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Research Article

Students' future thinking skills: Implications for school education programs

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Future-thinking skills are crucial competencies to prepare students to face global challenges through sustainable education. However, until now there is no comprehensive profile of this skill in the context of secondary school students. This research aims to map students' future thinking skills, starting from the development and validation of multidimensional-based instruments. The five main dimensions that are the focus of the analysis include visioning and emotion, predicting, planning, anticipating, and evaluating. The instrument was developed through the stages of readability test, small-scale trial, and wide-scale validation. Rasch analysis is used to evaluate the quality of items in an instrument, while Partial Least Squares Structural Equation Modelling is applied to analyze causal relationships between dimensions. The results of the study revealed significant differences in the profile of future thinking skills based on demographic groups, such as education level and gender. In addition, the visioning and emotion dimensions were found to be key dimensions that significantly influenced other dimensions, demonstrating the importance of emotional aspects and vision in building future thinking skills. This research not only provides a map of students' future thinking skills, but also offers a robust evaluation framework based on valid and reliable instruments. The findings provide valuable insights for designing and implementing school education programs that enhance students' future-thinking competencies.

Keywords: Evaluation framework; Future thinking skills; Sustainable education; School education programs

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1. Introduction

Future thinking has become an important topic in various disciplines, especially in the development of holistic skills that support sustainability education (Julien et al., 2018; Laherto & Rasa, 2022). Future-thinking competencies are recognized as a crucial element to prepare individuals for ever-changing global challenges (Alqahtani & Elsayed, 2023; Durance, 2010). However, the measurement of these competencies still faces challenges, such as the complexity of integrating analytical abilities and the emotional aspects of prospective thinking (Cole & Kvavilashvili, 2021; Szpunar et al., 2014).

Although the urgency of future thinking skills has been widely recognized, research on the measurement of these skills among high school students is still limited (Afikah et al., 2022; Nagai,

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2019). Most research only focuses on critical thinking skills or problem-solving in general, without touching on specific dimensions such as vision, prediction, planning, anticipation, and evaluation (Afikah et al., 2022; González-Pérez & Ramírez-Montoya, 2022). In addition, diverse educational contexts in terms of culture and socio-economic conditions add to the challenges in the development and evaluation of these skills (France & Krieviņa, 2022; Manggopa & Batmetan, 2024). A comprehensive future thinking skills profile is urgently needed to design effective and inclusive educational strategies, so as to increase students' readiness to face global challenges and a sustainable future (Alharbi, 2022; Amin et al., 2024).

The integration of future thinking dimensions into school education programs provides significant benefits. Embedding visioning skills encourages students to set goals aligned with sustainable development. Prediction exercises, such as trend analysis and forecasting, develop strategic foresight in decision-making (González-Pérez & Ramírez-Montoya, 2022). Planning activities in project-based learning enhance organizational and collaborative skills essential for long-term success (Laherto & Rasa, 2022). Anticipation and evaluation through reflective tasks help students assess decision impacts and refine actions based on feedback (Durance, 2010). These dimensions collectively offer a structured framework to prepare students for complex, uncertain futures.

To answer this challenge, this study uses a hybrid approach with the Rasch Model and Partial Least Squares Structural Equation Modeling [PLS-SEM] in developing and validating multidimensional instruments to measure future thinking skills. This approach allows for the assessment of the quality of instrument items and the analysis of causal relationships between dimensions, such as vision and emotions, prediction, planning, anticipation, and evaluation (Boone et al., 2014; Hairida et al., 2023). With this robust methodology, the research is expected to generate reliable data on students' future thinking skills profiles as well as provide insights for more effective educational interventions (Julien et al., 2018; Laherto & Rasa, 2022).

This research aims to map the future thinking skills of high school students through the development of valid and reliable multidimensional instruments. In addition, this study also seeks to identify the influence of demographic factors, such as education level and gender, on future thinking skills. The novelty of this study lies in the emphasis on the dimensions of vision and emotion as the main drivers that influence other dimensions of future thinking skills. By providing a framework for developing these skills, schools can align their educational programs with the demands of a sustainable future. Incorporating these dimensions into existing curricula, such as science or social studies, will ensure that students are not only equipped with theoretical knowledge but also practical competencies to address global challenges (Drake & Reid, 2020; Franco et al., 2019; Nguyen et al., 2020).The results of this study provide practical implications for educational programs in schools, especially in designing a curriculum that is integrated with the development of future thinking skills. Thus, students can be better prepared to face a sustainable and challenging future.

2. Literature Review

2.1. Future Thinking Skills

Future-thinking skills are essential abilities that lead students to understand, plan, and prepare for the complex challenges of the future. These competencies involve aspects such as scenario thinking, systemic thinking, and understanding uncertainty and risk, which are essential for managing social, technological, and environmental change. Students are invited to develop evidence-based solutions through the exploration of trends and consequences of their actions towards sustainability (Lloyd & Haraldsdottir, 2021). Education that integrates these skills allows students to understand the impact of science and technology on future society, as well as design mitigation and adaptation measures to potential global issues (Levrini et al., 2021; Rickards et al., 2014).

The competency dimension of thinking about the future is getting more attention in the context of continuing education. Laherto and Rasa (2022) emphasized the importance of integrating future perspectives in science learning as part of the transformation of global education. Approaches such as systemic thinking, scenario development, and backcasting methods allow students to expand their perception of future possibilities, deal with uncertainty, and create a vision of a sustainable future.

The dimensions of future thinking competence formulated by UNESCO include the evaluation of possibilities, the formation of a vision for the future, the application of the prudential principle, the assessment of the consequences of actions, and the ability to deal with risks and changes (UNESCO, 2017). This ability can be improved by cultivating emotions such as hopes and worries, an appreciation perspective for nature, and a forecasting and backcasting-based mindset (DeHaan, 2009; Gardiner & Rieckmann, 2015). A study by Szpunar et al. (2014) stated that prospective thinking skills involve episodic simulations, predictions, intentions, and planning. These four elements serve to assist individuals in the adaptive decision-making process, both in daily life and in long-term planning (Szpunar et al., 2014). The competency dimension of future thinking also includes interrelated cognitive and emotional components. Suddendorf and Corballis (2009) showed that the future thinking process involves episodic simulations that help individuals imagine future scenarios based on past experiences (Corballis, 2009). This is in line with the episodic construction hypothesis that emphasizes the importance of memory in constructing realistic future scenarios (Loose & Vásquez-Echeverría, 2022; Schacter & Addis, 2007).

