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Article

Futures Thinking in Middle School Science Textbooks: A Perspective from Japan

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Abstract

Futures Thinking (FT) is a core competency in ESD, that may enable learners to "picture, predict and plan" a desired future. This paper explores the integration of FT in Japanese middle school science textbooks. It revolves around two research questions: RQ1, about specific contents of FT in these textbooks, and RQ2, about the contexts and methods of its delivery. The study employs a content analysis, scrutinizing three interdisciplinary sections of third-grade textbooks. It quantitatively and qualitatively assesses the presence of FT. The qualitative analysis reveals an emphasis on FT in the "Nature and Human" sections, through case studies, such as the predator-prey dynamics between the Canadian lynx and the snowshoe hare. Meanwhile, the "Science, Technology, and Human" sections concentrate on the societal impacts of technological advancements. However, the treatment of the SDGs is found to be superficial. Quantitative results indicate a focus on future scenarios and a diverse range of delivery methods. The study underscores the integrated approach of FT within different contexts, highlighting its potential to align science education with the SDGs. However, it also identifies a critical need for a more comprehensive engagement with SDGs, suggesting that textbooks could better facilitate a holistic understanding of futures thinking by expanding on this aspect. While the textbooks include FT in certain contexts, enhancing the depth and breadth of FT content could further empower students to actively engage with and shape their futures.

Keywords: Middle school science, Futures Thinking, textbook analysis, Japan, interdisciplinarity

Introduction

Education for Sustainable Development (ESD) in Japan

Japan's deliberate incorporation of Education for Sustainable Development (ESD) into its educational framework marks a significant alignment with international sustainability efforts, representing a multifaceted strategy rather than a standalone initiative. However, this transformative journey faces challenges, most notably the issue of "*shallow ESD*" (e.g., Nagata, 2017). This phenomenon, where educators conflate the use of the Sustainable Development Goals (SDGs) symbols with a holistic approach to ESD, undermines the substantive change necessary for authentic sustainability education. In response, the concept of "deep ESD" has emerged, advocating for a comprehensive understanding and practical application of sustainability competencies. It requires educators to evolve from mere conveyors of information into facilitators of a sophisticated, global sustainability discourse. This shift is not merely pedagogical; it is about empowering students to recognize their actions' global ramifications, thereby nurturing a society anchored in principles of sustainable development.

This commitment to a more profound, practical understanding of sustainability is further evidenced in Japan's educational policies. The Japanese Course of Study (MEXT, 2017), integrates these ideals, especially within the middle school science curriculum. The curriculum accentuates scientific rigor in environmental conservation and the discerning use of technology, serving as a conduit between educational theory and students' active role in a globally sustainable future. This effort is part of a broader pedagogical shift catalysed by the Japanese Central Education Council's 2016 report, positioning ESD as pivotal for future educational trajectories. The Council's vision interlinks policy and practice, aspiring to cultivate globally conscious citizens adept at navigating the delicate interplay between environmental needs, societal demands, and technological advancements. The strategy hinges on a balance of critical analytical skills and responsible, informed action, tailored to respect both global standards and local cultural considerations.

Correspondingly, the nuanced pathway forward is encapsulated by UNESCO's 2017 definition of "*competency*," which emphasizes a repertoire of skills enabling individuals to interact effectively in diverse, often challenging, environmental contexts. This approach necessitates a departure from traditional academic perimeters, championing instead the development of adaptive, pragmatic skills pivotal for conscientious decision-making and community engagement. Reinforcing this approach is the Japan National Institute for Educational Policy Research's initiative (NIER, 2012), which endorses a competency-driven ESD framework, integrating crucial life skills into the very fabric of the educational experience. This framework aims to inculcate in the younger generation a mindset harmonized with sustainability, adept at aligning technological progression with environmental preservation. The continuous interlinking of these steps, from high-level policy formulation to tangible curriculum applications, epitomizes Japans strategy to advance ESD.

Futures Thinking as the key competency in ESD

Within the Japanese ESD competency framework, a critical skill that stands out is the ability to "*Envision the Picture of the Future to Make Plans*" (NIER, 2012). This particular competency derives its significance from the fundamental principles laid out by the World Commission on Environment and Development (WCED) in 1987. The WCED, known for the Brundtland Report, conceptualized sustainable development as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*." This philosophy inherently stresses the importance of forward-thinking and strategic planning, pivotal components in sustaining the health and vitality of our future world. Delving into the specificities of this competency, scholarly dialogues present various theoretical frameworks and terminologies. For instance, Wiek et al. (2011) introduced the term "*anticipatory competency*" to describe the capacity to foresee future scenarios and prepare accordingly. In a similar vein, the terminology *Futures Thinking* was later proposed by Redman,Wiek and Barth in 2021, contributing to an evolving academic conversation around this crucial skillset.

Despite the variety in nomenclature, the essence remains consistent—it is about fostering an ability to project into the future, understand potential consequences, and make informed decisions in the present that serve both current and forthcoming generations. Interestingly, a review of contemporary literatures (e.g. Jones et. al., 2012; Laherto & Rasa, 2022; Levrini et. al., 2019) indicates a stronger prevalence of the term Futures Thinking over phrases like "*anticipatory competency*." This research, acknowledging the broader academic adoption, opts to refer to the competency of "*Envision the Picture of the Future to Make Plans*" primarily as Futures Thinking. This choice reflects not just a linguistic preference but also an alignment with a more widely recognized and expansive discourse on the subject in educational and sustainable development circles. By emphasizing Futures Thinking educators and policymakers advocate for a proactive, anticipatory approach that empowers students to conceive, analyse, and actively shape the forthcoming realities they and succeeding generations will inhabit.

Role of student textbook in fostering Futures Thinking

The integration of Futures Thinking into science education is a globally recognized trend, marked by innovative approaches from various regions. In New Zealand, Jones et al. (2012) showcased this by employing futures thinking to delve into the ecological and societal impacts of topics like genetically modified foods and the sustainability of dairy farming. This movement extends to France, where the work of Julien et al. (2018) and Hervé & Panissal (2022) involved students in envisioning the future through drawing and fictional narratives. In Italy, Branchetti et.al. (2018) initiated a project to intersect Science, technology, engineering, and mathematics (STEM) education and Futures Thinking. A significant contribution within this project was made by Levrini et al. (2019), who focused on operationalizing future-scaffolding skills, particularly in the context of the long-term consequences of climate change. Collaborating within the same project, Laherto and Rasa in Finland (2022) brought to light the societal and ethical dimensions of emerging technologies. In Japan, particularly in the aftermath of the 2011 disaster, Uchida (2015) emphasized the critical role of scenario workshops in proactive engagement with future energy challenges. This array of diverse and global initiatives highlights the crucial importance of Futures Thinking in advancing and enriching science education. These efforts collectively contribute to a broader understanding and preparedness for future scientific and environmental challenges.

