Enhancing Interdisciplinary Critical Thinking Skills in Higher Education With Improved Content Selection and Syllabus Sequencing Presented by Relationship Mapping

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Abstract

This paper presents an integrated teaching approach aimed at enhancing interdisciplinary critical thinking (CT) skills in higher education by improving content selection and syllabus sequencing. The approach is grounded in Cognitive Load Theory (CLT), which states that course content is biologically secondary knowledge and should be selected and sequenced in an organized manner to minimize cognitive load, allowing students to better grasp interdisciplinary connections. Based on the CLT, the approach proposes that the content and syllabus should be sequenced through three primary stages, including Core Domain, Complementary Domains, and Exogenous Domains. A key feature of this approach is the use of Relationship Mapping (RM), a visual-based tool that helps students understand and apply interdisciplinary relationships within the course material. RM is used to enhance the presentation of topic sequencing and lecture summaries, while students are required to design and develop RM in their assignments to support understanding and answer visualization. The effectiveness of this approach was tested using the Mann-Whitney U test with survey results from students taking a final-year undergraduate course on Intermodal Transportation, a senior year undergraduate course. The experimental group demonstrated significant improvement in analytical skills, self-efficacy, self-regulation, and out-of-the-box thinking compared to the control group. However, no significant gains were observed in evaluative reasoning, interpretation, inference, creative self-concept, and personal identity, suggesting areas for further refinement. This study contributes to the existing literature by providing a novel method for enhancing interdisciplinary CT in higher education, particularly with mapping tools like RM.

Keywords: Interdisciplinary Critical Thinking, Content Selection and Syllabus Sequencing, Relationship Mapping

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Introduction

As outlined in the Delphi Report (Facione, 1990a), critical thinking (CT) is defined as the purposeful, self-regulatory process that involves interpretation, analysis, evaluation, and inference, along with the explanation of the evidential, conceptual, methodological, criteriological, or contextual factors that form the basis of judgment. CT encompasses a range of skills and dispositions essential not only for achieving academic success but also for equipping students to handle complex real-world challenges (Puig et al., 2019). It is recognized as one of the most vital cognitive skills for students (Din, 2020). Numerous studies have highlighted employers' concerns that university graduates may lack adequate CT development (Hart Research, 2018; OECD, 2022). Therefore, the adoption of effective pedagogical strategies to enhance student's CT is imperative.

Given the various definitions and characteristics of CT, this paper seeks to focus on enhancing the interdisciplinary thinking component of CT in higher education, aiming to better equip students with the ability to adapt to change and make sound decisions when confronted with complex problems in both academic and professional settings (Abrami et al., 2008; Calma & Davies, 2021). Interdisciplinary thinking involves the ability to integrate knowledge from diverse disciplines (Spelt et al., 2009). With the increasing need for graduates to collaborate across various fields, interdisciplinary education has gained significant attention in the existing literature (Lindvig et al., 2019). Interdisciplinary CT refers to CT skills specifically applied within interdisciplinary contexts. By evaluating issues from an interdisciplinary perspective, there is considerable potential for improving CT, particularly in the interpretation of information (Bassachs et al., 2020).

In this research, an integrated approach has been developed for content selection and syllabus sequencing in higher education courses, with a primary focus on cultivating interdisciplinary CT within the subject matter. The approach centers on grouping topics that are strategically sequenced and introduced in stages. As the course advances, students gain a deeper understanding of the progressively constructed interdisciplinary "big picture", thereby enhancing their interdisciplinary CT skills. The content selection and syllabus design are grounded in Cognitive Load Theory proposed by (Sweller, 1988), which emphasizes minimizing the cognitive load on students' working memory. This reduction in cognitive load allows students to more effectively grasp the interconnections between disciplines and apply these skills in problem-solving scenarios (Leppink & Duvivier, 2016). A key component of the integrated approach is the use of a visual-based mapping tool known as Relationship Mapping (RM) (Teo et al., 2023). RM is consistently employed in the classroom to illustrate the interdisciplinary and systemic relationships among selected topics. Students also utilize RM in problem-solving exercises to generate ideas and establish connections between interdisciplinary factors or concepts.

