MADAKO ELEMENTARY SCHOOL
VOL. 4 NO. 1 JUNE 2025; pp: 16-37
E-ISSN: 2964-5719

PROGRAM STUDI PENDIDIKAN GURU SEKOLAH DASAR (PGSD)
UNIVERSITAS MADAKO TOLITOLI
https://ojs.fkip.umada.ac.id/index.php/mes

Mastery Learning Based Elementary School Learning for Philippines' Students with the Schneeball-Wirbelgruppe Model

[1] Marie Freddie Gladys, [2] Isaiah Jacinto Naparan
[1] Saint Columban College Philippines, mariafg76@gmail.com
[2] Saint Columban College Philippines, isaiahjnaparan@gmail.com

Article Info

Keywords:
Mastery Learning; Elementary School Learning; Schneeball-Wirbelgruppe Model

ABSTRACT

21st century learning demands mastery of scientific thinking concepts and skills through collaborative approaches and active discussion. This study aims to analyze the effectiveness of the Schneeball-Wirbelgruppe learning model in improving the mastery of concepts in the science material studied by students. The study took place in Lam-an, Ozamiz City, Misamis Occidental, Philippines, focusing on an elementary school namely Philippine Schools Overseas (PSO). The study uses a one-group pretest-posttest class experimental design with a sample of 19 elementary school students in 2025. The instrument used is a concept mastery test in the form of multiple choice and descriptions that have been validated and reliable. Data were analyzed using descriptive (N-gain test) and inferential (paired t-test) analysis. The results showed a significant increase between pretest and posttest scores, indicating that the Schneeball-Wirbelgruppe model was effective in improving conceptual mastery, especially in science learning. These findings suggest that the model can be an alternative to innovative learning strategies that support students' conceptual understanding in a more in-depth way. The implication of this study is that the Schneeball-Wirbelgruppe model has the potential to be applied to a wide range of other concepts and subjects at the elementary school level.

Informasi Artikel

Kata Kunci:
Mastery Learning; Pembelajaran Sekolah Dasar; Model Schneeball-Wirbelgruppe

ABSTRAK

Pembelajaran abad ke-21 menuntut penguasaan konsep dan keterampilan berpikir ilmiah melalui pendekatan kolaboratif dan diskusi aktif. Penelitian ini bertujuan untuk menganalisis efektivitas model pembelajaran *Schneeball-Wirbelgruppe* dalam meningkatkan penguasaan konsep terhadap materi sains yang dipelajari siswa. Penelitian berlangsung di Lam-an, Kota Ozamiz, Misamis Occidental, Filipina, dengan fokus pada sekolah dasar yaitu Philippine Schools Overseas (PSO). Penelitian menggunakan desain eksperimen kelas *one-group pretest-posttest* dengan sampel sebanyak 19 siswa jenjang sekolah dasar di tahun 2025. Instrumen yang digunakan berupa tes penguasaan konsep dalam bentuk pilihan ganda dan uraian yang telah tervalidasi dan reliabel. Data dianalisis menggunakan analisis deskriptif (uji N-gain) dan inferensial (uji t berpasangan). Hasil menunjukkan adanya peningkatan signifikan antara nilai pretest dan posttest, yang mengindikasikan bahwa model *Schneeball-Wirbelgruppe* efektif dalam meningkatkan penguasaan konsep, khususnya dalam pembelajaran sains. Temuan ini menunjukkan bahwa model tersebut dapat menjadi alternatif strategi pembelajaran inovatif yang mendukung pemahaman konseptual siswa secara lebih mendalam. Implikasi dari penelitian ini adalah model *Schneeball-Wirbelgruppe* berpotensi diterapkan pada berbagai konsep dan mata pelajaran lain di tingkat sekolah dasar.

Article History

Received	:	15 April 2025
Revised	:	15 June 2025
Accepted	:	16 June 2025

✉ ***Corresponding Author:*** (1) Marie Freddie Gladys, (2) Elementary School, (3) Saint Columban College Philippines, (4) Lam-an, Ozamiz City, Misamis Occidental, Philippines, (5) Email: mariafg76@gmail.com

How to cite:
Gladys, M.F. & Naparan, I.J. (2025). Mastery learning based elementary school learning for Philippines' students with the schneeball-wirbelgruppe model. *Madako Elementary School, 4*(1), 16-37. https://doi.org/10.56630/mes.v4i1.291

INTRODUCTION

In the era of Education 4.0, it is imperative for all students to have a solid understanding of key concepts, including those studying science in the development of scientific thinking concepts. The concept of science learning is generally challenging to understand. These concepts may seem somewhat boring, resulting in students who are less engaged or passive (Casler, 2022).

Materials that are considered boring and teaching methods that are still one-way cause students to be less active and tend to be passive in learning. Teachers need to find solutions to make it easier to understand these concepts and keep students active using teaching methods that stimulate critical thinking (Hsu et al., 2022; Hyrkkö & Kajamaa, 2025). However, this is only possible through the creation of an interactive learning atmosphere to keep students actively engaged during the learning process (M. Lee et al., 2023).

On the other hand, teachers also face challenges in creating an interactive learning atmosphere and encouraging students' active participation (Aubert et al., 2017; K.-H. Cheng & Tsai, 2019). This problem shows that there is an urgent need for a learning model that is not only able to improve students' conceptual understanding, but also cultivate their critical thinking skills through collaborative activities and structured discussions (Amani & Mkimbili, 2025; Lv et al., 2025). Therefore, it is necessary to conduct research to examine learning models that can answer these problems effectively, one of which is through the integration of the Schneeball and Wirbelgruppe models.

Mastery of critical thinking skills and mastery of concepts are two main elements in shaping 21st century competencies (Maxwell, 2023; Nikkola et al., 2024; Weil & Mayfield, 2020), especially in the context of learning in the era of the Industrial Revolution 4.0. (Abulibdeh et al., 2024; C. Lee & Lim, 2021; Souza & Debs, 2024; Teo et al., 2021) emphasized that learning that is designed interactively and the use of appropriate models and methods will equip learners with essential skills, such as communication, problem-solving, entrepreneurship, and critical and digital thinking skills. In this case, critical thinking is the dominant element of higher-order thinking skills that are indispensable in solving complex problems in a reflective and logical manner (AlMalki & Durugbo, 2023).

Alpizar et al. (2022) define critical thinking as an open-minded process that considers various alternatives and is geared towards problem solving. Cananau et al. (2025) add that these abilities include argument analysis, drawing conclusions, the use of inductive-deductive reasoning, evaluation, and decision-making. Individuals who have critical thinking skills are characterized by an attitude of openness, curiosity, the habit of asking questions, and flexibility in thinking (Falloon, 2024). This is reinforced by Vuk (2023) who emphasize the linkage of these skills to intellectual discipline, integrity, and creativity. Meanwhile, Umar & Rathakrishnan (2012) stated that critical thinking evaluation is an important indicator in higher education assessment and can be carried out through essay-based instruments. In practice, the use of the right learning strategies plays a crucial role in fostering and directing students' critical thinking potential (Kim et al., 2025; Seibert, 2021).