Dual-process model of future thinking that distinguishes between spontaneous thinking and constructive thinking (Cole & Kvavilashvili, 2021). Spontaneous thinking often arises without intention or reflexively in response to environmental stimuli, while constructive thinking involves a deliberate and more structured process. The combination of these two approaches allows for cognitive flexibility that is essential for adaptation in complex situations. Furthermore, research by (Ward, 2016) highlights the validity of "episodic future thinking" [EFT] as the ability to mentally simulate the future. EFT, which involves simulating specific future events, was found to be essential for adaptive function and decision-making. This is especially relevant in the context of education, where students are trained to anticipate future challenges based on real scenarios and imaginative simulations.

The dimension of future thinking has a diverse pattern or arrangement. It is asserted that the dimensions of future thinking start from looking at the future vision, identifying the trend of change and uncertainty, anticipating the risks and consequences of decisions and actions, understanding emotions (for example, hopes, worries, or anger) related to anthropocene threats, and imagining solutions or ways of action (Barelli et al., 2022; Hervé & Panissal, 2022). Although in line, (UNESCO, 2017) starts the dimension or indicator of future thinking by evaluating various possibilities, determining a vision for the future, applying the principle of prudence, assessing the consequences of an action, and facing risks and changes. Different opinions explain that thinking about the future starts from the cultivation of emotions such as hopes and worries, the emergence of a perspective that views nature as something worthy of appreciation, the formation of a mindset based on the concept of forecasting, looking back to realize pre-set goals (backcasting) (de Haan, 2006; Gardiner & Rieckmann, 2015; Ojala, 2015). From all the dimensions that have been presented, it can be synthesized that there are five main dimensions in thinking about the future, namely visioning and emotion, predicting, planning, anticipating, and evaluating.

With the right approach, teachers can help students connect different alternative solutions to build a vision of a sustainable future, so that they can address global challenges through responsible and anticipatory action. The integration between futures thinking and science learning, as shown by (Laherto & Rasa, 2022), opens up opportunities to drive transformative learning that allows students to become agents of change in their communities.

2.2. School Education Programs

The development of future-thinking skills in secondary school requires the implementation of a variety of innovative and effective learning strategies. Strategies such as future episodic thinking, the use of information and communication technology [ICT], and positive future thinking have been proven to improve students' ability to imagine, plan, and prepare for the future (Elazzab, 2022; Nagai, 2019). Teachers play a key role in implementing these strategies through methods such as problem-based learning [PBL], small group discussions, virtual simulations, and the use of design thinking techniques in the curriculum (Aflatoony et al., 2018; Bangun & Pragholapati, 2021). With this approach, students are not only trained to think critically and creatively, but also to develop metacognitive awareness that helps them design innovative solutions to future problems (Amin et al., 2024).

However, there are several obstacles that need to be overcome, such as limited technological resources, lack of understanding of teachers, and cultural and social challenges (France & Krieviņa, 2022; Manggopa & Batmetan, 2024). To overcome these obstacles, the integration of future thinking skills in the curriculum needs to be supported by an interdisciplinary approach and adequate teacher training (Van den Beemt et al., 2020; Vidergor, 2023). In addition, schools need to create a learning environment that supports the exploration of future ideas, including providing adequate access to technology and building a culture of reflection and collaboration. Thus, a holisticly designed educational program will help students become adaptive, innovative, and ready individuals to face dynamic global challenges (Branchetti et al., 2018; Julien et al., 2018).

To successfully implement future-thinking skills in school programs, a scaffolded curriculum is essential, particularly in science education. This curriculum should follow the stages of vision and emotion, prediction, planning, anticipation, and evaluation, ensuring a structured progression in skill development. For instance, students can begin by envisioning sustainable futures and exploring the emotional connections, such as hope or concern, tied to global challenges (Laherto & Rasa, 2022; Rickards et al., 2014). They can then engage in activities like scenario analysis and environmental forecasting, which develop their ability to predict potential outcomes and assess associated risks. By integrating these stages, science education can provide a clear framework for addressing sustainability challenges while fostering critical future-thinking competencies.

Teachers play a key role in facilitating this process by employing reflective practices and collaborative activities that promote diverse perspectives and problem-solving skills (Vidergor, 2023). Experiential learning, such as field studies and community engagement projects, further enhances students' ability to anticipate risks and plan adaptive solutions in real-world contexts. Additionally, integrating evaluation processes allows students to reflect on the effectiveness of their strategies and make informed decisions for future improvements (Gardiner & Rieckmann, 2015; González-Pérez & Ramírez-Montoya, 2022). This structured approach not only equips students to address complex global challenges but also transforms science classrooms into dynamic spaces for building sustainable futures. Recent studies highlight the importance of aligning these practices with global educational trends to ensure relevance and effectiveness (UNESCO, 2017).

The following research question was formulated to explore and analyze the future thinking skills of students, which involves the development of instruments based on five main dimensions: Visioning and Emotion, Predicting, Planning, Anticipating, and Evaluating, as well as considering the validity of the instrument and demographic factors:

RQ 1) What is the profile of students' future thinking skills based on five main dimensions: Visioning and Emotion, Predicting, Planning, Anticipating, and Evaluating?

RQ 2) Are there differences in students' future thinking skills based on gender and school level?

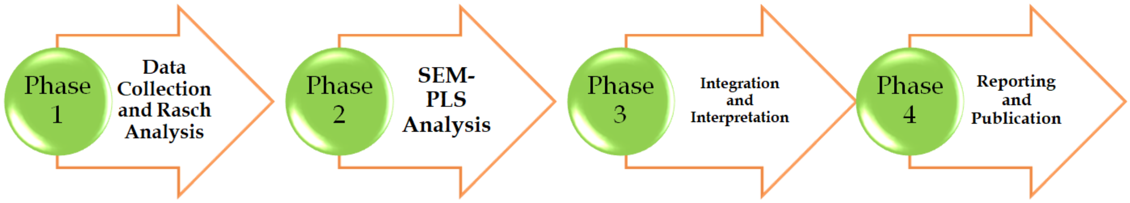
RQ 3) What is the relationship between dimensions and sub-dimensions of students' future thinking skills?

3. Methodology

3.1. Research Design

This study uses a quantitative approach with an explanatory sequential design, which integrates the Rasch Model and Partial Least Squares Structural Equation Modelling to analyze students' future thinking skills. This approach is designed to evaluate the validity and reliability of instruments, as well as explore the structural relationships between dimensions of future thinking skills. It can be clearly seen in Figure 1.