The remainder of this paper is structured as follows. The next section outlines the integrated approach, encompassing content selection, syllabus sequencing, RM, and the relevant literature. Section 3 presents the methodology, including the application of the integrated approach in an authentic classroom setting and the survey conducted. Section 4 provides a discussion of the findings, with concluding remarks presented in Section 5.

Integrated Approach & Literature Review

This section outlines the development of the integrated approach and reviews the related literature.

Content Selection and Syllabus Sequencing

The approach developed aims to enhance interdisciplinary CT, focusing on the integration of knowledge across diverse disciplines rather than merely accumulating information, which is characteristic of a multidisciplinary approach (Spelt et al., 2015). The goal is to establish effective content selection and syllabus sequencing in higher education courses to strengthen students' ability to connect distinct disciplines and integrate relevant knowledge and skills, which equips students to address complex problems (Gao et al., 2020).

Syllabus design plays a crucial role in fostering CT (Bean & Melzer, 2021). The literature on effective syllabus design often emphasizes the alignment of learning objectives, assessments, and instructional methods (Kandlbinder, 2020; Wagner et al., 2023; Wiggins & McTighe, 2007). Among various approaches, content selection and syllabus sequencing are foundational because they ensure a logical progression of knowledge, which is essential for facilitating comprehension and retention (Chi, 2009).

In the proposed approach of this study, the course content is organized and presented sequentially through three primary stages: (1) the *Core Domain*, which encompasses the foundational knowledge essential for comprehending the subject matter, including key theories, methodologies, and concepts; (2) the *Complementary Domains*, which cover related disciplines or sub-disciplines within the broader framework of the Core Domain; and (3) the *Exogenous Domains*, which, while less directly connected to the Core Domain, exert significant interdisciplinary influence. For instance, in the context of Intermodal Transportation, the Core Domain pertains to the efficient movement of primarily containerized goods using multiple modes of transport. The Complementary Domains address areas such as product management, focusing on the types of goods transported, and production management. The Exogenous Domains explore the impact of technological innovations, environmental regulations, and social responsibility. As the course progresses through these stages, the connections between the Core Domain and the other domains are highlighted to emphasize interdisciplinary relevance and a holistic view.

Sequencing the syllabus involves more than merely arranging topics in order; it focuses on reinforcing the connections between them, especially the interdisciplinary relationships as the course advances through different domains. The proposed syllabus sequencing is designed to align with the natural cognitive process involved in problem-solving. When addressing challenges within a specialized area, individuals typically begin by considering the most relevant factors, or "control variables" (Core Domain), that are directly related to the field. Subsequently, they examine less directly related factors, or "less controllable" elements (Complementary Domains), that may still prove useful, before moving on to broader and external influences (Exogenous Domains). The sequencing strategy in our approach follows a bottom-up methodology, beginning with problem-solving at the most immediate level to allow for a more customized solution before exploring other aspects of the issue. This method enables students to concentrate on specific concepts within the Core Domain before integrating these ideas into a broader, more comprehensive framework as they tackle complex problems.

Another key rationale for this sequence lies in the necessity of establishing a solid foundation of subject-specific knowledge (Core Domain) before integrating it with interdisciplinary areas (Complementary and Exogenous Domains). Cognitive Load Theory supports this strategy by highlighting the constraints of working memory on individuals' cognitive capabilities (Paas et al., 2003; Sweller, 2011). This theory emphasizes the critical role that working memory plays in effective instruction, making it a fundamental consideration in content selection and syllabus sequencing (Venkat et al., 2020). Cognitive Load Theory advocates for reducing unnecessary information complexity and cognitive burden, ensuring that all new information is effectively organized and processed within the limitations of working memory, which interacts with knowledge stored in long-term memory (Caskurlu et al., 2021; Owens & Sweller, 2008). The proposed content selection and syllabus sequencing align with these principles, aiding students in acquiring new knowledge by building on their existing knowledge base stored in long-term memory, thereby alleviating the demands on working memory, and consequently promoting better knowledge acquisition and retention in higher education.