On the other hand, conceptual mastery is also a core competency in the cognitive domain. The improvement of cognitive abilities is determined by a variety of factors, such as students' active participation in learning tasks (Lv et al., 2025), learning attitude skills and dispositions (Williams et al., 2025), speed in processing information (M. Liu, 2025), and the interconnectedness of neurobehavioral processes in the brain (Winget & Persky, 2022). In addition, emotional involvement and the role of parents also make important contributions to the formation of students' cognitive abilities (Chen et al., 2025).

According to Celio et al. (2011), the conceptualization process is influenced by the ability of cognitive meta-analysis, which is to organize parts of information into a whole conceptual structure. Annetta et al. (2024) emphasize that the process of concept formation takes place through the recognition of meaning, past experiences, as well as the activity of remembering and composing words in a pleasant context. Meanwhile, McCorkle (1995) emphasized that mastery of concepts is an accumulation of learning experiences that develop over time through application and repeated practice.

This narrative reflects a theoretical and empirical integration of the importance of learning design that not only facilitates cognitive mastery of concepts, but also supports the formation of adaptive and reflective critical mindsets. Although a variety of innovative learning models have been developed to improve students' critical thinking skills and concept mastery, most research has still focused on using a single learning model separately, such as Schneeball or Wirbelgruppe. For example, the results of Yeh et al. (2019) research found that the application of Schneeball learning to science materials in elementary schools is able to improve students' ability to ask and answer questions in a more structured manner and build courage in expressing opinions. Research on the Schneeball learning model shows that it is effective in increasing students' active participation as well as their academic achievement. In addition, research by Crijnen et al. (2021) shows that Schneeball learning can significantly improve student learning outcomes because it involves students in the process of forming understanding through small group stages to large groups gradually.

Meanwhile, separately the Wirbelgruppe model has been shown to be effective in encouraging collaboration and mastery of material through the formation of expert groups. Smeding et al. (2015) explains that this model allows students to delve deeper into a topic more specifically before sharing that understanding with other groups, resulting in a meaningful exchange of knowledge. Research by H. Cheng et al. (2014) also states that Wirbelgruppe supports the development of critical thinking skills because students not only understand their own topic, but also need to be able to explain and defend arguments in the presence of new group members.

Furthermore, research by Tíjaro-Rojas et al. (2016) shows that the combination of a tiered discussion approach such as Schneeball and a group rotation system such as Wirbelgruppe is able to improve students' high-level thinking skills (HOTS) in the context of science learning at the elementary level. They concluded that collaborative models like this are well-suited to be applied in 21st century competency-based curricula because they integrate the cognitive and affective aspects of students (Pineida, 2011).

There has not been much research that integrates these two models in an integrated and systematic learning flow, especially in the context of science learning at the elementary school level. In addition, previous studies were more conducted at the secondary or tertiary level, so there was a research gap in the combined implementation of the Schneeball-Wirbelgruppe model at the elementary level that had different characteristics of students, such as the ability to think concretely and the need for fun and meaningful learning.

The Schneeball-Wirbelgruppe model is a combination of collaborative learning strategies oriented towards the gradual and deep formation of conceptual understanding. This model combines the strengthening of understanding through layered discussions (Schneeball) and the exchange of information between expert groups (Wirbelgruppe), which encourages active engagement, scientific reasoning, and the simultaneous development of critical thinking skills. This approach supports 21st-century pedagogical principles that emphasize collaboration, communication, and problem-solving (Herlinawati et al., 2024). Thus, this research positions itself as a learning innovation that has not been widely explored in the context of basic education in Indonesia, especially in science learning that integrates science content. This is an important contribution in enriching the literature on innovative learning strategies based on model integration to improve the quality of student learning outcomes in the era of the Industrial Revolution 4.0 (Bohari et al., 2025; Oke & Fernandes, 2020).

The integration of the Schneeball-Wirbelgruppe learning method in science learning is expected to significantly improve students' mastery of concepts and critical thinking skills. This learning method is also relevant to the demands of science learning in the era of the Industrial Revolution 4.0 which has become the main phenomenon in the 21st century (Jain et al., 2025; Osiesi & Blignaut, 2025). Therefore, this study aims to analyze the effectiveness of students' mastery of science learning in elementary schools through the application of the Schneeball-Wirbelgruppe method.

METHOD

This study uses a quantitative approach with a one-group pretest-posttest design. This design was used to determine the effectiveness of the Schneeball-Wirbelgruppe learning model on improving students' mastery of concepts before and after treatment without using a control group. The subjects in this study were 19 students of Philippine Schools Overseas (PSO). The selection of samples was carried out purposively by considering the characteristics of students and the readiness of the class to apply a collaborative learning model.

The learning model used is a combination of Schneeball and Wirbelgruppe. The learning process begins with the formation of a small group (Partnergruppen) to discuss the subtopic material. The two small groups are then combined to form a large group that discusses and creates a concept map. Next, members were rotated into new groups (Wirbelgruppe model) to share and present their understanding of the previous subtopics. This activity aims to create a complete conceptual understanding through multi-level discussions and skill-rotation-based discussions. The instrument used in this study is a concept mastery test, which consists of multiple-choice questions and description questions.

Table 1. Results of the Validity and Realibility Test of the Mastery Learning Test Question Instrument

Mastery Learning Test Questions	Corrected Item-Total Correlation	Mastery Learning Test Questions	Corrected Item-Total Correlation
SW_1	.825	SW_11	.638
SW_2	.953	SW_12	.785
SW__3	.873	SW_13	.839
SW_4	.552	SW_14	.711
SW_5	.775	SW_15	-.054
SW_6	.858	SW_16	-.076
SW_7	.753	SW_17	.721
SW_8	.722	SW_18	.887
SW_9	.717	SW_19	.798
SW_10	.688	SW_20	-.045

Reliability Statistics	
Cronbach's Alpha	**N of Items**
.923	20

The validity test results of the assessment instrument used in the implementation of the Schneeball-Wirbelgruppe Learning model indicate that the majority of test items meet the criteria for empirical validity, as evidenced by corrected item-total correlation values exceeding the threshold of 0.30. Of the 20 items analyzed, 17 were found to be valid and contributed positively to measuring learning outcomes, particularly within the collaborative and constructivist framework that characterizes the model. Conversely, three items were identified as invalid due to low or negative correlation values, suggesting a potential threat to the overall consistency and accuracy of the instrument. These findings suggest that, while the instrument demonstrates an adequate level of quality in assessing mastery-based learning outcomes, further refinement is needed for several items to align more closely with principles of validity and construct relevance. A robustly valid instrument is essential for accurately evaluating the effectiveness of instructional strategies such as Schneeball-Wirbelgruppe, which emphasize active engagement, social interaction, and conceptual understanding through structured group collaboration.