Building on this global trend, Smart et al. (2020) critically examine traditional educational methods, spotlighting the inadequacies of textbook-based learning in preparing students for uncertain futures. They argue for a "*strong content–strong pedagogy*" model in textbooks proposes an integration of diverse, inclusive content and pedagogies that encourage open-ended learning and higher-order thinking. Such an approach goes beyond ensuring scientific accuracy: it actively engages students with the future implications and ethical dimensions of scientific advancements. Further, the paper highlights the significant role of textbooks in linking learners with their communities and environments, making education more relevant and contextual. This advocacy for redefined textbook content and teaching methods resonates with the overarching goals of Futures Thinking in science education, ensuring a seamless transition from global initiatives to specific educational practices.

On the other hand, Chou (2021) underlined the importance of textbooks in Asian educational systems, while studies by Okamoto (2015) began to address the inclusion of ESD within these texts. However, Chou (2021) also pointed out a significant limitation: these textbooks often focus predominantly on current global issues, lacking historical perspectives or future projections—a key element of Futures Thinking. This gap indicates an urgent need for a thorough re-evaluation and update of textbook content to more effectively prepare students for future challenges and opportunities. Such an update would ensure that students not only learn about present-day scientific concepts but also develop the foresight and skills necessary to become proactive and informed citizens in a rapidly changing world.

Focus of the research

This research delves into the integration of Futures Thinking in science textbook, with a specific focus on Japanese middle school science textbooks, particularly those utilized in the third grade. By examining how these textbooks incorporate interdisciplinary units that blend scientific disciplines with elements of Futures Thinking, the research aims to respond to the call for textbooks that not only ensure scientific accuracy but also engage students in the future implications and ethical dimensions of scientific advancements. This approach aligns with Smart et al.'s (2020) advocacy for redefined textbook content and teaching methods, emphasizing the importance of making education more relevant and contextual by linking learners with their communities and environments. The methodological backbone of this research is content analysis, steered by two principal research questions:

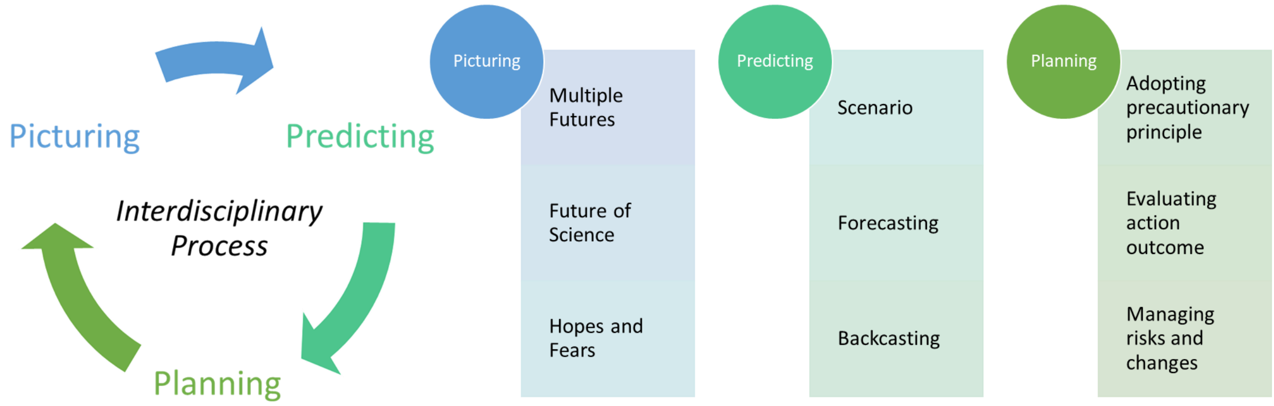
> **RQ1 Content related to Futures Thinking:** The first question, "*What content related to 'futures thinking' is present in the interdisciplinary units of third-grade middle school science textbooks in Japan?*" aims to explore the specific 'futures thinking' concepts, topics, and information embedded within these textbooks. It seeks to understand the nature of 'futures thinking' content within curriculum.
>
> **RQ2 Context and Methods of Delivery:** The second question asks, "*In what context and by which methods are 'futures thinking' concepts delivered within the interdisciplinary units of these textbooks*?" This inquiry is designed to unravel the context and delivery method employed to convey 'futures thinking' content. It examines the integration of these concepts within the curriculum and the strategies recommended for teachers to foster student understanding and engagement.

By first outlining the content with the initial question and then analysing the context and method of delivery with the second, this research aims to provide a thorough overview of how 'futures thinking' is embedded in science education through textbooks. This exploration is crucial for understanding how such content can shape the minds of young learners in Japan. The content analysis conducted will offer a detailed examination of both the substance and the structure of 'futures thinking' within these educational materials, shedding light on their potential impact on equipping students for future challenges.

Theoretical framework

In constructing the framework for textbook analysis, this research utilizes the conceptual foundation provided by the Japanese National Institute for Educational Policy Research (NIER, 2012), specifically harnessing the "*Abilities and attitudes emphasized by learning instructions from the viewpoints of Education for Sustainable Development*." A focal point of this framework is the ability known as "*Envisioning the Picture of the Future to Make Plans*." While NIER (2012) does not explicitly breakdown Futures Thinking into distinct segments, it identifies a vital, three-stage interdisciplinary process as outlined in Figure 1.

Figure 1. Theoretical framework of the Futures Thinking process



This process initiates with "*Picturing the Future*," an imaginative exercise of projecting various potential futures. It advances to "Predicting," a systematic approach to forecasting probable futures using current data and trends. The process culminates in "Planning," where strategic action plans are developed for navigating towards these preferred futures. The forthcoming sections of this research will delve into each stage, clarifying their importance, operational mechanics, and synergistic impact in scrutinizing the integration of Futures Thinking within the content of middle school science textbooks.

Picturing the Future

"Picturing the Future" is a foundational stage in Futures Thinking in science education, broadening students' horizon to multiple futures (Voros, 2003), emphasizing the importance of anticipatory competencies (Wiek et al., 2011). This phase is about conceiving a spectrum of futures, facilitated by diverse informational forms, from narratives to quantitative data, fostering critical reflection on present actions' long-term impacts (Voros, 2003; Wiek et al., 2011). Recognizing the multiplicity of outcomes is crucial, as the futures cone conceptually illustrates a range from probable to preferable futures, highlighting the role of anticipatory competency in informed decision-making (Voros, 2003). The discussion around the "future of science and technology" in shaping sustainable solutions is vital, encouraging students to consider how innovations can address global challenges (Laherto & Rasa, 2022). Moreover, acknowledging the emotional dimensions of envisioning, such as "hope and fear", adds depth to students' engagement and moral responsibility, preparing them for a future filled with uncertainties (Dahlbeck, 2014; Ojala, 2017). Overall, integrating "Envisioning/picturing the future" in science education is a multifaceted approach aimed at enhancing students' capacity to navigate diverse futures, comprehend the role of science and technology in shaping these futures, and understand the emotional and ethical implications of their choices and actions.