Figure 1
Explanatory Sequential Design



This study employs an explanatory sequential design to analyze students' future thinking skills, beginning with the collection of quantitative data through essay questions covering five key dimensions: visioning and emotion, predicting, planning, anticipating, and evaluating. Using a stratified random sampling method, data were gathered to ensure representation based on gender and education level (junior high and high school).

3.2. Participants

Participants were selected using the stratified random sampling method to ensure the diversity of the sample based on gender and level of education. Of the total number of students, 445 students are female (70.08%) and 190 students are male (29.92%). The selection of participants was carried out to identify students' future thinking skills in different contexts based on demographic characteristics (see Table 1).

Table 1
Demographic profile of high school students in this study

Demographics	*Frequency*	*Percentage (%)*
Gender		
Female	445	70.08
Male	190	29.92
School level		
Junior high school	415	65.35
Senior high school	220	34.65

3.3. Data Collection

The data collection process in this study followed a systematic approach to ensure the accuracy and reliability of the findings. Using an explanatory sequential design, data was gathered in stages, beginning with a pilot study to refine the instrument and assess readability. The full-scale implementation involved 635 students selected through stratified random sampling from junior and senior high schools. Data was collected through an essay-based assessment measuring five dimensions of future thinking skills: visioning and emotion, predicting, planning, anticipating, and evaluating. Students responded to open-ended questions designed to assess their ability to anticipate challenges, propose solutions, and reflect on consequences.

The instrument used in this study is a future thinking skill essay developed based on five main dimensions: visioning and emotion [VE], predicting [PR], planning [PL], anticipating [A], and evaluating [E]. Each dimension consists of several sub-dimensions with specific statements, such as envisioning a future vision [VE1], collecting data to predict future trends [PR1], planning preventive actions [PL1], anticipating the worst risks [A2], and evaluating the negative impact of actions [E1] (see Table 2). The instrument is validated using the Rasch Model to ensure the reliability, validity, and accuracy of the measurements. Validation analysis includes evaluation of item fit, instrument reliability, and Differential Item Functioning [DIF] analysis based on gender and education level to detect bias.

Table 2
Dimensions and Sub-dimensions of Future-Thinking Skills

Dimensions and sub-dimension	*Future Thinking Sub Dimensions*	*Future-Thinking Dimensions*
Visioning and emotion		
VE1	Envisioning or creating a vision into the future	Visioning and Emotion Defining a long-term vision through hopes and worries about the future
VE2	Wishes that are expected to happen in the future	
VE3	Describe emotions or feelings related to a future envisioned condition	
VE4	Expressing hopes and concerns about the future	
Predicting		
PR1	Collecting data and information to describe trends or trends of future change	Predicting Using data and information to predict future trends of change and uncertainty
PR2	Ensuring the validity and reliability of the data collected	
Planning		
PL1	Demonstrate concrete action steps in the form of preventive, mitigation, and climate change adaptation activities in the future	Planning Planning problem-solving in the form of preventive, mitigation, adaptation, and take-off measures. Precise decisions on future issues
PL2	Involve many communities in realizing the action plan	
Anticipating		
A1	Identify clear risks with detailed anticipatory steps related to future climate change action plans	Anticipating Anticipate risks, apply the principle of prudence, and take into account various possibilities that will occur
A2	Identify the worst-case scenario of the action plan undertaken and the steps to prepare for it	
Evaluating		
E1	Identify the negative impact of the action plan and the solutions chosen to address it	Evaluating Assess the consequences of an action
E2	Efforts to provide long-term benefits	

To ensure the validity and reliability of the instruments used in this study, an analysis was carried out using the Rasch model. This analysis aims to evaluate the performance of items in measuring students' future thinking skills based on five main dimensions, namely *Visioning and Emotion, Predicting, Planning, Anticipating,* and *Evaluating.* Each dimension is analyzed separately to identify the extent to which the item conforms to the Rasch model, as well as to evaluate the reliability and separation of the item and respondent.

Table 3 presents the results of Rasch's analysis, including the number of items, the average student score, *the mean square error [MNSQ]* value for *infit* and *outfit*, the reliability of the items, *Cronbach's alpha*, and the percentage of variance explained by the model. These results are the basis for ensuring that the instruments used in this study are of good quality and reliable to analyze students' future thinking skills thoroughly.

Table 3
Summary of Rasch Parameters for Future Thinking Skills Essay Questions

Psychometrics Attribute	*Subscale*					*Future Thinking Skills*
	VE	*PR*	*PL*	*A*	*E*	
Number of Items	4	2	2	2	2	12
Mean	10.9	4.8	5.1	4.9	5.2	30.9
item outfit MNSQ	0.99	0.98	0.95	0.98	0.96	1.01
item infit MNSQ	0.99	1.01	0.99	0.98	0.96	0.99
Person outfit MNSQ	0.99	0.98	0.95	0.97	0.96	1.01
Person infit MNSQ	0.99	0.97	0.95	0.97	0.96	1.00
Item separation	7.50	8.58	8.25	10.07	4.80	6.69
Person separation	1.79	1.36	1.43	1.66	1.35	2.65
Item Reliability	0.98	0.99	0.95	0.99	0.96	0.98
Cronbach's Alpha	0.79	0.68	0.65	0.74	0.58	0.90
Unidimensionality						
Raw variance explained by measure	55.8%					
Unexplained variance 1st contrast	16.9%					

The study results indicated that all subscales' infit and outfit mean square error values fell within the expected range (0.95–1.01), confirming consistency with the Rasch model. Item reliability and separation metrics showed excellent performance, with the Anticipating subscale achieving the highest item separation (10.07), reflecting the instrument's precision in distinguishing students' abilities. Most subscales demonstrated high reliability (above 0.90), except Planning, which requires further evaluation. The hybrid approach combining Rasch analysis and Partial Least Squares Structural Equation Modelling validated the instrument's reliability and explained 55.8% of the variance, confirming its strength in assessing future thinking skills across dimensions.