The questions are prepared based on competency achievement indicators (GPA) and have been validated by experts. Data was collected through two stages, namely the pretest given before the treatment, and the posttest after the learning treatment was completed. Data analysis in this study was carried out through two main approaches, namely Descriptive Analysis and Inferential Analysis. In Descriptive Analysis, the average score, standard deviation, and N-Gain score were calculated to measure the increase in students' mastery of concepts quantitatively. Furthermore, Inferential Analysis was applied using a paired sample t-test to assess the significance of the difference between students' pretest and posttest scores.

The research procedure begins with the provision of a pre-test as an initial measurement of students' abilities, followed by the implementation of a learning process that adopts the Schneeball-Wirbelgruppe method, and ends with a post-test to measure the learning outcomes obtained. Data is collected through instruments designed to measure students' mastery of concepts and critical thinking skills.

The data obtained were then analyzed using descriptive and inferential evaluation techniques. In descriptive analysis, the N-Gain score is used to assess the degree of improvement in concept mastery. Meanwhile, inferential analysis was carried out with a t-pair test according to the reference, to test whether there was a significant difference between the pretest and posttest results.

The implementation of the N-Gain score calculation was carried out using Microsoft Excel, while the t-pair test was carried out using SPSS software for Windows. Before the inferential analysis is carried out, prerequisite testing is first carried out in the form of normality and homogeneity tests using SPSS. The normality test was carried out using the Shapiro-Wilk method, and the homogeneity test used the Levene test.

$$N - gain = \frac{posttest\ score - pretest\ score}{maximum\ possible\ score - pretest\ score}$$

$$t = \frac{\breve{d} - \mu d}{\frac{S_d}{\sqrt{n}}}$$

The N-gain values obtained are then classified based on the categories presented in Table 5. In the analysis process, d represents the difference between each pair of individuals or objects, while μd is the population average of the value of the difference taken from all data pairs. In addition, d also refers to the mean value of the difference, Sd indicates the standard deviation from the value of d, and n is the total number of data pairs analyzed.

Table 2. N-gain Classification

Limits	Categories
$g > 0.7$	High
$0.3 < g \leq 0.7$	Moderate
$g \leq 0.3$	Low

Then, pre-test and post-test data that measure conceptual mastery and critical thinking skills are tested first against the assumption of normality and homogeneity. The test results showed a significance value (sig) greater than 0.05, which indicates that the data met the requirements of normality and homogeneity. Therefore, further statistical analysis using a paired sample t-test can be performed to determine whether there is a significant difference between the pre-test and post-test values.

Table 3. Prasyarat Analisis Normalitas dan Homogenitas

Parameters	Normality Test		Homogeneity Test	
Pretest	0.199	Normal	0.606	Homogenious
Posttest	0.200		0.601	
Precritical	0.200		0.746	
Postcritical	0.122		0.146	

The test data obtained from the implementation of the Schneeball-Wirbelgruppe learning model in the context of mastery learning meet the assumptions of normality and homogeneity required for parametric statistical analysis. The normality test results indicate that all data sets pretest, posttest, precritical, and postcritical have significance values greater than 0.05. This suggests that the data are normally distributed and do not deviate significantly from the expected distribution pattern. Similarly, the homogeneity test results demonstrate that the variances across data groups are homogeneous, as evidenced by significance values exceeding the 0.05 threshold.

These findings are critical, as they validate the use of parametric statistical methods such as t-tests or ANOVA for further data analysis. The fulfillment of these statistical prerequisites indicates that the implementation of the Schneeball-Wirbelgruppe model occurred under statistically sound conditions, allowing the observed improvements in students' learning outcomes and critical thinking abilities measured through pretest–posttest and precritical–postcritical comparisons to be interpreted with scientific reliability. This reinforces the model's status as an effective pedagogical approach in supporting the attainment of mastery learning objectives.

RESULT AND DISCUSSIONS

A. Result

The Schneeball-Wirbelgruppe model, as implemented in this study, represents a strategic integration of two distinct collaborative learning frameworks Schneeball and Wirbelgruppe which were purposefully combined to examine their cumulative effect on the development of students' mastery learning. This hybrid model is grounded in progressive group dynamics, wherein learners transition from individual cognitive engagement to increasingly complex social interaction structures, ranging from dyadic partnerships to full-group collaborations. The methodological rationale behind combining these two models lies in their complementary functions: Schneeball fosters cumulative peer dialogue and gradual knowledge building, while Wirbelgruppe facilitates knowledge redistribution and reinforcement through the formation of cross-sectional expert teams.

The research design employed in this study was exploratory-explanatory in nature, aiming not only to observe learning outcomes, but also to investigate the underlying cognitive and social mechanisms that contribute to concept mastery. The implementation stages were deliberately structured to reflect a developmental progression in student agency and cognitive responsibility. Beginning with individual engagement, students moved into Partnergruppen, then merged into larger clusters for collaborative synthesis, before being reorganized into Wirbelgruppe units to ensure cross-topic integration and content reinforcement.

These procedural phases are not merely sequential steps but reflect a pedagogical cycle of internalization, articulation, negotiation, and recontextualization of knowledge. Such a design aligns with Vygotsky's sociocultural theory, particularly the concept of the Zone of Proximal Development (ZPD), where learning occurs most effectively through scaffolded social interaction. Within this framework, the Schneeball-Wirbelgruppe model was not only tested for outcome effectiveness but also examined in terms of its procedural efficacy in promoting distributed cognition and collective meaning-making.

The specific learning steps and instructional flow used in the study are systematically outlined in Table 3 and visually represented in Figure 1, which together serve as an operational blueprint for educators interested in replicating or adapting the model in comparable instructional contexts. The integration of both models, as captured in these

MADAKO ELEMENTARY SCHOOL
VOL. 4 NO. 1 JUNE 2025; pp: 16-37
E-ISSN: 2964-5719

visual and tabular formats, illustrates a coherent structure of instructional design that prioritizes both content mastery and social constructivist learning processes.