Predicting the Future

Jones et al. (2012) emphasize the importance of exploring future possibilities in science education, asserting that predicting the future prepares students to develop actionable strategies. This approach moves students from merely imagining various outcomes to actually planning for them. Wiek et al. (2011) suggested multiple methods for this predictive stage: Scenario, Forecasting, and Backcasting. Each method expands students' thinking, balancing hope, practicality, dreams, and data, while enhancing cognitive and emotional skills. An exemplary application of these methods is observed in Uchida's (2015) lesson on future energy options post-earthquake nuclear meltdown. The Scenario Method prompted students to consider different energy futures, enhancing critical thinking and adaptability. The Forecasting Method, through analysing past and present data, honed students' analytical abilities to predict future trends. Finally, the Backcasting Method encouraged students to envision a preferred future and work backwards to achieve it, fostering strategic and imaginative thinking in the context of energy planning.

Planning for the Future

Gibson (2006) emphasizes that sustainability involves a forward-looking perspective, focusing on meeting the needs of future generations, preventing unintended consequences, and ensuring fairness across generations. The concept of sustainability inherently involves long-term thinking, precaution, and consideration for the well-being of future communities. Rieckmann et al. (2017) elaborate on the "Planning" stage of Futures Thinking, highlighting it as a critical phase in which theoretical understanding transitions into practical application. In this stage, students learn to adopt precautionary principles, making decisions with awareness of their potential impact on sustainable futures. They engage in activities that encourage them to evaluate the outcomes of various actions, considering the holistic impact of human behaviour on future scenarios. Furthermore, students are taught to manage risks and adapt to changes, fostering resilience and flexibility in pursuit of long-term goals. This stage, therefore, reinforces the idea that the future is not a fixed destination but an ongoing journey of thoughtful decisions, learning, and adjustment, in line with the sustainable and equitable future vision articulated by Gibson (2006).

Futures thinking from the lens of interdisciplinarity

Drawing from Erduran (2014), the Futures Thinking framework is notably enriched by an interdisciplinary approach that extends beyond traditional scientific confines to include societal, cultural, and ethical dimensions. This holistic perspective is crucial in each of the three stages of Futures Thinking -picturing, predicting, and planning. In the picturing stage, it broadens the scope of possible futures: for instance, when learning about climate change in a science classroom, students not only explore scientific data but also consider societal impacts and cultural narratives. This approach allows them to envision a future in which climate change influences various aspects of life, from urban planning to agricultural practices.

During predicting, the framework ensures that forecasts are socially and ethically grounded. In this context, students might analyse trends in renewable energy adoption, while also discussing the ethical implications of different energy sources on communities and ecosystems. In planning, the framework encourages strategies that are culturally sensitive and morally sound. Here, students could develop climate action plans that respect diverse cultural values and offer equitable solutions to different communities, considering both technological innovations and traditional practices. Further emphasizing the need for interdisciplinary integration, Kapon and Erduran (2021) underscore the importance of crossing disciplinary boundaries in science education, drawing on Akkerman and Bakker's (2011) framework. This approach not only enhances scientific literacy but also equips learners with the comprehensive insights necessary for navigating and shaping complex, multifaceted aspects of the future.

Methods

This study was conducted to examine the integration of Futures Thinking within Japanese middle school science education, guided by two research questions that focus on the content, context and delivery methods of futures thinking concepts. Utilizing a deductive content analysis method, as proposed by Mayring (2014) and implemented by Sprenger and Peter (2019) which consist of the following steps.

Step 1: Material/sample identification

This study samples textbooks adhering to the 2017 Japanese national curriculum guidelines, encompassing five authorized editions by diverse author teams and publishers: DT (Arima et. al., 2021); TS (Kajita et. al., 2021); KS (Murofushi et. al., 2021); K (Oya et. al., 2021); GT (Shimoda et. al., 2021). The sampling specifically targets third-grade textbooks renowned for their substantial inclusion of futures thinking concepts. These textbooks includes content and unit titles that advocate a forward-looking stance on science and global challenges, for instance, "*For a brighter future for the plane*t" in DT's edition (p. 284) and "*Nature and Technology: Shaping Our Future Together*" in KS' edition (p. 262), demonstrating the curriculum's focus on futures thinking.

Step 2: Determining criteria for the content analysis

In the subsequent step, criteria for content analysis were developed deductively, drawing upon central theoretical elements—specifically, the integration of Futures Thinking within science education. The categorization process was informed by the content's alignment with the three interdisciplinary themes: "*Nature and Humans*," addressing ecological and environmental concerns; "*Technology and Humans,*" focusing on the evolution and future potential of technology in conjunction with scientific advancement; and "*Sustainable Development*," centring on the SDGs or related overarching concepts. This deductive categorization facilitated a focused analysis, employing these themes to systematically dissect and examine the futures thinking content across 294 pages of the selected textbooks (Table 1).

Table 1. Sampled pages for the deductive content analysis

Publisher	Page number	Page count (exclude general page and test page)			
		Nature and Human	Science, Technology and Human	Sustainable Development	Total
DT	136 - 159 284 - 328	42	22	5	69
GT	240 - 263	7	10	7	24
K	230 - 249 250 - 309	34	38	8	80
KS	262 - 324	36	24	4	64
TS	255 - 311	24	18	15	57

Step 3: Defining coding guide

In this step, the study delineates categories for the coding guide based on the established criteria, ensuring a precise and systematic approach to analysing the content of science textbooks. This step is crucial for translating theoretical frameworks into actionable analytical tools. The coding unit is determined by paragraph per page for written content, while graphical elements such as graphs, tables, figures, and photos are coded individually. This granularity in coding allows for a detailed exploration of both textual and visual information, facilitating a comprehensive analysis of how futures thinking is integrated into the educational material. The following are detailed explanation for each of the codes generated:

- **Process:** This category encompasses key facets of futures thinking as outlined in our theoretical framework, with each aspect meticulously detailed in Table 2, providing a structured lens through which the integration of futures thinking in education can be analysed. The category is subdivided into nuanced processes including "Picturing the Future," "Predicting the Future," and "Planning for the Future," each supported by specific codes that reflect the diverse methodologies and approaches encapsulated within futures thinking. "Multiple futures" underscores the concept that the future consists of various possibilities, each shaped by our present decisions, hence emphasizing discussions on predicted, desirable, or undesirable futures. "Future of science" draws attention to segments where the potential of scientific advancements to forge sustainable futures is explored, highlighting the pivotal role of empirical data and scientific observations in forecasting future conditions. In contrast, "Hopes and fears" delves into the emotional responses to future scenarios, employing visual and narrative elements to illustrate the impact of potential future events, such as the implications of climate change. Through "Predicting the Future," methodologies like scenario planning are utilized to engage with different sustainable futures, promoting a critical examination of potential outcomes. This comprehensive approach not only facilitates a deeper understanding of how futures thinking is integrated into educational content but also underscores the importance of a multifaceted approach in fostering an adaptive, forward-thinking mindset among students.

- **Scale:** This code adopts a structured approach to analyse content, inspired by the methodologies demonstrated in the research by Chou (2021), which effectively utilized both spatial and temporal dimensions to explore futures thinking. This category is segmented into local, regional, and global scales, progressively broadening the learners' perspective from immediate, community-level issues to wider, global concerns. The local scale prompts students to consider their direct impact on their surroundings, fostering a sense of personal responsibility. Moving to the regional scale, the curriculum expands its reach, challenging students to grasp the broader implications of regional issues and their interconnectedness with global challenges. At the global scale, attention is focused on worldwide phenomena, emphasizing the necessity for collective action in addressing global challenges.