Figure 2 presents the Wright Map which depicts the distribution of students' abilities and the difficulty level of items on the instrument of measuring future thinking skills based on Rasch's analysis. The Wright Map (see Figure 2) illustrates the distribution of students' abilities and the difficulty levels of items in the future thinking skills instrument. The "#" symbol represents students' ability distribution, while items like VE1, PR6, and others indicate varying difficulty levels. VE1 aligns with the average student ability, reflecting an appropriate difficulty level, while A10, positioned at a higher logit, signifies greater difficulty. In contrast, VE4, located at a negative logit, reflects a lower difficulty level. These results validate the instrument's reliability in distinguishing abilities across five dimensions: visioning and emotion, predicting, planning, anticipating, and evaluating.

The results of Rasch analysis indicate that the instrument is valid, as shown by infit and outfit MNSQ values within the acceptable range (0.95–1.01) and high item separation, particularly in the Anticipating subscale, which demonstrates the instrument's precision. This supports the effectiveness of the Rasch model in ensuring unidimensionality and sensitivity to data variability (Şimal & Gursoy, 2020). Furthermore, these findings align with studies emphasizing the need for reliable tools to evaluate cognitive and emotional abilities to promote sustainable decision-making

(Bell & Hernandez, 2017; Cole & Kvavilashvili, 2021). By ensuring validity and reliability, this research contributes to improving the accuracy of assessing students' future thinking skills and supports sustainability-focused education.

Figure 2

Item-person maps

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Note. (#),3 participants, (.) 1–2 participants.

3.4. Data Analysis

This study employed a hybrid approach combining the Rasch Model, analyzed using WINSTEP 5.7.1 software, and Partial Least Squares Structural Equation Modelling, analyzed using SMART-PLS 4 software. This integrated approach ensured comprehensive instrument validation and explored the structural relationships between dimensions of students' future thinking skills. The first stage utilized the Rasch Model to validate essay questions by evaluating item and respondent suitability through Infit and Outfit Mean Square statistics. Reliability was assessed using item and respondent separation indices, and Differential Item Functioning was analyzed to detect potential biases related to demographic factors such as gender and education level. The instrument's unidimensionality was confirmed by ensuring the total variance explained exceeded 50%, affirming that each item measured a singular latent construct.

In the second stage, PLS-SEM was applied to evaluate structural relationships between constructs, including visioning and emotion, predicting, planning, anticipating, and evaluating. Validation of the measurement model included assessing reliability, convergent validity, and discriminant validity of the constructs. Structural model evaluation involved calculating path coefficients to measure the strength of relationships and R^2 values to determine the explanatory power of exogenous variables. Statistical significance of these relationships was tested using the bootstrapping procedure. The integration of these methods provided robust results, enhancing instrument validity and clarifying the complex interrelations among future thinking skill dimensions.

4. Results

4.1. Profile of Students' Future Thinking Skills in Five Main Dimensions

Rasch analysis shows that each dimension of future thinking skills has a varying level of item difficulty, with logical values reflecting students' ability to overcome various challenges related to each dimension. Table 4 summarizes student performance based on five main dimensions: Visioning and Emotion, Predicting, Planning, Anticipating, and Evaluating.

Table 4
Item measure and fit criteria

Item Number	*Measure (logit)*	*Outfit MNSQ*	*PTMA*
VE1	0.12	1.09	0.63
VE2	−0.55	0.79	0.69
VE3	−0.04	1.08	0.64
VE4	−0.75	0.86	0.69
PR1	0.00	1.30	0.65
PR2	074	1.18	0.69
PL1	0.04	0.85	0.70
PL2	0.05	0.76	0.71
A1	−0.07	0.86	0.72
A2	0.65	0.93	0.71
E1	0.11	1.60	0.58
E2	−0.31	0.79	0.67

Table 4 illustrates the results of the analysis of item measurements and fit criteria from the instruments used to measure students' future thinking skills. The results show that the logit value provides an idea of the item's difficulty level, where a positive value indicates a higher difficulty level, such as in item VE1 (0.12), compared to item VE4 which has a logit of −0.75. Most items exhibit *MNSQ Outfit* values that are within the appropriate range (0.76–1.60), indicating a good fit with the Rasch model, although item E1 (1.60) has a higher MNSQ value, indicating potential deviations that need to be further evaluated. The PTMA (Point Measure Correlation) value ranges from 0.58 to 0.72, indicating that each item contributes positively to the measurement of future thinking skills

4.2. Comparison of Students' Future Thinking Skills based on Gender and School Level

A comparative analysis was conducted to examine the influence of gender and school level on students' future thinking skills. The results of this analysis, as presented in Table 5, provide statistical comparisons based on a *t*-test, highlighting potential differences in future thinking abilities across demographic groups. The results of the *t*-test in Table 5 show a comparison of students' future thinking skills based on gender and school level. Female students had a higher average score of future thinking skills (mean = 31.9, measure = 0.38) than male students (mean =

28.6, measure = −0.23), with *t*-values of 5.05 and $p < .01$, indicating a significant difference between the two groups. In addition, high school students recorded higher average scores (mean = 33.7, measure = 0.70) than junior high school students (mean = 29.4, measure = −0.06), with *t*-values of −6.11 and $p < .01$, which also showed significant differences.

Table 5
Comparison of students' future thinking skills t-test

Demographic	*Mean*		*SD*	*t*	*p*
	Score	*Measure*			
Gender					
Female	31.9	0.38	1.39	5.05	< .01
Male	28.6	−0.23	1.29		
Level School					
Junior High School	29.4	−0.06	1.28	−6.11	< .01
Senior High School	33.7	0.70	1.44		

Table 6 presents the results of the *t*-test that compares students' future thinking skills based on gender and school level on each dimension, namely Visioning & Emotion, Predicting, Planning, Anticipating, and Evaluating.