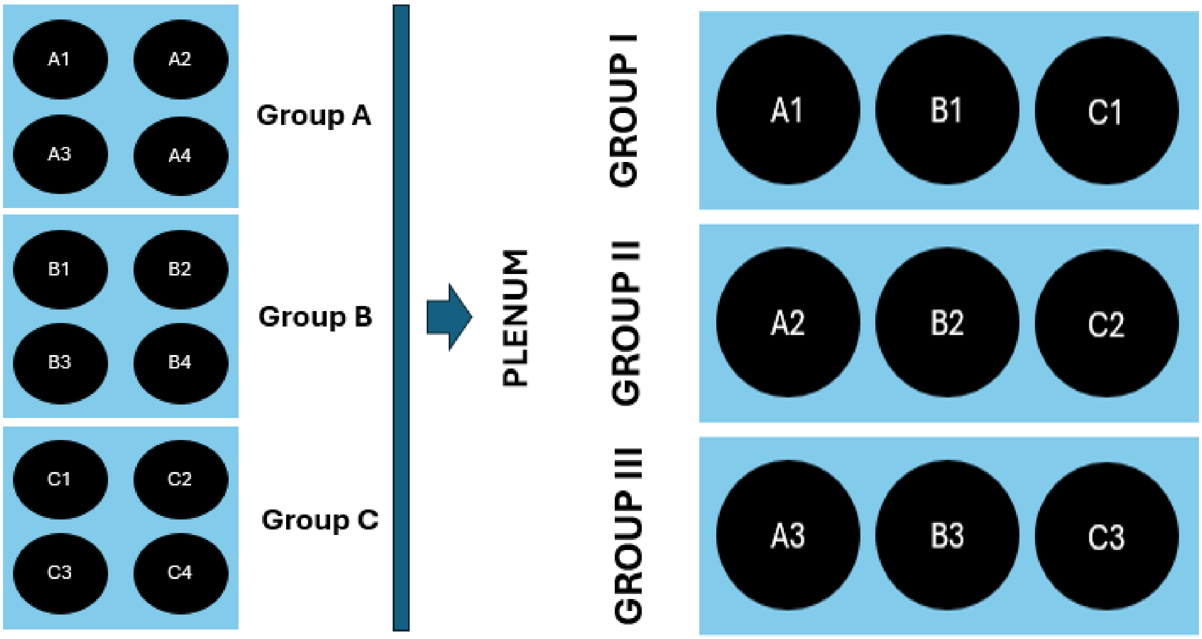

Figure 1. Design of the Schneeball-Wirbelgruppe Learning Model

The integration of collaborative learning models such as Schneeball and Wirbelgruppe has been empirically demonstrated to be an effective pedagogical strategy for enhancing conceptual understanding and promoting scientific thinking among elementary school students. Rooted in constructivist learning theory and social learning paradigms, these models foster active learner participation, dialogic engagement, and structured peer collaboration, all of which are essential for cultivating higher-order cognitive skills and deep conceptual mastery.

Figure 2. Learning Activities Based on the Schneeball-Wirbelgruppe Learning Model of Philippine Schools Overseas (PSO) Students Outside the Classroom

In the context of this study, the application of the Schneeball-Wirbelgruppe model was methodologically structured to support a gradual, scaffolded construction of knowledge. Initially, students are encouraged to comprehend subject matter individually before transitioning into Partnergruppen small, collaborative dyads or triads where they externalize and refine their understanding through dialogical exchange. These groups collaboratively produce visual learning artifacts, such as posters or mind maps, which serve as mediational tools to organize and deepen conceptual comprehension.

As learning progresses, two or more Partnergruppen are consolidated into larger discussion clusters to synthesize diverse perspectives, debate conceptual interpretations, and co-construct meaning in a more complex social configuration. This design promotes both horizontal (peer-to-peer) and vertical (individual-to-group) knowledge transfer. Notably, the plenary session traditionally associated with Schneeball learning is excluded in this intervention, under the rationale that sufficient content mastery has already been achieved within the large group discourse phase.

To further facilitate distributed expertise and reciprocal teaching, the study incorporates the Wirbelgruppe strategy, wherein students are reorganized into mixed-topic expert groups. Each group is composed of one representative from the prior subgroups (A, B, and C), ensuring cross-pollination of knowledge across topics. This jigsaw-like configuration reinforces accountability and positions each learner as a subject-matter specialist responsible for transmitting knowledge to peers, thus enhancing metacognitive engagement and explanatory precision.

Research-based accounts, including those by Marlena, affirm that Schneeball learning stimulates inquiry and questioning skills, while findings from Manemann, Rengstorf, and Schmutzer support the notion that Wirbelgruppe grouping strategies encourage the development of expert identities and deeper conceptual negotiation within nested group structures. Additionally, Koren and Rimmar emphasize that this dual-model approach is highly effective for collaborative synthesis and the presentation of group-generated content.

In sum, the strategic fusion of Schneeball and Wirbelgruppe within a Mastery Learning framework offers a robust instructional modality that not only enhances students' conceptual acquisition but also promotes critical thinking, peer teaching, and socially-mediated knowledge construction. The recursive and multi-phased nature of this collaborative design facilitates a more comprehensive and integrative learning experience, positioning learners as both consumers and producers of knowledge.

Table 4. Schneeball-Wirbelgruppe Learning Syntax

No.	Description of activities	Collaboration Stages
1	The teacher conveys the learning objectives explicitly to students to provide clear direction regarding competencies and expected results from the learning process to be implemented. The delivery of this goal aims to increase students' focus, motivation, and understanding of the material studied.	Schneeball Model
2	In this learning activity, the teacher gives instructions to each participant individually to learn tasks related to the morpheme formation process that has been carried out previously. It should be noted that the implementation of this task is carried out independently by participants from their respective homes. Each individual is given a specific topic of discussion, namely Flexion for members of groups A1, A2, A3, and A4; Derivation for members of groups B1, B2, B3, and B4; and Composites for members of groups C1, C2, C3, and C4. The division of this topic is intended to focus the study on different morphological aspects according to the predetermined group.	
3	The teachers form a tandem group or Partnergruppe with pairs of participants (A1 and A2 and A3 and A4). Each member of the couple has the same topic according to the individual tasks that have been given before. At this stage, participants are expected to unite their understanding of the material, then jointly compile a plaque or concept map (mind mapping) as a visual representation of the concepts learned. In addition, they were also asked to formulate explanations in the form of keywords and provide relevant examples to support understanding. The role of lecturers in this process is facilitative, namely providing assistance and guidance during the discussion without directly leading the discussion.	
4	Teachers form large groups (Group A, B, and C) by combining two tandem groups/Partnergruppe that have the same topic, namely groups A1 and A2, as well as A3 and A4. At this stage, each large group is	