Relationship Mapping

Visual-based mapping refers to the graphical structuring and virtual display of information, functioning as a vital educational tool (Choudhari et al., 2021). It begins with a central theme from which related concepts are connected, forming hierarchical and relational linkages. These two-dimensional visual structures encourage creativity and flexibility in logical reasoning, providing a contrast to the traditional linear approach of note-taking (Groffman & Wolfe, 2019). Key examples of mapping tools include mind mapping and concept mapping (Davies, 2011). Mind mapping focuses on an image-cantered diagram where related ideas or sub-topics radiate outward from a core theme, fostering a creative and fluid exploration of content within a domain (Eppler, 2006). On the other hand, concept mapping arranges ideas hierarchically to show meaningful relationships between them, thereby improving the clarity and organization of thought (Watson, 1989).

RM distinguishes itself from other mapping tools by emphasizing problem-solving within the interdisciplinary CT framework. Although RM shares the basic principle of creating "linkages" between ideas, concepts, or variables, it is particularly focused on highlighting the interdependencies between problem factors, which can be illustrated as either cause-and-effect links (single-headed arrows) or mutual dependencies (double-headed arrows). Unlike concept maps, RM does not impose a strict hierarchical structure, and unlike mind maps, it does not extend concepts from a single central idea. Instead, RM is centred on domains, expanding the map progressively across interdisciplinary areas. The method of content selection and syllabus sequencing in this study's syllabus design is closely aligned with RM's domain-focused methodology, enhancing students' comprehension of the material and their interdisciplinary CT skills. Moreover, RM's domain-based mapping approach is designed to be more straightforward, with the development of the map being introduced to students incrementally as the syllabus progresses. This straightforwardness reduces the instructional time needed to teach the mapping technique, addressing issues noted by Machado and Carvalho (2020), where students often find it challenging to draw connections in concept maps and may be discouraged by the time-intensive nature of mastering and applying this method.

Literature Gap and Objectives

Implementing effective and sustainable pedagogical strategies in higher education is crucial for helping students develop and apply CT skills in everyday situations (Salinas-Navarro et al., 2024). As a result, the literature has introduced a range of teaching methods designed to improve students' CT skills, including written tasks, group activities, inquiries, problem-solving exercises, case studies, oral presentations, and feedback (Bezanilla et al., 2019). Among these approaches, written assignments, group discussions and projects, oral presentations, and debates have been widely adopted in interdisciplinary curricula (Aslan & Aybek, 2020; Cowden & Santiago, 2016; Khan & Wells, 2023; Oudenampsen et al., 2023). These methods are particularly effective because they offer structured guidance and instruction from educators, which helps students develop and refine CT skills, including judgment and reflection (Alsaleh, 2020). However, challenges such as technical difficulties, increased workloads for both teachers and students, and students' lack of self-motivation for active participation hinder the broader adoption of these methods in interdisciplinary settings, thereby limiting the enhancement of students' CT skills (Nichat et al., 2023; Vu, 2023). In contrast, mapping as a tool for improving interdisciplinary CT has received relatively little attention. This highlights a gap in the literature regarding the impact of mapping tools, such as RM, on enhancing students' interdisciplinary CT skills in higher education.

To address this gap, this study aims to design and evaluate the impact of an integrated teaching strategy that incorporates enhanced content selection and syllabus sequencing using RM, with the goal of fostering students' interdisciplinary CT skills in higher education. The study distinguishes itself from existing literature in several ways. Firstly, it applies Cognitive Load Theory to optimize the selection and sequencing of content within interdisciplinary courses at the higher education level. Moreover, it develops a teaching methodology that combines content selection and syllabus sequencing with RM to effectively enhance interdisciplinary CT skills. Further, it explores broader applications of RM, focusing on its effectiveness in complex and interdisciplinary scenarios.