Table 6
Comparison of students' future thinking skills t-test on each dimension

	Gender						*Level School*					
	Female		Male				JHS		SHS			
Dimension	*M*	*SD*	*M*	*SD*	*t*	*p*	*M*	*SD*	*M*	*SD*	*t*	*p*
VE	11.2	1.90	10.1	2.01	4.69	<. 01	10.7	1.95	11.3	2.00	−2.72	.007
PR	5.0	2.27	4.3	2.04	4.53	<. 01	4.3	2.10	5.7	1.90	−9.95	<. 01
PL	5.3	2.69	4.7	2.72	3.90	<. 01	4.8	2.74	5.7	2.23	−6.11	<. 01
A	5.0	3.23	4.5	3.10	3.97	<. 01	4.5	3.05	5.6	3.10	−7.53	<. 01
E	5.4	2.27	5.0	2.21	2.49	.013	5.2	2.15	5.3	2.47	−1.29	.199

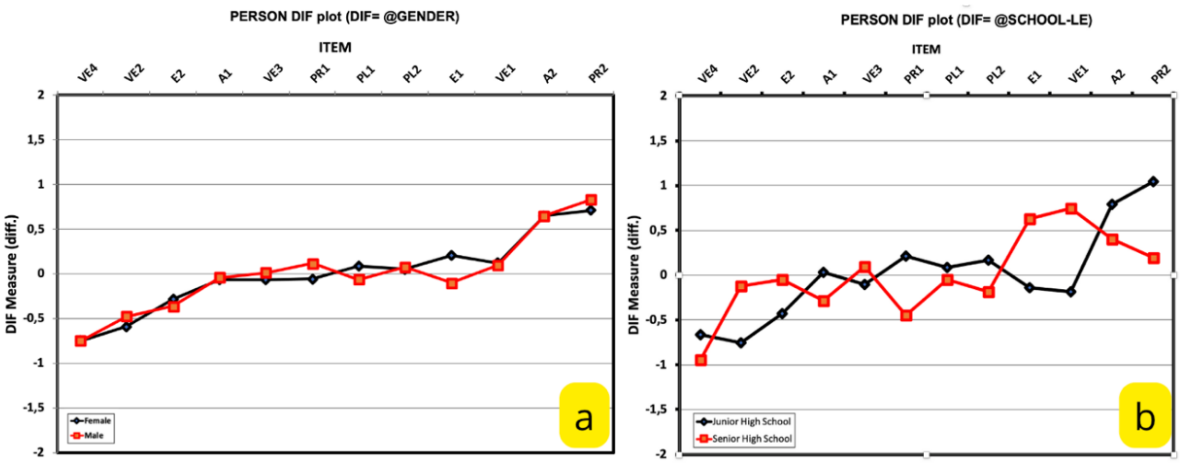
Note. JHS: Junior high school; SHS: Senior high school; VE: Visioning & Emotion; PR: Predicting; PL: Planning; A: Anticipating; E: Evaluating.

Table 6 presents analysis of students' future thinking skills across five dimensions—Visioning & Emotion, Predicting, Planning, Anticipating, and Evaluating—based on gender and school level. Female students scored higher than male students on all dimensions, with statistically significant differences in VE, PR, PL, A, and E ($p < .05$), highlighting their advantage in systemic and prospective thinking. Regarding school levels, high school students outperformed junior high school students on most dimensions, with significant differences in VE, PR, PL, and A ($p < .05$). However, no significant difference was observed in the Evaluating dimension ($p = .199$).

Figure 3 presents the results of Differential Item Functioning analysis to identify differences in student response patterns based on gender and school level on future thinking skills. Panel (a) shows the comparison of DIF between female and male students, while panel (b) compares junior high and high school students. These results provide important insights into how the items in the instrument interact with the demographic characteristics of students, which further supports the validity of the instrument in measuring future thinking skills holistically.

The analysis of Differential Item Functioning in Figure 3 highlights differences in students' abilities based on gender and school level. Panel (a) presents a gender-based DIF analysis, revealing significant differences for certain items. While most items perform consistently across gender groups, specific items, such as A2 and PR2, show a tendency to favor male students over female students. This suggests variability in item sensitivity to gender-related factors, which may influence performance.

Figure 3
DIF analysis based on (a) Gender, (b) School Level

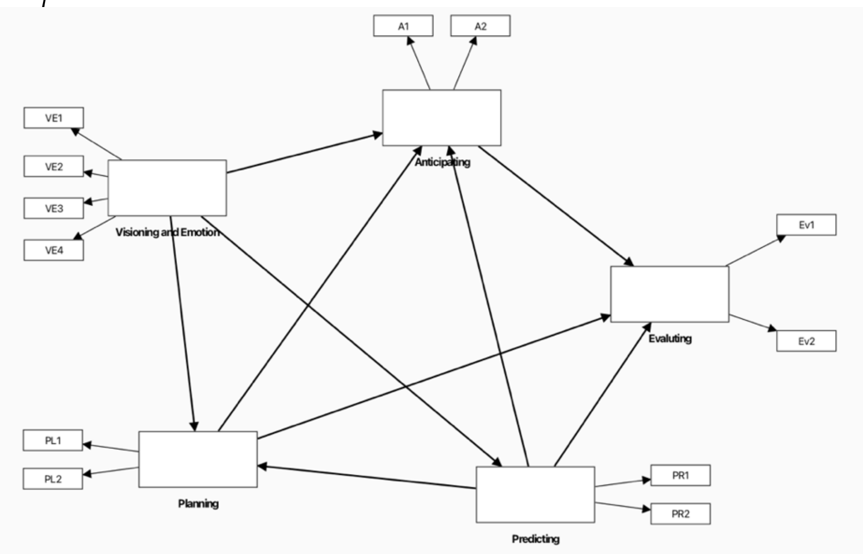


Panel (b) explores DIF based on school level, comparing junior high and high school students. Differences are evident in items like A2 and PR2, where high school students outperform their junior high counterparts. This disparity indicates that the complexity of these items aligns more closely with the cognitive and emotional maturity associated with higher educational levels. The analysis underscores the contextual relevance of items, reflecting differences in experiences and educational exposure between the two groups.

4.3. Relationship between Dimensions and Sub-dimensions of Students' Future Thinking Skills

Figure 4 presents a conceptual model that describes the relationship between latent variables in analyzing students' future thinking skills using a hybrid approach from the Rasch and SEM-PLS models.

Figure 4
Proposed model



The relationship model between latent variables shown in the figure 4 is the core of the analysis of students' future thinking skills using the SEM-PLS approach. The main latent variables, namely *Visioning and Emotion*, *Planning*, *Anticipating*, *Predicting*, and *Evaluating*, are measured through specific dimensions such as VE1-VE4 for *Visioning and Emotion*. This model describes the causal relationship between dimensions, where *Visioning and Emotion* have a direct influence on other dimensions, such as *Planning*, *Anticipating*, and *Predicting*. This approach strengthens the validity of the analysis because it incorporates the Rasch model to ensure the reliability and unidimensionality of the dimension before exploring the causal relationship with the SEM-PLS.

Table 7 presents the value of path coefficients that describe the strength of the relationship between the dimensions of students' future thinking skills based on the analysis of the SEM-PLS model.