	tasked with integrating the opinions of the members of the small group and compiling a more comprehensive and detailed record of the material studied. The teacher gives in-depth questions to each large group to strengthen their understanding of the topic being discussed. In addition, teachers also play the role of facilitators by continuing to accompany the large group discussion process, providing input and follow-up questions that aim to deepen and strengthen the mastery of students' concepts, considering that teachers are considered as a source of expertise in the material.	
5	The teacher gives directions to the members of group A (A1, A2, A3, A4), group B (B1, B2, B3, B4), and group C (C1, C2, C3, C4) to form a new group cross-topic. The formation of this new group was carried out by combining members from each initial group based on their sequence number, so that four new groups were formed, namely Group I consisting of members A1, B1, and C1; Group II consisting of A2, B2, and C2; Group III consisting of A3, B3, and C3; and Group IV consisting of A4, B4, and C4. The formation of these cross-topic groups aims to enrich discussions with diverse perspectives from various material focuses that have previously been studied separately.	Wirbelgruppe Model
6	The teacher instructs each member of groups I, II, III, and IV to explain the results of the discussion that has been obtained previously from their respective large groups (A, B, and C) to all members of the new group. This presentation process aims to transfer knowledge and findings from the initial discussion into a cross-topic forum, so that all members of the new group gain a comprehensive understanding from various perspectives of the material that has been studied.	
7	Teachers distribute worksheets with questions designed to deepen group members' understanding of the essence of the material presented in their group. This worksheet serves as a reflective guide that assists participants in reviewing key points and	

	developing a critical understanding of the content of the presentation that has been delivered.

Students' mastery of concepts is measured through essay tests that are carried out at the beginning (pretest) and end (posttest) of the learning session. The quantitative data obtained from the results of the two tests were then analyzed using the normalized gain (N-gain) test to determine the level of improvement in students' understanding of concepts. Based on the results of the N-gain analysis, it was obtained that the mastery of the concepts taught through the application of the Schneeball-Wirbelgruppe collaborative learning model was in the medium to high category. These findings show that the learning model is effective in improving students' understanding of the concepts taught, in this case related to the process of morpheme formation.

As part of statistical validation of the difference in learning outcomes before and after the intervention, a paired sample t-test was conducted. This test aims to identify the significance of the difference in pretest and posttest scores inferentially. The test results showed that there were statistically significant differences in students' mastery of concepts before and after Schneeball-Wirbelgruppe-based learning, which reinforced the finding that this model not only contributed to improved scores, but also significantly impacted the achievement of conceptual understanding. The results of a combination of essay test-based measurement approaches, N-gain analysis, and inferential statistical tests provide a strong methodological basis for concluding that learning collaboration in the Schneeball-Wirbelgruppe model is effective in improving mastery of linguistic concepts, particularly in basic morphology topics.

Table 5. N-gain Test of Students' Concept Mastery

Students	Pretest Scores	Posttest Scores	N-gain	Categories
1	65	96.3	0.89	High
2	55	85.3	0.67	Moderate
3	44	73.8	0.53	Moderate
4	43	79.5	0.64	Moderate
5	43	80	0.65	Moderate
6	50	85	0.7	Moderate
7	30	80	0.71	High
8	42	75.5	0.58	Moderate
9	45	75	0.55	Moderate
10	57	96.3	0.91	High
11	40	70.9	0.52	Moderate
12	46	70	0.44	Moderate
13	63	93.1	0.81	High
14	76	82.4	0.78	High
15	56	89	0.83	High
16	63	74.8	0.77	High

17	43	77	0.71	High
18	59	87	0.84	High
19	62	82.67	0.88	High

The results of data analysis showed a significant increase between pretest and posttest scores in all participants after the implementation of Mastery Learning-based learning through the Schneeball-Wirbelgruppe model. This increase occurred not only individually, but also in the aggregate, indicated by the average increase in posttest scores which reflected the effectiveness of the learning strategies applied in strengthening students' conceptual understanding.

The results of the normalized gain (N-gain) analysis showed that none of the students were in the low category (N-gain < 0.3), indicating that all students showed a substantial improvement in comprehension. As many as 100% of students were in the medium to high category, with details of 10 students (52.63%) in the high category, and 9 students (47.37%) in the medium category. These findings confirm that the Schneeball-Wirbelgruppe model, which is based on collaboration and active participation, within the framework of mastery learning, is effective in encouraging equitable distribution of learning outcomes. This model facilitates gradual learning through interaction between students that allows for a collective conceptual elaboration process, as well as provides remedial and reinforcement space in a conducive learning environment. Thus, this strategy contributes to an increase in end-to-end understanding that not only benefits high-achieving students, but also empowers students with lower initial abilities to achieve expected mastery of concepts.

Table 6. Student Concept Mastery T-Test

Variabel	**Mean**	**Standart Deviation**	**df**	**Sig. (2-tailed)**
Concept Mastery	-33.66923	6.31538	18	0.000

The results of the paired sample t-test analysis as shown in Table 8 showed that the significance value (2-tailed) was below the threshold of 0.05, which indicated a significant difference in students' mastery of concepts before and after the application of the Schneeball-Wirbelgruppe learning model. These findings show that the collaborative approach carried out by the model is not only able to create a comfortable and enjoyable learning atmosphere, but also effective in directing students' focus to in-depth understanding of concepts, especially in the process of morpheme formation as part of linguistic learning.

Methodologically, the research design uses a quantitative approach with pretest-posttest measurements combined with N-gain analysis as an indicator of improvement in conceptual ability. The results showed that the application of the Schneeball-Wirbelgruppe model contributed significantly to the improvement of students' conceptual understanding, with the average N-gain being in the medium to high category, and without students in the low category. This fact emphasizes that this model is effective in bridging the gap in students' initial understanding, as well as providing equal learning opportunities for all students.

One of the important findings of this study is the significant influence of the model on students with low initial scores. For example, students with a pretest score of 30 can experience an increase to a posttest score of 80, resulting in an N-gain of 0.71 which is in the high category. This indicates that the peer learning strategies integrated in the Schneeball-Wirbelgruppe model are able to provide adaptive learning support, allowing students with low initial ability to catch up and achieve overall mastery of the material.

Although the number of participants in this study was limited to 19 students, the consistent and significant pattern of improvement indicates that this model has the potential to be applied on a wider scale, including in Philippine Schools Overseas (PSO). Therefore, this study not only confirms the effectiveness of the Schneeball-Wirbelgruppe model in improving conceptual mastery, but also opens up opportunities for further exploration of the application of collaborative learning models in the context of mastery learning-based primary education.

B. Discussions

The effectiveness of the Schneeball-Wirbelgruppe model in the context of mastery learning at the elementary school level can be explained through its integration in facilitating student-centered learning and differentiation in the learning process. Mastery learning emphasizes that every student can achieve a high level of mastery of a competency as long as they are given the appropriate time, support, and learning strategies. In this regard, the Schneeball-Wirbelgruppe model is a very relevant pedagogical tool because it organizes learning gradually and systematically from the individual to the large group level, while maximizing social interaction as a medium for internalizing concepts.