Table 2. Coding guideline for each of the Futures Thinking Process Indicators

Picturing the Future	
Code	**Explanation**
1. Multiple futures	This code includes textbook content that portrays the future as multiple, nonlinear, and diverse, emphasizing the influence of current actions. It encompasses discussions of various possible futures, such as predicted, desirable, or undesirable scenarios.
2. Future of science	This refers to sections introducing advanced technologies or sustainable futures enabled by scientific progress. It specifically involves content featuring data, graphs, or tables from scientific experiments or observations used to forecast future conditions.
3. Hope and fears	This involves content that includes emotional aspects, such as photographs, illustrations, or factual case studies, particularly those aimed at illustrating the emotional impact of future scenarios like climate change or conservation efforts.
Predicting the Future	
Code	**Explanation**
4. Scenario	This pertains to content that utilizes scenario methods, presenting various sustainable future scenarios for analysis or selection. It includes examples and activities where students are encouraged to engage with multiple potential outcomes.
5. Forecasting	This includes instances where students are encouraged through textbook content to predict the future based on historical or current data, particularly in scientific or sustainability contexts. This often involves exercises in data interpretation or research into trends.

6. Backcasting	This category covers textbook content that encourages envisioning a desirable sustainable future and formulating strategies to realize it. This is often seen in planning and strategy exercises, such as those oriented towards achieving SDGs.
Planning for the Future	
Code	**Explanation**
7. Adopting precautionary principle	This involves sections discussing or promoting the principle of sustainable development. It includes content that balances the needs of the current generation with the capabilities of future generations.
8. Evaluating action outcome	This refers to activities or text encouraging students to consider and evaluate the broad impacts of human activities on potential futures. It includes discussions suggesting modifying actions accordingly to achieve desired outcomes.
9. Managing risks and changes	This includes discussions or activities emphasizing the need for ongoing action modification to achieve desirable futures. It acknowledges the inherent risks and the necessity for adaptability in response to changing circumstances.

- Additionally, this category also intricately integrates a temporal dimension, spanning past, present, and future, into its framework. This allows students to reflect on how historical events have shaped current realities and how present actions will influence future outcomes. The inclusion of temporal and spatial dimensions enriches the curriculum, offering students a comprehensive understanding of futures thinking. This approach not only broadens students' horizons but also deepens their insight into the complex, multifaceted nature of futures thinking, enabling them to critically evaluate potential futures and their roles in shaping them. By adopting this methodology, the "Scale" category enhances the curriculum, ensuring that students gain a robust understanding of futures thinking through the lens of both spatial and temporal analysis.
- **Delivery:** This code intricately addresses the diversity in educational content presentation, distinguishing between continuous and non-continuous text forms, a distinction that echoes the methodologies examined in international assessments like the Programme for International Student Assessment (PISA) (OECD, 2021). Continuous text, through narrative or expository paragraphs, offers a linear, in-depth exploration of futures thinking, facilitating comprehensive discussions on the subject. Conversely, non-continuous text—comprising diagrams, tables, figures, and other graphical elements—provides an alternative, visually engaging method of content delivery. Each graphical element is analysed individually, recognizing their significant contribution to illustrating futures thinking concepts. This approach not only caters to varied learning styles but also aligns with PISA's emphasis on assessing students' ability to interpret and analyse information across different formats, thereby enhancing student engagement and comprehension of futures thinking.

By systematically identifying these categories within the coding guide, this study lays a solid foundation for the content analysis phase, ensuring that the investigation into textbooks is meticulously aligned with the overarching research objectives. This detailed categorization process embarks on a thorough and comprehensive journey through the integration of Futures Thinking into the science curriculum. It sheds light on the instructional strategies and pedagogical approaches employed to nurture futures thinking competencies among middle school students, reflecting a deep commitment to preparing students for a complex future. Ultimately, this coding guide not only supports the analytical framework of the study but also contributes to a broader understanding of how Futures Thinking can be effectively woven into educational narratives, ensuring students are equipped with the critical thinking and strategic planning skills essential for navigating the future.

Step 4: Qualitative analysis

Following the establishment of a detailed coding guide, the study advances into a qualitative analysis phase, meticulously designed to uncover the underlying themes, values, and perspectives that permeate Futures Thinking within the third-grade science textbooks. This intricate exploration is committed to unraveling the complex and abstract nature of Futures Thinking, paying close attention to its diverse manifestations across the educational materials. By examining three distinct sections identified for their substantial representation of futures thinking processes—including picturing, predicting, and planning—this analysis carefully selects specific excerpts that serve as illuminating examples, thereby showcasing the various methods employed to engage students with these critical concepts. This qualitative inquiry is instrumental in revealing the nuanced ways of Futures Thinking is interwoven into the curriculum, emphasizing its pivotal role in cultivating a forward-looking outlook among students. Beyond mere numerical analysis, this phase enriches the study with a deeper, more textured understanding of the content, examining the pedagogical intentions and educational impacts of integrating futures thinking into Japanese middle school science education. Delving into the deeper meanings and implications of the texts, this qualitative analysis yields invaluable insights into the complexities of teaching and learning futures thinking, contributing to a comprehensive assessment of its integration and significance within the science curriculum.

Step 5: Quantitative analysis

The final step in this study involves a focused tabulation phase, where the content of the textbooks is systematically organized to reflect alignment with the established coding criteria, concentrating on the Futures Thinking Process, Scale, and Delivery Method. In this phase, the emphasis shifts from broad categorization to the precise tabulation of instances where futures thinking content is identified, following the intricate details outlined in the coding guide. This step starts with a pilot tabulation to evaluate the coding system's accuracy, allowing for adjustments to refine the tabulation process. A detailed review of all selected materials ensures that each relevant piece of content is accurately tabulated. This tabulation not only organizes the data for clarity but also facilitates a straightforward analysis of the prevalence and distribution of futures thinking themes across the textbooks. Results from this tabulation are presented in a clear, organized manner, highlighting how Futures Thinking is pedagogically integrated within the third-grade science curriculum. This focused approach provides insights into the scope of futures thinking content and underscores the instructional strategies deemed effective for fostering such competencies among middle school students, directly addressing the study's research objectives.

Results and Discussion

Qualitative analysis

Futures Thinking in "Nature and Human" chapters

1. **Picturing: hopes and fears about biodiversity Lloss**

   In the exploration of the "Nature and Human" chapters of Japanese middle school science textbooks, a clear illustration of Futures Thinking emerges, particularly in the realm of biodiversity. Futures Thinking in an educational context involves guiding students to consider both desired and undesired future scenarios based on present and past trends. This journey commences with a historical perspective, where textbooks illustrate the ecological balance that once existed, exemplified by the predator-prey relationship between the Canadian lynx (*Lynx canadensis*) and the snowshoe hare (*Lepus americanus*) (K, p.257; KS, p.268). This historical lens provides students with an understanding of the natural equilibrium, the desired state in which ecosystems function harmoniously. The narrative then shifts to the present, highlighting how human activities have disrupted this natural balance. The textbooks discuss the impact of altering "satoyama" landscapes—traditional rural environments in Japan—leading to disproportionate changes in animal populations, like an increase in deer (*Cervus nippon*) numbers (TS, p.274). Additionally, the introduction of invasive species such as the black bass (*Micropterus salmoides*) (GT, p.243)—species not native to the ecosystem and harmful to the local balance – further exemplifies current ecological challenges.