Table 7
Path Coefficients

Dimensions	*Path coefficients*
Anticipating → Evaluating	0.351
Planning → Anticipating	0.542
Planning → Evaluating	0.440
Predicting → Anticipating	0.124
Predicting → Evaluating	0.209
Predicting → Planning	0.342
Visioning and Emotion → Anticipating	0.334
Visioning and Emotion → Planning	0.658
Visioning and Emotion → Predicting	1.000

Table 7 shows the values of *path coefficients* that describe the strength of interdimensional relationships in the SEM-PLS model for students' future thinking skills. The strongest relationship is shown by the "Visioning and Emotion → Predicting" pathway with a coefficient of 1.000, which confirms that the ability to imagine the future and emotional engagement greatly affect students' prediction skills. The "Visioning and Emotion → Planning" pathway with a coefficient value of 0.658 also shows a significant contribution of vision and emotion to planning ability. Meanwhile, the "Predicting → Anticipating" path has the lowest coefficient value (0.124), which indicates that the influence of prediction on anticipation is relatively weaker than other paths. The relationship of "Planning → Anticipating" with a coefficient value of 0.542 highlights the important role of planning in improving anticipation ability.

Figure 5 shows a research structure model that visualizes the causal relationship between dimensions of students' future thinking skills, including *Visioning and Emotion*, *Predicting*, *Planning*, *Anticipating*, and *Evaluating*, based on SEM-PLS analysis.

Figure 5
Structure Model

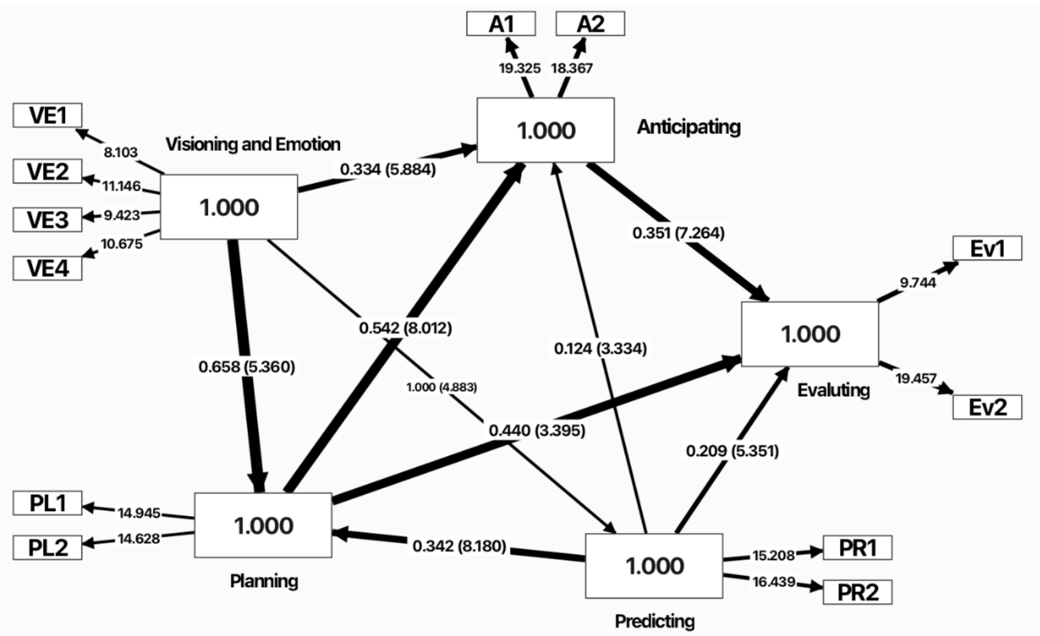


Figure 5 illustrates the *path analysis model* in the framework of *Partial Least Squares Structural Equation Modeling* (PLS-SEM). This model visualizes the relationship between five dimensions of future thinking skills: *Visioning and Emotion*, *Planning*, *Anticipating*, *Predicting*, and *Evaluating*. Each dimension is represented by a latent variable that has a causal relationship with other variables through specific paths that are weighted path *coefficients*.

The weight of the path reflects the strength of the causal relationship between dimensions, where values such as 0.658 between *Visioning and Emotion* and *Planning* show a strong influence. In addition, the numbers in parentheses (e.g., 5.360) indicate the *t-statistics* value, which tests the significance of this relationship through a bootstrapping approach. The model also includes measurement dimensions such as VE1 through VE4 that show how the *visioning and emotion* latent variables are measured. Overall, the results of this analysis confirm that the relationship between latent variables has high validity and significance.

Table 8 presents the results of the significance test using the bootstrapping method in the PLS-SEM model to evaluate the relationship between the dimensions of students' future thinking skills.

Table 8
Significance test with bootstrapping SEM PLS

Dimensions	*O*	*M*	*SD*	*t*	*p*
Anticipating → Evaluating	0.351	0.343	0.048	7.264	< .001
Planning → Anticipating	0.542	0.505	0.068	8.012	< .001
Planning → Evaluating	0.440	0.351	0.130	3.395	.001
Predicting → Anticipating	0.124	0.128	0.037	3.334	.001
Predicting → Evaluating	0.209	0.204	0.039	5.351	< .001
Predicting → Planning	0.342	0.362	0.042	8.180	< .001
Visioning and Emotion → Anticipating	0.334	0.306	0.057	5.884	< .001
Visioning and Emotion → Planning	0.658	0.568	0.123	5.360	< .001
Visioning and Emotion → Predicting	1.000	0.845	0.205	4.883	< .001

Note. O: Original sample; M: Sample mean; SD: Standard deviation.

The results of bootstrapping analysis in PLS-SEM show a significant relationship between latent variables on students' future thinking skills. The *Visioning and Emotion* dimensions consistently affect other dimensions, such as *Planning* (path coefficient 0.658; T-statistics 5.360; p < .001) and *Predicting* (path coefficient 1,000; T-statistics 4.883; p < .001), emphasizes its role as a foundation in the development of future thinking skills. In addition, *the Planning* dimension showed a strong influence on *Anticipating* (path coefficient 0.542; T-statistics 8.012; p < .001) and *Anticipating* affect *Evaluating* (path coefficient 0.351; T-statistics 7.264; p < .001). The entire pathway relationship tested had a value of p < .05, confirming the statistical significance of the model. With a high T-statistic value, the relationship between these dimensions of future thinking skills shows a strong and deep connection.

To evaluate the predictive ability of the model in explaining the variation of future thinking skills indicators, R-square and R-square adjusted analyses were performed, with the results summarized in Table 9.