Methodology

Intervention and Participants

To assess the effectiveness of the proposed approach, it was implemented in the final-year undergraduate course Intermodal Transportation, a senior year undergraduate course that focuses on a specialized area of freight transport. It is part of the Maritime Studies program at Nanyang Technological University, Singapore. By adopting the integrated approach, the course content was revised, the syllabus was restructured, and RM was utilized to present the material in a way that more effectively enhances students' interdisciplinary CT when engaging with real-life case studies and assignments.

The pre-intervention syllabus for Intermodal Transportation focused on topics related to the hardware, operations, and management of freight transportation across different modes, with particular emphasis on the movement of marine containers. These topics formed the Core Domain of the course. The redesigned syllabus introduced new topics that explore the interconnections with other closely related factors and decision-making processes, specifically those concerning transportation nodes (e.g., location and distance) and the materials or products being transported (e.g., inventory management). These additions are followed by discussions on other important, though less directly related, aspects that affect transportation decisions, including production, product sourcing, and sales/marketing, which collectively form the Complementary Domains. Finally, the syllabus covers the Exogenous Domains, which include environmental considerations (e.g., carbon footprint and regulations), government policies, social factors, and technological advancements. Due to the fixed number of class hours, the addition of new topics required the removal of certain existing ones. This intervention allowed for the identification of topics that could be omitted, primarily those related to transport equipment, which students are likely to learn more effectively through industry experience.

The RM was gradually introduced in alignment with the syllabus, serving both as a teaching aid and a problem-solving tool. Students were provided with opportunities to apply RM in problem-solving tasks during class discussions. Additionally, the intervention included a design-based take-home assignment, requiring students to develop a transportation plan for the international shipment of consumer goods with varying characteristics. A hypothetical company, along with its key features such as sales profile and strategic plans, was provided as the context. Given the open-ended nature of the problem, students were expected to state their assumptions to support their arguments and were encouraged to conduct independent research to substantiate their recommendations. The assessment was guided by rubrics derived from the California Critical Thinking Skills Test (CCTST) (Facione, 1990b). These rubrics were adapted to be observable and measurable, ensuring clarity and ease of understanding for students. The rubrics assessed four key areas: Interpretation and Analysis of the Problem, Recommendations, Limitations, and Overall Reasoning.

The effectiveness of the integrated approach was assessed by measuring and comparing student performances between an experimental group and a comparison group. Logistical constraints required these groups to be enrolled in different semesters, making a simultaneous experimental design impractical. Conducting the experimental group after the comparison group provided additional preparation time for the intervention. It is not expected that the order of the groups would impact the findings. Both groups comprised final-year Maritime Studies students who completed the same curriculum and met identical admission criteria, ensuring a consistent level of academic proficiency and inherent experimental control.

Survey

A survey was administered to both the comparison and experimental groups at the end of the course. The survey measured nine CT constructs identified from the literature, including analytical skills, evaluative reasoning, interpretation, inference, creative mindset, creative self-concept, creative personal identity, self-efficacy in CT, self-regulation, and out-of-the-box thinking (Dyck et al., 2012; Facione, 1992; Gelerstein et al., 2016; Stupple et al., 2017).

Analytical skill involves the ability to grasp the meaning and importance of statements and concepts and to determine how they are inferentially related (Facione, 1990a). Evaluative reasoning focuses on the ability to assess the credibility and relevance of statements, as well as to justify the logical connections between them (Facione, 1990a). Interpretation refers to the skill of clarifying and demonstrating an understanding of information, while inference pertains to drawing logically sound and defensible conclusions (Bellaera et al., 2021; Facione, 1990a). Self-efficacy in CT is defined as an individual's belief in their competence in CT (Stupple et al., 2017). Self-regulation encompasses the readiness and ability to consciously oversee one's cognitive processes, reflect on reasoning, perform self-assessments, and take corrective measures when necessary (Dyck et al., 2012). Thinking outside the box involves the inclination to surpass conventional thinking patterns (Tsui, 2008). Additionally, two creativity-related constructs are considered, which are creative self-concept and creative personal identity. Creative self-concept refers to how individuals perceive their creativity, while creative personal identity reflects the degree to which creativity is viewed as a central aspect of one's self-concept (Karwowski, 2016; Lebuda et al., 2020). Confidence in and beliefs about one's creativity can have a positive impact on CT (Álvarez-Huerta et al., 2022). Table 1 outlines samples of the survey questions and corresponding literature sources. All responses were recorded on a five-point Likert scale, with 1 representing strong disagreement, 3 indicating neutrality, and 5 signifying strong agreement.