   When projecting into the future, the textbooks use the case of the crested ibis known locally as "toki" (*Nipponia nippon*, with "Nippon" reflecting its endemic status in Japan) (DT, p.290) to illustrate both the hopes and fears inherent in Futures Thinking. The toki, once extinct in the wild, represents an undesired future where species are lost due to human impact. However, its revival, through the reintroduction of birds from a surviving population in China, embodies the hope and possibility of a desired future where such losses can be mitigated or reversed. This story of the toki not only highlights the fragility of ecosystems but also demonstrates the potential of human intervention for positive change. Throughout this progression, the concept of "hopes and fears" in Futures Thinking is strategically interwoven. "Hopes" here refer to the aspiration for a return to or maintenance of ecological balance, a future where biodiversity is preserved and natural systems are restored. Conversely, "fears" are rooted in the anxiety over an undesired future, where current patterns of ecological disruption lead to irreversible damage. By engaging students in this dichotomy, the textbooks not only educate about biodiversity but also emotionally and ethically engage them in thinking about their role in shaping future outcomes. This approach encourages students to critically evaluate current trends and empowers them to envision and strive for a sustainable, balanced future.

2. Predicting: case study of lynx and hare

In the analysed chapters, graphs depicting the interaction between lynxes and hares effectively illustrates key ecological concepts. This graph is a practical application of the Lotka-Volterra model (e.g. Nedorezov, 2016), a fundamental concept in ecological studies, underscoring the model's significance in educating students about the dynamics of natural ecosystems. This graph shows two distinct curves: one representing the lynx (predator) population and the other the hare (prey) population. It highlights how an increase in the prey population typically leads to a rise in predator numbers due to increased food availability. Conversely, a peak in predator numbers can result in over-predation, causing a significant decline in the prey population. This decrease in prey eventually leads to a reduction in predator numbers, demonstrating the self-regulating mechanisms within natural ecosystems. Such a graphical representation is instrumental in helping students understand the impact of species interdependencies on ecological balance and the potential disruptions caused by human activities, such as habitat destruction and the introduction of invasive species. By analysing these trends, students gain the skills to forecast various potential future scenarios in biodiversity, encompassing a comprehensive understanding of different anthropogenic factors.

Branchetti et al. (2018), integrated the Lotka-Volterra model into the I-SEE project's start-up module. This integration aimed to elucidate the complexity of ecological systems, using the interaction between wolves (*Canis lupus*) and moose (*Alces alces*) on Isle Royale as a case study, as highlighted by Sagoff (2016). The focus on non-linearity in ecological systems is a key aspect of their approach. Non-linearity implies that responses within ecological systems to changes are often disproportionate and unpredictable, challenging the traditional notion of straightforward extrapolation from past and present trends. This perspective is crucial for understanding that future ecological scenarios could unfold in various, often unexpected ways (Barelli, 2017). It highlights the complexity and unpredictability inherent in natural ecosystems. The integration of the Lotka-Volterra model in educational settings enables students to envision multiple potential futures, emphasizing the non-linear nature of ecological systems. It instils an appreciation for the delicate balance of ecosystems and the vital importance of preserving biodiversity. By comprehending the intricate interactions within ecosystems and the potential outcomes of disrupting these balances, students are better equipped to contemplate and contribute to a sustainable and dynamically balanced future. This educational approach is particularly relevant in today's world, where ecological considerations are increasingly at the forefront of scientific and societal discourse. The Lotka-Volterra model, therefore, serves not just as a scientific concept, but as a tool for deeper engagement with and understanding of the complexities and responsibilities inherent in environmental stewardship.

3. Planning: case study of black bass, deer and ibis

The chapters detail how the degradation of satoyama landscapes has led to ecological imbalances, notably the overpopulation of deer. Satoyama refers to traditional rural landscapes in Japan that represent a harmonious integration between human agricultural activities and the natural environment (Shimoda et. al., 2021; Takeuchi, 2010). These landscapes are characterized by a mosaic of different ecosystems, including forests, farmlands, and water bodies, managed in a way that maintains biodiversity and ecological balance. The section about satoyama illustrates a practical application of the precautionary principle in Futures Thinking, emphasizing proactive measures to prevent environmental degradation. It also reflects on evaluating actions and risks, teaching students how present decisions impact future states. This segment underscores the necessity of foresighted planning in maintaining ecological balance and biodiversity.

The issue of invasive species, with a focus on the black bass (*Micropterus salmoides*), illustrates the unforeseen consequences of introducing non-native species into ecosystems. The textbooks highlight how the black bass, initially introduced for sport fishing, now poses a significant threat to native aquatic life (Fujimoto et. al., 2021; Takamura, 2007). This case study encourages students to understand the importance of biosecurity and the risks associated with human intervention in nature. The narrative emphasizes the need for stringent measures to prevent similar future occurrences, embodying the principle of evaluating actions and risks. It demonstrates how adaptive management and continuous monitoring are integral to mitigating the impact of invasive species, aligning with the Futures Thinking approach of embracing change for ecological well-being.

The story of the toki serves as an exemplary case of reversing biodiversity loss through strategic conservation efforts (Li et al., 2009; Wingfield et al., 2000). The textbooks describe the toki's journey from near extinction to revival, highlighting the successful collaboration between Japan and China and the implementation of breeding and reintroduction programs. This case encapsulates the essence of planning for future biodiversity preservation. It exemplifies the precautionary principle, where early intervention prevented total loss, and shows the importance of assessing risks and implementing informed conservation strategies. The toki's revival is a testament to the power of human intervention in positively influencing biodiversity outcomes and embodies the principle of embracing innovative solutions in conservation efforts.

Overall, these sections in the textbooks provide students with a comprehensive view of how thoughtful, strategic planning and actions can mitigate future biodiversity loss. They encourage students to think critically about their role in shaping sustainable futures, emphasizing that informed and proactive measures today can lead to a more balanced and biodiverse world tomorrow. This educational approach equips students with the knowledge and perspective necessary to contribute effectively to environmental stewardship and the preservation of biodiversity**.**

Futures Thinking in "Science, Technology, and Human" chapters

1. Picturing: technology for equality

The chapter "Science, Technology, and Human" in the Japanese middle school science textbook exemplifies the concept of "Science of Future," weaving advanced technologies and visions of sustainable futures, supported by scientific progress, into the curriculum. This approach underscores the significance of inclusivity and accessibility for all individuals, particularly focusing on empowering those with disabilities. The chapter begins by discussing the innovation of specialized wheelchairs for Paralympic athletes (DT, p. 318), highlighting the fusion of advanced engineering and ergonomic design to enhance sports performance. This section not only emphasizes the importance of inclusivity in sports but also illustrates how athletes of all abilities can excel at the highest levels.