Table 9
Coefficient of Determination (R^2)

Dimensions	*R-square*	*R-square adjusted*
Anticipating	1.000	1.000
Evaluating	1.000	1.000
Planning	1.000	1.000
Predicting	1.000	1.000

Table 9 shows the results of R-square and R-square adjusted analysis with a perfect value of 1.000 for all dimensions of future thinking skills, namely Anticipating, Evaluating, Planning, and Predicting. This value indicates that the model has very high predictive power, where all variations in these dimensions can be fully explained by the relationships between dimensions in the model.

5. Discussion

5.1. Profile of Students' Future Thinking Skills in Five Main Dimensions

The findings of this study indicate that students' future thinking skills vary across different dimensions, reflecting differences in their ability to plan for and respond to future challenges. This analysis provides insights into the dimensions in which students demonstrate proficiency and the areas that require further development in the learning process. In the Visioning and Emotion dimension, most students exhibit a strong ability to imagine the future and express emotions related to their aspirations and concerns. They can visualize various future scenarios; however, challenges arise when they need to deeply understand the emotional impact of anticipated events. This finding aligns with the study by Laherto and Rasa (2022), which emphasizes that having a clear vision is a crucial element in developing future thinking skills. Therefore, integrating discussions and scenario-based explorations into the curriculum could further enhance students' ability to conceptualize and reflect on future possibilities.

In the Predicting dimension, students struggle with long-term trend forecasting and data verification. While they can identify risk factors, they find it more difficult to understand how information evolves and influences future outcomes. This difficulty highlights the need to improve students' data literacy and their ability to critically assess information for making reliable predictions. Consistent with the recommendations of Gardiner and Rieckmann (2015), strengthening analytical skills through education can enhance students' predictive thinking. Therefore, learning strategies should place greater emphasis on data analysis, pattern recognition, and the application of technology to formulate evidence-based future predictions.

Regarding the Planning dimension, students demonstrate competency in designing strategies for addressing future challenges. However, they face difficulties in incorporating broader community participation in their planning process. The findings suggest that students tend to focus on individual problem-solving rather than collaborative and participatory approaches. Paige and Lloyd (2016) highlight the importance of action-based learning that fosters teamwork, which can enhance students' planning skills. Therefore, incorporating project-based learning and real-world problem-solving activities into the curriculum can help students develop a more inclusive and community-oriented approach to planning.

In the Anticipating dimension, students can identify general risks but struggle with foreseeing worst-case scenarios. This suggests that they are not yet fully accustomed to uncertainty-based thinking. Schacter and Addis (2007) propose that experiential simulation-based learning can help students develop stronger anticipation skills by engaging them in scenario-building exercises. Implementing case studies and decision-making simulations in the learning process can strengthen students' ability to assess risks and prepare for various uncertainties they may face in the future.

The Evaluating dimension reveals that students tend to focus more on short-term consequences rather than long-term evaluations. They are still in the early stages of developing future-oriented evaluation skills, which involve considering long-term impacts when making decisions. Szpunar et al. (2014) argue that future evaluation requires a combination of analytical and reflective thinking, which can be enhanced through reflective learning methods. Encouraging students to engage in metacognitive reflection, such as journaling or peer-reviewed discussions, may facilitate a more comprehensive approach to evaluating future possibilities.

Overall, the findings suggest that students exhibit relative strengths in Visioning and Emotion as well as Planning, whereas Predicting and Anticipating require further reinforcement through targeted instructional strategies. The results indicate that education systems should prioritize scenario-based learning, data analysis training, and collaborative decision-making exercises to enhance students' future thinking competencies.

A holistic curriculum design that integrates interdisciplinary problem-solving, sustainability education, and experiential learning will be instrumental in strengthening students' ability to navigate future challenges effectively. Additionally, these findings provide important insights for educators and policymakers in designing a future-oriented curriculum that fosters critical foresight, strategic planning, and anticipatory decision-making skills. Integrating these dimensions into school-based learning will better equip students with the necessary competencies to engage in proactive, solution-oriented thinking in an increasingly uncertain world.

5.2. Comparison of Students' Future Thinking Skills based on Gender and School Level

The findings of this study emphasize the significance of demographic factors in shaping students' future thinking skills, particularly in terms of gender and educational level. These demographic characteristics influence cognitive processing, emotional integration, and analytical reasoning, which are essential for constructing future-oriented thought patterns. Previous studies suggest that gender differences affect both emotional intelligence and analytical skills related to future thinking (Cole & Kvavilashvili, 2021; Gott & Lah, 2014). Similarly, educational level contributes to the cognitive and emotional development of students, fostering their prospective thinking skills (Loose & Vásquez-Echeverría, 2022; Szpunar et al., 2014).

The results indicate that gender and educational level significantly influence students' future thinking abilities, reinforcing the applicability of the hybrid Rasch and PLS-SEM model in analyzing the multi-dimensional aspects of future thinking, including Visioning & Emotion, Predicting, Planning, Anticipating, and Evaluating. Female students demonstrated greater proficiency in Visioning & Emotion and Planning, highlighting the crucial role of emotional integration in decision-making. These findings align with previous research, which suggests that women are more likely to incorporate emotional and social considerations when evaluating future scenarios, thereby enhancing their ability to engage in proactive and collaborative planning (Gardiner & Rieckmann, 2015; Julien et al., 2018).

Conversely, higher education enhances metacognitive skills and the ability to evaluate complex scenarios (Laherto & Rasa, 2022). The study's findings reveal that high school students outperform junior high school students in future thinking skills, supporting the argument that cognitive maturity and accumulated learning experiences contribute to students' ability to assess, anticipate, and plan for future events (Thorstad & Wolff, 2018). The significant differences across educational levels suggest that academic progression facilitates the development of future-oriented cognition, enabling older students to engage in more sophisticated strategic thinking and scenario evaluation.

The Differential Item Functioning analysis further reveals specific gender- and education-based variations in future thinking competencies. While most items perform consistently across demographic groups, some items, such as Anticipating worst-case scenarios and Predicting long-term trends, favor male students and higher-grade students, respectively. This suggests that cognitive tendencies related to gender, as well as exposure to advanced educational experiences, influence students' ability to assess risks and predict future scenarios. These findings reinforce the need for gender-sensitive and developmentally appropriate educational strategies to ensure equitable growth in future thinking competencies (Schacter & Addis, 2007).