This model is effective because it aligns the key principles of mastery learning, namely formative feedback, adaptive remedial, and mastery-based progress, with the collaborative dynamics that emerge in the peer teaching process (Guo et al., 2025). When students first understand the material independently, then share it with members of small groups and finally discuss it in large groups, they engage in a process of deep cognitive elaboration (Gyimah, 2022). This process strengthens information retention, improves clarity of understanding, and minimizes misconceptions that are common in science learning at the elementary level.

Furthermore, this approach supports the progress of inclusive learning. Based on empirical data from the implementation of this model in Philippine Schools Overseas (PSO), no low-gain category was found in N-gain achievement, indicating that students with low initial ability also experienced a significant increase. This proves that Schneeball-Wirbelgruppe not only facilitates excellent students, but also provides room for growth for students who were previously passive or left behind. Involvement in small groups gives them a sense of security to learn and participate, while exposure to large group discussions trains their courage and ability to articulate understanding openly (Benita et al., 2022; Gray et al., 2015).

In addition, the progressive group learning elements in this model reinforce the social-affective dimensions of students such as confidence, sense of responsibility, and cooperation, all of which are integral to success in the mastery learning approach (Anna & Spyros, 2025). When students not only graduate cognitively, but also develop in affective and psychomotor aspects, then learning outcomes become more meaningful and sustainable (Miesner et al., 2022). Thus, the integration of Schneeball-Wirbelgruppe in the practice of mastery learning in elementary schools is not only pedagogically relevant, but also proven to be empirically effective in improving conceptual mastery, minimizing learning gaps, and building an active, collaborative, and supportive learning ecosystem for all students.

The application of the Schneeball-Wirbelgruppe model, which combines the technique of group-building gradually from individuals to large groups, has been shown to encourage active participation as well as increase students' learning responsibilities equally. Based on empirical findings, this model results in a significant improvement in students' conceptual understanding, which occurs not only in high-achieving students, but also in students with low levels of initial understanding (Gal & Ryder, 2025). This is reflected in the increase in the average posttest score and the even N-gain value without the presence of a low category, indicating the effectiveness of this model in facilitating thorough mastery of the concept.

Through its implementation in class V science learning in Philippine Schools Overseas (PSO), which involved 19 students as research subjects, the Mastery Learning approach through the Schneeball-Wirbelgruppe collaborative model showed a consistent pattern of improvement. Classroom observation data and recordings of learning activities show that most students become more independent, actively discuss, and are able to reconstruct their understanding of scientific concepts such as changes in the shape of objects, the respiratory system, and the properties of light. This improvement is not only identified through the results of written tests, but also through students' ability to discuss, present, and relate concepts to everyday life phenomena (Benita et al., 2022).

This model supports the development of scientific thinking skills, which include the ability to analyze, ask questions, and answer based on scientific principles that have been learned. Literature support also corroborates these findings; for example, Hu & Bi (2025) emphasized that the Schneeball model encourages active participation and builds a conducive learning atmosphere. Similarly, D. Liu (2022) emphasize the effectiveness of Schneeball when combined with appropriate media or teaching techniques. The integration of Wirbelgruppe group techniques enriches the dynamics of discussions and improves students' communication skills.

Furthermore, research by Sun et al. (2022) shows that group discussions in this approach are able to improve speaking skills and mastery of concepts through formulation and answers to teaching material-based questions. This is reinforced by the results of Guay et al. (2024) research which emphasizes the achievement of higher concept mastery in students who follow this learning model.

The final stage in the learning process that prioritizes concept-based question and answer activities proves that students not only understand the material, but are also able to construct and express their knowledge. Although challenges in learning science in class V are often related to disparities in early abilities between students, research shows that the Schneeball-Wirbelgruppe approach is effective in bridging these gaps. Students who were initially passive or lacking confidence showed significant improvements in academic participation and performance after participating in this gradual collaboration-based learning. Findings from teachers at PSO support this claim, where students who previously had difficulty answering questions or compiling practicum reports began to show positive progress. In summary, this approach can be categorized as an adaptive and transformative learning model, especially in the context of strengthening mastery of scientific communication concepts and skills at the basic education level. These findings make an important contribution to the development of science learning models that emphasize concept mastery and active student engagement, and open up space for further exploration of the effectiveness of collaborative approaches in mastery learning at the elementary level (Klaveren et al., 2017).

CONCLUSIONS

Learning that integrates the Schneeball model with the Wirbelgruppe approach has been proven to be able to significantly improve students' understanding of science concepts, both through quantitative indicators in the form of test results and qualitative indicators observed in the dynamics of classroom activities. The Mastery Learning-based learning model that adopts the Schneeball-Wirbelgruppe collaborative framework has shown high effectiveness in strengthening mastery of science concepts at the elementary school level, especially in the context of Philippine Schools Overseas (PSO). The application of this model not only has an impact on improving students' academic achievement, but also forms a collaborative, fun, and meaningful learning experience that is essential in science education at the elementary level. Methodologically, these results were obtained through a quasi-experimental design approach with a combination of pretest-posttest measurements and participatory observation techniques in the classroom. The data collected showed a consistent increase in conceptual comprehension scores in almost all participants, which was reinforced by observational findings regarding increased student participation, learning independence, and the ability to convey and present science concepts more fully. This indicates that the Schneeball-Wirbelgruppe functionally supports the achievement of mastery through a collaborative and progressive learning process. However, this study has important limitations to pay attention to in the process of interpreting the results and generalizing the findings. The relatively small number of participants as many as 19 students limits the representativeness of the sample to the general elementary school student population in the PSO. The implication of these limitations is that the results obtained cannot be generalized widely in the absence of study replication with greater sample coverage and higher diversity of participant backgrounds. Therefore, further research is urgently needed to re-examine the external validity of these findings, while also exploring the potential application of the model in various other educational contexts.