Further, it delves into the advancements in artificial limb technology (K, p. 281), showcasing limbs that integrate advanced materials and robotics to offer more natural movement and enhanced control. This part of the textbook introduces students to the concept of biomimicry (e.g., Xu & Todorov, 2016) and the integration of biology with technology, stressing the need for designs that are centred around the users' experiences. The textbook (GT, p. 256) also covers the role of exoskeleton robots (e.g., Kiguchi et. al., 2003) in aiding individuals with varying mobility levels. These devices exemplify the application of technology to assist in daily activities, enhancing independence and autonomy for individuals with mobility challenges. Additionally, there's a focus on robots designed to assist individuals without limbs in performing daily tasks (K, p. 281), such as meal-assisting robots (e.g., Yamazaki & Masuda, 2012). This technology is not just a convenience but is crucial in providing independence and enhancing the quality of life for those facing challenges in basic tasks.

Overall, these sections of the textbook do more than just inform students about scientific and technological advancements. They embed values of inclusivity, empathy, and social responsibility, highlighting how technology can be thoughtfully designed to meet diverse needs. This educational approach cultivates a forward-thinking mindset among students, fostering appreciation for the role of science and technology in creating a more inclusive and equitable society for everyone.

2. Predicting: fossil fuel scarcity

The "Science, Technology, and Human" chapters in the analysed textbook also encompass sections on energy, delving into issues related to energy scarcity and the evolving landscape of energy production and consumption. These sections offer an insightful look at energy trends across different levels, from household (DT, p. 303) to national (K, p. 231; KS, p. 299) and global scales (KS, p. 317), providing a multifaceted view of energy dynamics. One significant aspect of these chapters is their focus on the concept of multiple futures, as evidence by a passage about energy source availability (GT, p. 24) This passage discusses the estimated duration for which various resources can be mined, based on data from 2018. It includes a bar graph with estimated reserves and highlights that the projected number of years for resource availability can change based on conservation efforts or the discovery of new resources. This presentation embodies the concept of multiple futures, illustrating the dynamic nature of energy resources and emphasizing human agency in predicting and influencing future energy scenarios.

Moreover, these chapters stand out for explicitly acknowledging that the data and projections for future years (2030 and beyond) are based on forecasting. This is further emphasized through the use of different visual elements in the textbook, such as colour variations in charts (e.g., K, p. 238). Such differentiation helps students understand that these are not just extrapolations but informed predictions that consider various factors and trends. The incorporation of these forecasting techniques is a crucial element of Futures Thinking, an educational approach that encourages students to think critically about the long-term consequences of present-day actions and decisions. By integrating these elements into the curriculum, the textbook not only provides students with a thorough understanding of current and projected energy scenarios but also equips them with the cognitive tools to engage with the concept of Futures Thinking. This approach fosters an awareness of the interconnectedness of present actions and future outcomes, highlighting the importance of informed decision-making in shaping sustainable and resilient energy futures. It emphasizes the role of students as active participants in shaping these futures, cultivating a sense of responsibility and agency in addressing energy scarcity.

3. Planning: renewable energy

The textbooks (e.g., K, p.234; TS, p. 289) extensively discuss the catastrophic incident at the Fukushima Daiichi Nuclear Power Plant following the 2011 earthquake and tsunami (Hirano et. al., 2012; Thielen, 2012). The meltdown is contextualized as a basis for understanding the precautionary principle in energy production. This highlights the need for stringent safety protocols and advanced planning to mitigate potential risks associated with nuclear power plants, particularly in seismically active regions like Japan. Emphasising precautionary measures, the textbooks educate students on the importance of foresight and preparation in managing complex, high-risk technologies. Building on this foundation, the sections on nuclear energy and renewable alternatives (e.g., GT, p.247-249;) engage students through project-based learning in evaluating actions related to energy choices. By comparing the aftermath of the nuclear disaster with the benefits and challenges of renewable energy sources, students critically assess different energy strategies. This comparative analysis (as exemplified in Uchida, 2015) deepens understanding of the far-reaching consequences of decisions in the energy sector, underlining the need for careful evaluation and informed decision-making.

Furthermore, the textbooks address understanding risks and adapting to changes as central themes. They delve into the complex nature of risk, especially regarding radiation exposure and environmental impacts post-nuclear incidents (K, p. 237; KS, p. 303). They also explore the evolving landscape of energy production, emphasizing technological advancements, policy changes, and shifting societal attitudes towards energy consumption. This focus on risks and changes equips students to navigate and respond to the uncertainties and dynamics inherent in the energy field. In summary, the textbooks offer a comprehensive approach to energy education, combining lessons from historical events like the 2011 earthquake with forward-looking discussions on renewable energy and risk management. This approach not only informs students about the complexities of the energy sector but also instils principles of precaution, critical evaluation, and adaptability, which are essential for navigating the challenges and opportunities in the context of energy.

Futures Thinking in "Sustainable Development" chapters

In the textbooks, the chapter on sustainable development, though brief, provides a valuable perspective on SDGs, particularly highlighting the concept of backcasting. Backcasting is a planning method that starts with defining a desirable future and then works backward to identify steps that will connect that future to the present. This approach contrasts with traditional forecasting methods, which extrapolate future developments based on current trends. The application of backcasting is exemplified in the discussion of SDG 7 within the context of the 2025 Osaka Kansai World Expo (K, p. 248). This section effectively illustrates how envisioning a desired future state can guide current strategies to achieve sustainable energy goals. By focusing on a future where human well-being is central, as seen in the Expo's theme "Designing a Future Society Where Life Shines," the chapter conveys how current actions can be aligned with long-term sustainability objectives. The integration of this theme with SDG 7 "Affordable and Clean Energy" reflects a holistic approach, intertwining environmental sustainability with human-centric development. This suggests a future where energy advancements improve the quality of life, not just achieve technological milestones.

However, the text also points out the superficial use of SDGs in some contexts. As noted, (KS, p. 324; p. 257), instances of SDG logos being used in a minimalistic or merely supplementary fashion raise questions about the depth of commitment to these goals. Additionally, the brief exploration of SDG 2, focusing on eradicating hunger and promoting sustainable agriculture (KS, p. 234), exemplifies the chapter's conciseness. This limited treatment suggests the necessity for a more expansive discussion on achieving sustainable and equitable development. Despite its brevity, the chapter underscores the importance of long-term thinking and incorporating principles of sustainable development into broader planning and policy frameworks.

