T. (2018). Cognitive conflict and conceptual change. Research in Science Education, 48(3), 545-563.

[18] Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). Adding it up: Helping children learn mathematics. National Academy Press.

[19] Kusumaningpuri, A. R., Murtiyasa, B., Fuadi, D., R, L. E., & Fauziati, E. (2022). Skills in solving mathematical problems in the statistics subject using interactive multimedia in Grade VI of elementary school. JTAM (Jurnal Teori dan Aplikasi Matematika), 6(3), 557-564. https://doi.org/10.31764/jtam.v6i3.8439

[20] Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). TIMSS 2019 international results in mathematics and science. TIMSS & PIRLS International Study Center, Boston College.

[21] OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. https://doi.org/10.1787/53f23881-en

[22] Rahman, M. S., Juniati, D., & Manuharawati. (2022). Strategic competence in solving-problem and productive disposition of high school students based on cognitive styles. AIP Conference Proceedings, 2577(1), Article 020053. https://doi.org/10.1063/5.0096029

[23] Schukajlow, S., Blomberg, J., Rellensmann, J., & Leopold, C. (2022). The role of strategy-based motivation in mathematical problem solving: The case of learner-generated drawings. Learning and Instruction, 80, Article 101561. https://doi.org/10.1016/j.learninstruc.2021.101561

[24] Thurm, D., & Barzel, B. (2022). Effects of a professional development program on teachers' beliefs, self-efficacy and practices in technology-enhanced mathematics education. ZDM Mathematics Education, 54(6), 1143-1159. https://doi.org/10.1007/s11858-022-01396-w

[25] Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: Where are the educators? International Journal of Educational Technology in Higher Education, 16, Article 39. https://doi.org/10.1186/s41239-019-0171-0