REFERENCES

Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production*, *437*(2), 849–865. https://doi.org/10.1016/j.jclepro.2023.140527

AlMalki, H. A., & Durugbo, C. M. (2023). Evaluating critical institutional factors of Industry 4.0 for education reform. *Technological Forecasting and Social Change*, *188*(1), 521–552. https://doi.org/10.1016/j.techfore.2023.122327

Alpizar, D., Vo, T., French, B. F., & Hand, B. (2022). Growth of critical thinking skills in middle school immersive science learning environments. *Thinking Skills and Creativity*, *46*(1), 329–345. https://doi.org/10.1016/j.tsc.2022.101192

Amani, J., & Mkimbili, S. T. (2025). Developing critical thinking skills among secondary schools students: The role of research project. *Thinking Skills and Creativity*, *58*(1), 315–326. https://doi.org/10.1016/j.tsc.2025.101883

Anna, G., & Spyros, V. (2025). Group dynamics in collaborative learning: Impact of emergent and scripted roles in tangible mobile augmented reality games. *Computers & Education: X Reality*, *7*(2), 666–687. https://doi.org/10.1016/j.cexr.2025.100102

Annetta, L. A., Newton, M. H., Franco, Y., Johnson, A., & Bressler, D. (2024). Examining reading proficiency and science learning using mixed reality in elementary school science. *Computers & Education: X Reality*, *5*(1), 35–55. https://doi.org/10.1016/j.cexr.2024.100086

Aubert, A., Molina, S., Schubert, T., & Vidu, A. (2017). Learning and inclusivity via Interactive Groups in early childhood education and care in the Hope school, Spain. *Learning, Culture and Social Interaction*, *13*(4), 1057–1073. https://doi.org/10.1016/j.lcsi.2017.03.002

Benita, M., Matos, L., & Cerna, Y. (2022). The effect of mastery goal-complexes on mathematics grades and engagement: The case of Low-SES Peruvian students. *Learning and Instruction*, *80*(2), 437–449. https://doi.org/10.1016/j.learninstruc.2021.101558

Bohari, A., Wider, W., Jiang, L., Tanucan, J. C. M., Lim, S. P., & Hossain, S. F. A. (2025). Exploring the key factors influencing the adoption of Education 4.0 in the Malaysian institute of teacher education (IPGM). *Asian Education and Development Studies*, *14*(3), 436–456. https://doi.org/10.1108/AEDS-10-2024-0223

Cananau, I., Edling, S., & Haglund, B. (2025). Critical thinking in preparation for student teachers' professional practice: A case study of critical thinking conceptions in policy documents framing teaching placement at a Swedish university. *Teaching and Teacher Education*, *153*(2), 847–966. https://doi.org/10.1016/j.tate.2024.104816

Casler, K. (2022). Escape passive learning: 10 steps to building an escape room. *The Journal for Nurse Practitioners*, *18*(5), 569–574. https://doi.org/10.1016/j.nurpra.2022.01.020

Celio, C. I., Durlak, J., & Dymnicki, A. (2011). A Meta-analysis of the impact of service-learning on students. *Sage Journals*, *34*(2), 164–181.

https://doi.org/10.1177/105382591103400205

Chen, L., Lin, J., Wang, Z., & Wu, G. (2025). The impact of student's ordinal cognitive ability rank on school violence: Evidence from China. *Economic Modelling*, *143*(1), 42–66. https://doi.org/10.1016/j.econmod.2024.106967

Cheng, H., Wu, G., Gao, L., Zhu, J., & Liu, D. (2014). Research on status and characteristics of the mastery of students' mathematical learning strategies in chinese junior high schools. *Procedia - Social and Behavioral Sciences*, 3218–3225. https://doi.org/10.1016/j.sbspro.2014.01.738

Cheng, K.-H., & Tsai, C.-C. (2019). A case study of immersive virtual field trips in an elementary classroom: Students' learning experience and teacher-student interaction behaviors. *Computers & Education*, *140*(1), 428–448. https://doi.org/10.1016/j.compedu.2019.103600

Crijnen, A. A. M., Feehan, M., & Kellam, S. G. (2021). The course and malleability of reading achievement in elementary school: The application of growth curve modeling in the evaluation of a mastery learning intervention. *Learning and Individual Differences*, *10*(2), 137–157. https://doi.org/10.1016/S1041-6080(99)80138-1

Falloon, G. (2024). Investigating pedagogical, technological and school factors underpinning effective 'critical thinking curricula' in K-6 education. *Thinking Skills and Creativity*, *51*(1), 157–173. https://doi.org/10.1016/j.tsc.2023.101447

Gal, C., & Ryder, C. H. (2025). Unlocking potential: comparing collaborative and traditional learning methods for students with learning disabilities in special education classrooms. *Social Sciences & Humanities Open*, *11*(3), 579–594. https://doi.org/10.1016/j.ssaho.2025.101521

Gray, D. L., Chang, Y., & Anderman, E. M. (2015). Conditional effects of mastery goal structure on changes in students' motivational beliefs: Need for cognition matters. *Learning and Individual Differences*, *40*(1), 9–21. https://doi.org/10.1016/j.lindif.2015.03.025

Guay, F., Racine, P., & Bradet, R. (2024). Parents' implicit intelligence beliefs about children's intelligence: Implications for children's academic self-concept and achievement in Maths, English, and French. *Learning and Individual Differences*, *116*(2), 104–123. https://doi.org/10.1016/j.lindif.2024.102576

Guo, X., Jiang, J., Fu, S., Feng, M., Sun, S., & Bai, X. (2025). The relationship between mastery-approach goals and perseverance in senior high school students: The chain mediating role of self-esteem and positive rumination. *Personality and Individual Differences*, *246*(1), 79–98. https://doi.org/10.1016/j.paid.2025.113307

Gyimah, G. (2022). Effectiveness of group investigation versus lecture-based instruction on students' concept mastery and transfer in social studies. *The Journal of Social Studies Research*, *8*(3), 646–655. https://doi.org/10.1016/j.jssr.2022.05.001

Herlinawati, H., Marwa, M., Ismail, N., Junaidi, Liza, L. O., & Situmorang, D. D. B. (2024). The integration of 21st century skills in the curriculum of education. *Heliyon*, *10*(15), 453768–453788. https://doi.org/10.1016/j.heliyon.2024.e35148

Hsu, F.-H., Lin, I.-H., Yeh, H.-C., & Chen, N.-S. (2022). Effect of socratic reflection prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*(2), 307–328. https://doi.org/10.1016/j.compedu.2022.104497

Hu, X., & Bi, H. (2025). Exploring and validating the componential model of students' scientific critical thinking in science education. *Thinking Skills and Creativity*, *55*(1), 45–65. https://doi.org/10.1016/j.tsc.2024.101695

Hyrkkö, S., & Kajamaa, A. (2025). Teachers' transformative agency in a Change Laboratory in a Finnish elementary school. *Teaching and Teacher Education*, *159*(2), 324–344. https://doi.org/10.1016/j.tate.2025.105011

Jain, A., Naik, K. R., Kakade, K., Bhanot, S., & Kulkarni, S. C. (2025). Reimagining management education: Navigating the shift to education 4.0 in the digital era. *The International Journal of Management Education*, *23*(2), 627–636. https://doi.org/10.1016/j.ijme.2025.101182

Kim, L., Imjai, N., Kaewjomnong, A., Dowpiset, K., & Aujirapongpan, S. (2025). Does experiential learning matter to strategic intuition skills of MBA students? Implications of diagnostic capabilities and critical thinking skills. *The International Journal of Management Education*, *23*(2), 1276–1299. https://doi.org/10.1016/j.ijme.2025.101138