Quantitative analysis

As shown in Table 3, content analysis revealed that "Science, Technology and Human" had the highest content representation at 46%, while "Sustainable Development" had the lowest at 17%. Within the "Picturing the Future" theme, "Multiple futures" was the least represented at 4%, whereas "Futures of science" and "Hopes and fears" both showed a higher representation at 17%. For "Planning for the Future," the highest focus was on adopting the precautionary principle at 20%. The temporal scale analysis showed a dominant focus on the "Future" at 82%, significantly higher than the "Past" and "Present," both at 9%. In temporal nuances, "Desirable" outcomes were most represented at 48%. The spatial scale revealed "National" as the highest at 28% and "Personal," "Regional," and "Natural" as the lowest, each at 9%. Lastly, delivery methods showed a higher inclination towards "Non-continuous" formats at 56% compared to "Continuous" at 44%.

Table 3. Content Analysis Result

Code	Sub-code	n	%
Representation in Content	Nature and Human	162	37%
	Science, Technology and Human	199	46%
	Sustainable Development	72	17%
Picturing the Future	Multiple futures	18	4%
	Futures of science	75	17%
	Hopes and fears	72	17%
Predicting the Future	Scenario	37	9%
	Forecasting	44	10%
	Backcasting	28	6%
Planning for the Future	Adopting precautionary principle	88	20%
	Evaluating action outcome	32	7%
	Managing risk and changes	39	9%
Temporal Scale	Past	38	9%
	Present	39	9%

Code	Sub-code	n	%
Temporal Nuance	Future	356	82%
	Desirable	210	48%
	Probable	110	25%
	Undesirable	113	26%
	Unspecified	89	21%
Spatial Scale	Personal	39	9%
	Regional	38	9%
	National	122	28%
	Global	105	24%
	Natural	40	9%
Delivery	Continuous	189	44%
	Non-continuous	244	56%

The quantitative analysis of the textbooks offers key findings that further elucidate the extent and focus of Futures Thinking within the curriculum. The analysis highlights those discussions on science, technology, and their impact on humanity dominate the content, reflecting a strong emphasis on preparing students for technological advancements and their societal implications. Nature and human-related content, focusing on biodiversity and ecological balance, also forms a substantial portion of the curriculum, indicating a significant focus on environmental education. A notable aspect of the quantitative findings is the detailed exploration of future scenarios, with a particular emphasis on the future itself, suggesting that the curriculum is designed to orient students towards thinking about long-term impacts and outcomes.

The analysis also reveals a balanced representation of hopes and fears, underscoring an approach that encourages students to consider both positive and negative future possibilities. In terms of Temporal Scale, the future-oriented content significantly outweighs the past and present discussions, highlighting an educational strategy aimed at fostering forward-thinking. The Spatial Scale analysis shows a preference for national and global contexts, which suggests that the curriculum aims to develop students’ understanding of both local and worldwide issues. The method of Delivery, as revealed through the content analysis, leans towards non-continuous formats, indicating a diverse approach to presenting futures thinking content, possibly to cater to different learning styles and to facilitate a more engaging and reflective learning experience. These key findings from the quantitative analysis provide a clear picture of how Futures Thinking is embedded within the curriculum, emphasizing a forward-looking, globally conscious, and technologically informed educational approach. This not only addresses the first research question but also sets the stage for understanding the methods and contexts of delivery, which are crucial for fostering a deep engagement with futures thinking concepts among students.

Comparing these quantitative results from third-grade middle school science textbooks in Japan with Chou’s (2021) study of elementary school textbooks in Taiwan highlights key differences in the presentation and emphasis of global issues and Futures Thinking, attributable not only to the educational level but also to the methodological approaches of each study. Chou's findings indicate that global issues within Taiwanese elementary textbooks are predominantly framed within the present, with a spatial focus on immediate, relatable settings like the classroom and family. This contrasts with the Japanese middle school textbooks, which exhibit a pronounced orientation towards future scenarios and a broader spatial context, including national and global scales alongside personal and natural environments. This difference in focus can partly be attributed to the distinct units of analysis used in the two studies: while this analysis on Japanese textbooks employed paragraph-level coding to dissect content themes, Chou's study might have utilized a different coding unit, potentially influencing the granularity and scope of identified themes. Additionally, the variance in educational levels—elementary in Taiwan versus middle school in Japan—naturally predicates a deeper and more expansive exploration of topics in the latter, as older students are expected to engage with more complex and forward-looking content. This methodological and contextual divergence underlines why Japanese textbooks might prioritize a broader and more future-focused approach. This approach aims to equip students with a nuanced understanding of their role in shaping both immediate and wider global futures, contrasting with the present and proximate focus observed in Chou's study of Taiwanese elementary education.

Conclusion

Addressing RQ1: Futures thinking content

Addressing the first research question on the content related to "Futures Thinking" present in the interdisciplinary units of third-grade middle school science textbooks in Japan, the analysis highlights a comprehensive incorporation of futures thinking concepts across different themes. Specifically, the curriculum embeds Futures Thinking within the "Nature and Human," "Science, Technology, and Human," and "Sustainable Development" chapters, demonstrating a broad and interdisciplinary approach to future-oriented education. In the "Nature and Human" chapters, Futures Thinking is articulated through discussions on biodiversity loss, the balance of ecosystems, and human impacts on natural environments. The curriculum guides students to envision both desired and undesired future scenarios based on current and historical ecological trends. This is exemplified in case studies like the predator-prey relationship between the Canadian lynx and the snowshoe hare, the degradation of satoyama landscapes, and the reintroduction of the crested ibis (toki) in Japan. These sections not only educate on biodiversity but also engage students in thinking about their role in shaping future ecological outcomes, emphasizing hopes for ecological balance and fears of irreversible biodiversity loss. In the "Science, Technology, and Human" chapters, futures thinking is explored through the lens of technological advancements and their societal implications. This includes discussions on the innovation of specialized wheelchairs for Paralympic athletes, advancements in artificial limb technology, and the role of exoskeleton robots in aiding mobility. Furthermore, these chapters delve into the critical issues of energy scarcity, fossil fuel depletion, and the push towards renewable energy sources, highlighting the need for sustainable and inclusive technological development. This content not only informs students about scientific advancements but also instils values of inclusivity, empathy, and the importance of technology in creating a more equitable society. The "Sustainable Development" chapters focus on the SDGs and the concept of backcasting, a planning method that starts with defining a desirable future and works backward to identify steps to achieve it. This is particularly applied to discussions on SDG 7 ("Affordable and Clean Energy") within the context of the 2025 Osaka Kansai World Expo. Additionally, these chapters critically examine the use of SDGs and advocate for a deeper engagement with sustainable and equitable development goals.

Quantitatively, the analysis underscores that "Science, Technology, and Human" chapters have the highest representation of futures thinking content, followed by "Nature and Human," with "Sustainable Development" being less represented. The thematic exploration of Futures Thinking demonstrates a significant focus on envisioning future scenarios, highlighting both positive and negative possibilities. The curriculum places a strong emphasis on the future, aiming to foster a forward-thinking mindset among students. This is further reflected in the method of delivery, which favours non-continuous formats to engage students in a diverse and reflective learning experience. Overall, the content related to Futures Thinking in these textbooks is designed to equip students with the knowledge, skills, and perspectives necessary to actively engage in shaping sustainable, inclusive, and technologically advanced futures. This approach not only addresses the curriculum's content requirement but also cultivates a sense of responsibility and empowerment among students to contribute effectively to future societal and environmental outcomes.