The validation of the hybrid Rasch and SEM-PLS model in detecting demographic differences underscores its relevance as an analytical tool in future thinking education research. The model effectively identifies variations in cognitive and emotional engagement across student demographics, providing evidence for the need to tailor instructional approaches to different student profiles. Given the observed disparities, it is crucial to implement adaptive teaching strategies that account for gender-based strengths and cognitive maturity levels. For instance, educators should integrate scenario-based learning, predictive modeling, and experiential simulations to strengthen students' ability to anticipate and plan for the future.

Overall, these findings highlight the necessity of gender-adjusted and education-level-specific pedagogical strategies to enhance students' future thinking abilities in a sustainable and inclusive manner. By aligning educational interventions with demographic-based cognitive and emotional strengths, schools can better equip students with the cognitive flexibility, strategic foresight, and evaluative reasoning needed to navigate an increasingly uncertain future.

5.3. Relationship between Dimensions and Sub-dimensions of Students' Future Thinking Skills

The SEM-PLS model used in this study reveals that Visioning and Emotion exert the strongest influence on other dimensions, particularly Planning and Predicting. This finding underscores the critical role of visioning and emotional engagement in shaping future thinking skills. These results align with Richardson et al. (2024), who highlighted that the emotional aspect serves as a cognitive framework that supports vision-based decision-making.

Furthermore, the significant relationship between Planning, Anticipating, and Evaluating reinforces the central role of planning abilities in managing uncertainty. This is consistent with the study by Paige and Lloyd (2016), which emphasized that strategic planning is a key component of future thinking development. Specifically, the highest path coefficients in the model indicate that Visioning and Emotion strongly influence Predicting and Planning. These results confirm that the ability to envision the future and engage emotionally with potential challenges directly impacts students' capability to develop strategic plans and generate accurate future predictions.

These findings highlight the necessity of systematically designing school-based learning to align with the stages of future thinking development, namely Visioning and Emotion, Predicting, Planning, Anticipating, and Evaluating. Instruction should begin with Visioning and Emotion, where students are guided to envision a sustainable future and develop emotional engagement with global challenges. This can be facilitated through scenario exploration using visual media, documentaries, or reflective discussions that foster empathy and a sense of hope in addressing complex global issues (Laherto & Rasa, 2022; Rickards et al., 2014). Strong emotional engagement has been shown to significantly enhance students' abilities to formulate strategies and make predictions, as demonstrated by the path coefficients between Visioning and Emotion and Planning, as well as Visioning and Emotion and Predicting.

The next stage, Predicting, focuses on equipping students with the ability to analyze data and project future scenarios based on observable trends. Educators can employ data-driven approaches, such as trend analysis on climate change, technology-based simulations, or scenario-based problem-solving activities, to enhance students' predictive skills (Gardiner & Rieckmann, 2015; González-Pérez & Ramírez-Montoya, 2022). Following the establishment of visioning and predictive capabilities, Planning becomes a critical stage. Project-based learning is particularly effective at this stage, as it allows students to integrate strategic planning into sustainability-related solutions, such as designing interventions for addressing local or global environmental challenges. This approach provides practical experiences that align with students' envisioned futures, as emphasized by Paige and Lloyd (2016).

In the Anticipating stage, students are trained to foresee risks and obstacles in their plans. Educators can employ role-based simulations or exploratory games to help students identify and respond to potential risks proactively (Vidergor, 2023). Finally, the Evaluating stage involves guiding students through reflective processes to assess the effectiveness of their strategies. Collaborative evaluation, facilitated through group discussions or peer-review sessions, enables students to critically analyze their outcomes and receive constructive feedback for continuous improvement (Elazzab, 2022).

Additionally, the bootstrapping analysis in PLS-SEM confirms that the relationships between latent variables in future thinking skills exhibit high statistical significance and strong T-statistics, indicating robust interconnections among dimensions. The model demonstrates a strong predictive capacity, suggesting that the interrelated dimensions effectively explain variations in students' future thinking skills, reinforcing the validity of the proposed framework. These findings further support the structured learning stages, as each dimension of future thinking contributes to a cohesive developmental process that enhances students' cognitive and strategic abilities.

By implementing these structured learning stages, school-based education not only fosters students' future thinking skills but also empowers them to become adaptive, innovative individuals capable of addressing complex global challenges. This structured approach ensures a progressive learning experience, where students build their foresight abilities step by step—from envisioning the future to evaluating their strategies. Such a pedagogical framework aligns with the objectives of sustainable education and global educational trends, as advocated by UNESCO (2017). Transforming classrooms into "future laboratories" enables students to develop creative solutions for sustainability while enhancing their readiness to shape a more resilient and forward-thinking society.

6. Conclusions

The mapping of students' future thinking skills reveals variations in abilities across five main dimensions. The Visioning and Emotion dimension emerges as a key strength, showcasing students' ability to imagine future scenarios and grasp associated emotional aspects. Conversely, the Planning dimension highlights potential in designing preventive action plans, although challenges persist in fostering community involvement. On the other hand, the Predicting and Anticipating dimensions demand significant reinforcement, as students struggle with data verification, forecasting long-term trends, and identifying worst-case scenarios, emphasizing the need for improved data literacy and uncertainty analysis. Meanwhile, the Evaluating dimension remains underdeveloped, with students excelling in direct evaluations but lacking competence in assessing long-term impacts. These findings underscore the importance of simulation-based learning, enhanced data analysis, and community collaboration to strengthen Predicting and Anticipating skills. A holistic and inclusive educational approach is essential to equip students to face global challenges sustainably.

Gender and school level significantly influence future thinking skills. Female students consistently outperform male students across all dimensions, showcasing superior integration of emotional and cognitive aspects in decision-making. High school students exhibit greater competence than their junior high school counterparts, particularly in complex dimensions like predicting and planning, underscoring the role of cognitive maturity and experience in shaping these skills. A PLS-SEM analysis reveals strong interrelationships among latent variables, with "Visioning and Emotion" as the most influential dimension driving other dimensions like planning and predicting. This aligns with research emphasizing visionary and emotional abilities as foundational to comprehensive future thinking. The high predictive accuracy across dimensions validates the model's ability to explain these relationships. These findings provide valuable insights for the design of educational programs in schools that focus on strengthening future thinking skills to face global challenges in a sustainable manner.

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Declaration of interest: The authors declare that no competing interests exist.

Data availability: The datasets analyzed during the current study are available at this link: http://doi.org/10.6084/m9.figshare.28380446. The data generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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