Klaveren, C. van, Vonk, S., & Cornelisz, I. (2017). The effect of adaptive versus static practicing on student learning - evidence from a randomized field experiment. *Economics of Education Review*, *58*(1), 175–187. https://doi.org/10.1016/j.econedurev.2017.04.003

Lee, C., & Lim, C. (2021). From technological development to social advance: A review of Industry 4.0 through machine learning. *Technological Forecasting and Social Change*, *167*(1), 527–549. https://doi.org/10.1016/j.techfore.2021.120653

Lee, M., Lee, S. Y., Kim, J. E., & Lee, H. J. (2023). Domain-specific self-regulated learning interventions for elementary school students. *Learning and Instruction Journal*, *88*(12), 1–18. https://doi.org/10.1016/j.learninstruc.2023.101810

Liu, D. (2022). Exploring innovation with scientific thinking. *Chinese Medical Sciences Journal*, *37*(2), 77–90. https://doi.org/https://doi.org/10.24920/004123

Liu, M. (2025). Information literacy formation through the use of library resources: Thinking, selection, and information processing skills of students. *Thinking Skills and Creativity*, *57*(1), 278–296. https://doi.org/10.1016/j.tsc.2025.101789

Lv, X., Zhou, J., & Ren, X. (2025). The bidirectional relationship between critical thinking and academic achievement is independent of general cognitive ability: A three-year longitudinal study on elementary school children. *Learning and Individual Differences*, *120*(1), 204–225. https://doi.org/10.1016/j.lindif.2025.102666

Maxwell, G. S. (2023). Assessment and accountability global trends and future directions in 21st century competencies. In *International Encyclopedia of Education (Fourth Edition)* (pp. 313–323). https://doi.org/10.1016/B978-0-12-818630-5.09069-2

McCorkle, C. M. (1995). Back to the future: Lessons from ethnoveterinary RD&E for studying and applying local knowledge. *Agriculture and Human Values*, *12*(2), 52–80. https://doi.org/10.1007/BF02217297

Miesner, H. R., Blair, E. E., Packard, C. C., Velazquez, M., Macgregor, L., & Grodsky, E. (2022). Collaborating in context: Relational trust and collaborative formats at eight elementary schools. *Teaching and Teacher Education*, *115*(3), 869–889. https://doi.org/10.1016/j.tate.2022.103729

Nikkola, T., Kangas, J., & Reunamo, J. (2024). Children's creative participation as a precursor of 21st century skills in Finnish early childhood education and care context. *Learning and Individual Differences*, *111*(4), 47–63. https://doi.org/10.1016/j.lindif.2024.102437

Oke, A., & Fernandes, F. A. P. (2020). Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th Industrial Revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(2), 488–501.

https://doi.org/10.3390/joitmc6020031

Osiesi, M. P., & Blignaut, S. (2025). Impact of the teacher education curriculum on the development of 21st-Century skills: Pre-service teachers' perceptions. *Social Sciences & Humanities Open*, *11*(1), 423–441. https://doi.org/10.1016/j.ssaho.2025.101317

Pineida, F. O. (2011). Competencies for the 21st century: Integrating ict to life, school and economical development. *Procedia - Social and Behavioral Sciences*, 54–57. https://doi.org/10.1016/j.sbspro.2011.11.011

Seibert, S. A. (2021). Problem-based learning: A strategy to foster generation Z's critical thinking and perseverance. *Teaching and Learning in Nursing*, *16*(1), 85–88. https://doi.org/10.1016/j.teln.2020.09.002

Smeding, A., Dompnier, B., Meier, E., Darnon, C., Baumberger, B., & Butera, F. (2015). The motivation to learn as a self-presentation tool among Swiss high school students: The moderating role of mastery goals' perceived social value on learning. *Learning and Individual Differences*, *43*(2), 467–482. https://doi.org/10.1016/j.lindif.2015.08.036

Souza, A. S. C. de, & Debs, L. (2024). Concepts, innovative technologies, learning approaches and trend topics in education 4.0: A scoping literature review. *Social Sciences & Humanities Open*, *9*(1), 647–661. https://doi.org/10.1016/j.ssaho.2024.100902

Sun, H., Xie, Y., & Lavonen, J. (2022). Exploring the structure of students' scientific higher order thinking in science education. *Thinking Skills and Creativity*, *43*(2), 106–121. https://doi.org/10.1016/j.tsc.2022.100999

Teo, T., Unwin, S., Scherer, R., & Gardiner, V. (2021). Initial teacher training for twenty-first century skills in the Fourth Industrial Revolution (IR 4.0): A scoping review. *Computers & Education*, *170*(1), 316–329. https://doi.org/10.1016/j.compedu.2021.104223

Tíjaro-Rojas, R., Arce-Trigatti, A., Cupp, J., Pascal, J., & Arce, P. E. (2016). A systematic and integrative sequence approach (sisa) for mastery learning: anchoring bloom's revised taxonomy to student learning. *Education for Chemical Engineers*, *17*(1), 31–43. https://doi.org/10.1016/j.ece.2016.06.001

Umar, I. N., & Rathakrishnan, M. (2012). The effects of online teachers' social role and learning style on students' essay writing performance and critical thinking in a wiki environment. *Procedia - Social and Behavioral Sciences*, 5730–5735. https://doi.org/10.1016/j.sbspro.2012.06.506

Vuk, S. (2023). Development of creativity in elementary school. *Journal of Creativity*, *33*(2), 10055–10064. https://doi.org/10.1016/j.yjoc.2023.100055

Weil, D., & Mayfield, M. (2020). Tomorrow's critical design competencies: Building a course system for 21st century designers. *She Ji: The Journal of Design, Economics, and Innovation*, *6*(2), 157–169. https://doi.org/10.1016/j.sheji.2020.03.001

Williams, K. E., Burr, T., L'Estrange, L., & Walsh, K. (2025). Early childhood educators' use of neuroscience: Knowledge, attitudes, self-efficacy and professional learning. *Trends in Neuroscience and Education*, *38*(2), 537–556. https://doi.org/10.1016/j.tine.2025.100247

Winget, M., & Persky, A. M. (2022). A practical review of mastery learning. *American Journal of Pharmaceutical Education*, *86*(10), 6275–6290. https://doi.org/10.5688/ajpe8906

Yeh, Y., Chang, H.-L., & Chen, S.-Y. (2019). Mindful learning: A mediator of mastery experience during digital creativity game-based learning among elementary school students. *Computers & Education*, *132*(2), 937–952. https://doi.org/10.1016/j.compedu.2019.01.001