Addressing RQ2: Futures Thinking context

The quantitative analysis of the integration and delivery of Futures Thinking within the interdisciplinary units of third-grade middle school science textbooks in Japan offers a comprehensive overview, informed by the detailed coding outlined in the analysis results. This analysis sheds light on the curriculum's structured approach to equipping students with the knowledge and skills necessary to navigate future challenges and opportunities. The curriculum integrates futures thinking across various thematic areas, with "Science, Technology, and Human" receiving the highest representation, indicating a strong focus on preparing students for the impacts and ethical considerations of scientific and technological advancements. Despite "Sustainable Development" being less represented, it plays a crucial role in fostering an understanding of environmental stewardship and sustainable practices, emphasizing the importance of addressing global challenges through sustainable solutions. The thematic exploration within "Picturing the

Future" reveals a balanced emphasis on "Futures of Science" and "Hopes and Fears," both receiving considerable attention. This balance underscores the curriculum’s objective to engage students in envisioning both the promising advancements in science and technology and the potential concerns and challenges that may arise, fostering a nuanced understanding of future possibilities. In "Planning for the Future," the curriculum places a significant focus on adopting the precautionary principle, highlighting the importance of proactive and preventative measures in addressing future uncertainties and challenges. This focus is complemented by the inclusion of content related to evaluating action outcomes and managing risks and changes, further emphasizing the curriculum’s commitment to preparing students for dynamic and uncertain future landscapes.

The analysis indicates a diverse methodological approach to delivering futures thinking content, with a higher representation of "Non-continuous" formats. This suggests the curriculum employs a variety of instructional strategies, such as project-based learning, case studies, and scenario planning, to engage students in active and reflective learning experiences. These methods aim to foster a deep understanding of futures thinking by encouraging students to explore different scenarios, analyse potential outcomes, and consider the implications of their decisions and actions. The temporal scale analysis further emphasizes the curriculum’s future orientation, with a significant focus on future scenarios over historical or present contexts. This forward-looking approach is designed to cultivate a mindset among students that is attuned to long-term impacts and the broader implications of current decisions. Within this future orientation, "Desirable" outcomes are most highlighted, suggesting an educational emphasis on inspiring students towards positive contributions to future societies. Spatially, the curriculum spans a range of scales from personal to global, with a notable emphasis on national contexts. This reflects an intention to ground futures thinking in contexts that are both relatable and expansive, enabling students to understand their role in shaping the future within their immediate environments and the wider world.

Futures Thinking in the textbooks from the lens of interdisciplinarity

The application of Futures Thinking within Japanese middle school science textbooks, as informed by Erduran (2014), exemplifies an interdisciplinary approach that transcends traditional scientific boundaries. This approach integrates societal, cultural, and ethical dimensions, essential in the three critical stages of Futures Thinking: envisioning, predicting, and planning. During the envisioning stage, this interdisciplinary perspective, as highlighted by Erduran (2014), broadens the scope of potential futures. This is evident in the "Nature and Human" chapters, where the combination of historical, societal, and environmental aspects fosters a multifaceted understanding of human-nature interactions. Such a comprehensive view is vital for predicting future scenarios, ensuring that forecasts are not only scientifically robust but also socially and ethically informed. The discourse on biodiversity, blending ecological knowledge with cultural and ethical implications, is a clear manifestation of this approach.

In the "Science, Technology, and Human" chapters, the integration of societal and ethical considerations in discussions about technological advancements reflects the principles outlined by Kapon and Erduran (2021). They emphasize the importance of crossing disciplinary boundaries in science education, resonating with Akkerman and Bakker's (2011) framework. This methodology extends beyond traditional scientific education, encouraging students to envision a future where technology is aligned with broader societal values and ethical considerations. The chapters on "Sustainable Development" operationalize Futures Thinking through backcasting from the SDGs and the 2025 Osaka Kansai World Expo. This approach underscores the need for a holistic perspective in strategic planning, as recommended by Erduran (2014). It emphasizes the importance of considering diverse societal, cultural, and ethical factors in envisioning and actualizing sustainable futures, thereby aligning with the interdisciplinary approach advocated by Kapon and Erduran (2021).

Limitations and implications

In considering the findings related to the delivery and context of Futures Thinking in Japanese third-grade science textbooks, it is important to view the limitations as opportunities for growth and reflection. The scope of content analysis, while specific to third-grade science textbooks in Japan, opens the door for broader investigations across different educational levels and subjects, potentially enriching our understanding of Futures Thinking in diverse educational contexts. The dynamic nature of educational content, rather than a constraint, is an exciting reminder of the evolving landscape of education and the continuous need for updates and revisions to keep pace with scientific and societal changes. Similarly, the cultural context, specific to Japan, provides a unique case study, encouraging cross-cultural comparisons and adaptations of Futures Thinking education globally. The focus on quantitative aspects of Futures Thinking paves the way for more in-depth qualitative research to gauge the impact and resonance of these concepts with students, teachers, and educational stakeholders.

The implications of these findings are profound and far-reaching, laying a foundation for significant educational enhancements. They underscore the necessity of a diversified and comprehensive curriculum that embraces a wide range of interdisciplinary contexts and interactive methodologies. Such a curriculum will not only engage students more effectively but also provide them with a richer understanding of the complexities of the future. This need for a dynamic curriculum further highlights the importance of robust teacher training programs and resources to empower educators with the skills required to navigate and impart complex Futures Thinking. Moreover, these findings can influence educational policy decisions, advocating for increased research, investment, and integration of Futures Thinking in national curricula. The emphasis on global challenges, particularly climate change, calls for an education system that fosters a planetary perspective, preparing students to address transnational issues collaboratively and ethically.

Lastly, the study opens numerous avenues for further research, inviting more comprehensive and comparative studies that could provide deeper insights and guide the development of more effective Futures Thinking educational strategies. As we embrace these opportunities and implications, we move towards cultivating an informed, adaptive, and proactive society, well-equipped to navigate and shape the future.

To optimize the integration of Futures Thinking in science textbooks, it is recommended that future editions further diversify the contexts and methods of delivery to enhance student engagement and understanding. While the current curriculum effectively addresses various aspects of Futures Thinking through a blend of thematic areas, there is an opportunity to expand on less represented themes such as "Sustainable Development" to provide a more balanced view of future challenges and opportunities. Incorporating more interactive and experiential learning methods, such as augmented reality experiences or virtual simulations, could offer students immersive ways to explore complex future scenarios and the consequences of different decisions. Additionally, increasing the emphasis on "Multiple Futures" and "Backcasting" methodologies could encourage students to critically evaluate a wider range of potential outcomes and develop robust strategies for achieving desirable futures. Engaging with Futures Thinking through a multidisciplinary lens, integrating insights from social sciences, ethics, and environmental studies, would also enrich the curriculum, fostering a holistic understanding of how various factors interplay to shape future realities. By enhancing the curriculum with these recommendations, textbooks can better prepare students to navigate, contribute to, and thrive in an uncertain and rapidly changing world.

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