Table 1: Survey Questions

Construct	Samples of measurement items	References
Analytical skill	Total of 4 questions. *Sample: I identify causal relationships among the components in the information given.*	(Teo et al., 2023)
Evaluative reasoning	Total of 4 questions. *Sample: I evaluate the credibility of every detail in the information given.*	(Sosu, 2013)
Interpretation	Total of 3 questions. *Sample: I identify which elements are important for solving a problem.*	(Gelerstein et al., 2016)
Inference	Total of 4 questions. *Sample: I identify what additional information is needed to decide between two contradicting opinions.*	(Gelerstein et al., 2016)
Self-efficacy	Total of 3 questions. *Sample: It is useful in improving my confidence in identifying what is important in solving logistics problems.*	
Self-regulation	Total of 4 questions. *Sample: I think critically/creatively about the procedures needed for effective logistics management.*	(Dyck et al., 2012)
Think-out-of-the-box	Total of 4 questions. *Sample: I analyze logistics management problems from different perspectives.*	
Creative self-concept	Total of 5 questions. *Sample: I am good at proposing original solutions to problems.*	(Karwowski et al., 2013)
Creative personal identity	Total of 5 questions. *Sample: Being clever, original, and inventive are characteristics which are important to me.*	(Karwowski et al., 2013)

The survey participants were selected through convenience sampling, comprising all students from both the comparison and experimental groups. These participants were intended to represent university students, particularly those with fundamental knowledge of their major and a general understanding of interdisciplinary studies. To ensure the quality of responses, students were required to record their start and finish times during the survey. Responses were considered invalid if they lacked start/end times or if the survey was completed in less than 3 minutes. In the comparison group, 47 responses were collected with 39 deemed valid for data analysis. In the experimental group, 53 responses were obtained with 51 qualifying for analysis.

Results and Discussion

The reliability and validity of the survey's measurement model were first evaluated for each group. The omega values for all constructs are above 0.7, with only one marginally below the threshold (0.691 for *Inference*). Therefore, the model's internal consistency is justified (Hayes & Coutts, 2020). Composite reliability for each construct was also calculated, with values exceeding 0.7, except for one instance (0.697 for *Inference*), confirming the reliability of the measurement model (Hair et al., 2019). Convergent validity was assessed through the average variance extracted, and all statistics were found to be above the recommended threshold of 0.50 (Hair et al., 2019). The heterotrait-monotrait (HTMT) ratios between each pair of constructs for both groups, all of which are below the recommended threshold of 0.9, thereby confirming the discriminant validity of the model (Henseler et al., 2015). Table 2 presents the descriptive statistics. An increase in mean values across all constructs is noted in the experimental group compared to the comparison group. According to existing literature, a two-sample t-test is appropriate for comparing the means of two independent samples (i.e., the comparison and experimental groups) if the normality assumption is satisfied, as indicated by the Shapiro-Wilk test. If this assumption is violated, the Mann-Whitney U test is recommended instead (Rochon et al., 2012). In this study, the normality assumption was not met, prompting the use of the Mann-Whitney U test to further substantiate the approach's effectiveness. The results, detailed in Table 4, reveal significant improvements in analytical skill, self-efficacy, self-regulation, and out-of-the-box thinking, while no significant differences were observed in the other constructs.

Table 2: Comparison on Survey Results

	Mean (S.D.)		Mean difference	Mann-Whitney U test	
	C(n=31)	E(n=38)	E - C	*p-value*	Effect size[a]
Analytical skill	3.58 (0.696)	3.84 (0.571)	0.261*	0.064	0.213
Evaluative reasoning	3.39 (0.824)	3.59 (0.787)	0.205	0.218	0.109
Interpretation	3.56 (0.757)	3.65 (0.605)	0.090	0.488	0.005
Inference	3.81 (0.654)	3.99 (0.526)	0.181	0.246	0.095
Creative self-concept	3.45 (0.660)	3.58 (0.661)	0.127	0.241	0.098
Creative personal identity	3.12 (0.875)	0.15 (0.873)	0.026	0.529	0.009
Self-efficacy	3.76 (0.546)	4.12 (0.474)	0.36***	0.002	0.346
Self-regulation	3.29 (0.786)	3.67 (0.624)	0.391*	0.057	0.220
Think-out-of-the-box	3.32 (0.823)	3.71 (0.591)	0.388**	0.039	0.244

Note: E: Experiment group. C: Comparison group. *, **, ***: Significance at 0.10, 0.05, 0.01 level. [a]: Rank biserial correlation.

The improvement in students' analytical skills aligns with the objective of the integrated approach, as the interdisciplinary CT process underlying this method helps clarify the inferential connections between different disciplines (Davies, 2011). This enhancement was also likely supported by the content selection and syllabus sequencing, which follows RM's systematic process of establishing and inferring interdisciplinary relationships. Moreover, the inclusion of a design-based assignment allowed students to utilize RM and interdisciplinary CT skills to address open-ended, real-world problems, which not only strengthened their confidence in their thinking abilities but also enhanced their self-efficacy. The observed improvement in self-regulation can be attributed to the focus on a mapping process that is consistent with the content selection and syllabus sequencing across disciplinary domains. This approach, by reducing cognitive load, may have encouraged students to consciously evaluate their cognitive processes. Additionally, the emphasis on interdisciplinary CT likely promoted deeper reflection on their reasoning and self-assessment, particularly when creating linkages in the maps. The intervention also provided concrete evidence of learning outcomes and conceptual understanding, which likely contributed to enhanced self-regulation in students' learning processes (Chularut & DeBacker, 2004). Furthermore, the interdisciplinary content, combined with CT fostered by RM, encouraged students to explore various innovative solutions, thereby improving their ability to think outside the box.

Conclusion

This study introduced a teaching approach that integrates content selection and syllabus sequencing, presented through RM. By leveraging Cognitive Load Theory, this integrated approach helps students in higher education enhance their interdisciplinary CT by minimizing unnecessary information complexity within the constraints of working memory, and by promoting a bottom-up thinking pattern (i.e., starting with the Core Domain, followed by Complementary and Exogenous Domains). The approach has been shown to effectively improve certain CT dispositions, including analytical skill, self-efficacy, self-regulation, and think out-of-the-box. However, other CT dispositions, such as evaluative reasoning, interpretation, inference, creative self-concept, and creative personal identity, require further refinement of the approach to achieve significant improvement.

This integrated approach makes a notable contribution to the existing literature by addressing the gap concerning the lack of studies on the impact of mapping tools in enhancing students' interdisciplinary CT, particularly in higher education. Additionally, it provides a theoretical foundation for using RM to structure content selection and syllabus sequencing in an interdisciplinary learning context.

However, there are some limitations to this study. First, the sample size is relatively small. Although the study met the requirements for the Mann-Whitney U test, future research should aim to gather data from a larger participant pool to yield more robust insights under normal conditions. Second, the approach was tested only on similar samples (i.e., undergraduate students from two cohorts of the same course). Future studies should apply the approach to more diverse samples (e.g., varying ages, institutions, majors, and courses) to validate its effectiveness in different contexts. This would allow for further refinement of the approach based on both quantitative (e.g., surveys) and qualitative (e.g., interviews and assignments) data. Finally, future research should incorporate the suggested improvements to the current approach (e.g., e-learning modules, critical evaluations of existing RM, and the development of individual RM) to test the effectiveness of these enhancements. This would help establish the approach as a more comprehensive intervention for enhancing interdisciplinary thinking in higher education.

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