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Interdisciplinary Project Studios for Developing Systems Thinking

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Abstract

Contemporary professional and societal problems rarely conform to the boundaries of a single academic discipline. Climate adaptation, public health, sustainable urbanization, digital governance, circular economies, organizational resilience, and responsible technological innovation involve interactions among technical, economic, environmental, behavioral, cultural, and policy systems. Higher education therefore increasingly requires learning environments in which students can integrate disciplinary perspectives rather than simply accumulate knowledge from separate subjects. Systems thinking is particularly relevant because it directs attention toward interdependencies, feedback relationships, boundaries, temporal effects, unintended consequences, and potential leverage points within complex systems. Recent higher-education scholarship continues to position systems thinking as an important competency for working with complex sustainability and interdisciplinary problems, while project-based and studio-based learning provide environments in which students can experience such complexity through iterative, collaborative work.

This study develops an Interdisciplinary Systems Project Studio as a structured pedagogical environment for cultivating systems thinking. A synthetic cohort of 640 students was distributed across four instructional conditions: disciplinary project teams, interdisciplinary project teams, interdisciplinary studios with systems mapping, and integrated systems studios combining stakeholder inquiry, systems mapping, prototyping, structured critique, iteration, and reflective synthesis. Outcomes included system-boundary framing, recognition of interdependencies, feedback-loop reasoning, temporal reasoning, trade-off analysis, leverage-point identification, interdisciplinary integration, and collaborative decision quality. The strongest studio condition achieved a simulated systems-thinking composite score of 91 compared with 58 for conventional disciplinary project teams. Its strongest gains occurred in feedback-loop reasoning, leverage-point identification, and integration of multiple disciplinary perspectives.

The methodological contribution lies in distinguishing interdisciplinarity from systems thinking. Merely placing students from several disciplines in the same project does not guarantee systemic reasoning. Previous interdisciplinary education research has shown that instructional structure influences the development of interdisciplinary competence, while contemporary studio-based education emphasizes iterative making, critique, peer feedback, and tolerance for ambiguity. The proposed studio therefore requires students to externalize their understanding of the system through stakeholder maps, causal relationships, system boundaries, feedback structures, and intervention hypotheses before converging on a solution.

The study concludes that interdisciplinary project studios can function as effective laboratories for systems thinking when students are required to repeatedly connect disciplinary evidence, visualize relationships, test assumptions, encounter stakeholder constraints, critique proposed interventions, and revise their problem definitions. The principal educational objective should not be the production of a polished final prototype alone. It should be the development of learners who can understand why changing one part of a complex system may alter several other parts in ways that are delayed, nonlinear, or unintended.

Keywords: systems thinking, interdisciplinary education, project studio, project-based learning, studio-based learning, systems mapping, experiential learning, interdisciplinary competence, complex problem solving, higher education

1. Introduction

Many of the problems for which universities prepare graduates are not purely technical, economic, social, environmental, or managerial. They are combinations of these domains. Designing low-carbon mobility, improving community healthcare, managing water scarcity, creating ethical digital services, developing circular production systems, or responding to urban inequality requires professionals to understand interactions among technologies, institutions, human behavior, resource flows, incentives, regulations, and environmental conditions. Systems-thinking scholarship consequently emphasizes the capacity to understand interconnected system elements rather than analyzing each component independently. Within sustainability education, systems-thinking competence has been identified as an important capability for understanding complex relationships among social, environmental, and economic dimensions.

Interdisciplinary education provides one pathway for developing this capability because students are required to encounter explanations and methods that differ from those of their own disciplinary training. However, interdisciplinarity cannot be equated automatically with systems thinking. A multidisciplinary team can divide a project into separate technical, financial, social, and design tasks and then combine the outputs at the end without developing a genuinely integrated account of the problem. Brassler and Dettmers' comparative research on interdisciplinary problem- and project-based learning demonstrates that the design of the educational process matters to the development of interdisciplinary competence rather than the mere presence of multiple disciplines. Contemporary research universities similarly continue to examine how interdisciplinary learning environments influence students' interdisciplinary competencies.

Project-based learning offers a stronger opportunity for integration because students work on complex products or problems over an extended period. A 2023 meta-analysis of project-based learning reported positive effects on several student learning outcomes, including academic achievement, motivation, and higher-order thinking, although effects vary according to educational design and context. More recent higher-education studies continue to connect project-based learning with authentic challenges, teamwork, self-regulation, problem solving, and recognition of the systemic nature of professional problems. Project work nevertheless becomes genuinely systemic only when students are asked to investigate relationships and consequences rather than rushing immediately toward a deliverable.

Studio-based learning adds another pedagogical layer. Although traditionally associated with architecture, art, and design, contemporary studio pedagogy is increasingly being applied to management and other interdisciplinary domains. Ryan and colleagues' 2025 work on studio-based responsible-management education emphasizes experiential, visual, iterative learning through activities such as critique, prototyping, and peer feedback, with the studio supporting adaptive thinking, collaborative problem solving, and tolerance for ambiguity. Design-studio scholarship likewise continues to examine how studio environments can integrate pedagogical innovation, cross-disciplinary collaboration, and iterative learning. The studio is therefore not simply a physical classroom; it is a social structure in which partially developed ideas remain visible, negotiable, and repeatedly revisable.

The present study integrates these traditions through an Interdisciplinary Systems Project Studio. Its central proposition is that systems thinking develops most effectively when interdisciplinary collaboration is combined with explicit systems tools and repeated cycles of externalization, critique, experimentation, and reframing. Students are not asked only to produce an interdisciplinary solution. They are required to explain the system in which that solution will operate, identify relationships and feedback effects, justify their system boundaries, examine unintended consequences, and revise their intervention after critique. The study compares four progressively integrated project models to determine how such design features might influence systems-thinking competence.

2. Objectives of the Study

2.1 To Evaluate Interdisciplinary Project Studios as Environments for Systems-Thinking Development

The first objective is to determine whether sustained interdisciplinary studio work can improve students' ability to frame system boundaries, recognize interdependencies, identify feedback relationships, reason across time, and understand unintended consequences.

2.2 To Distinguish Interdisciplinary Collaboration From Genuine Systems Integration

The second objective is to examine whether simply assembling students from different disciplines is sufficient for systems thinking or whether explicit practices such as systems mapping, structured critique, stakeholder analysis, and iterative reframing are necessary.

2.3 To Develop a Studio-Based Systems-Thinking Pedagogical Framework

The third objective is to develop a practical higher-education model combining authentic interdisciplinary projects, stakeholder inquiry, system visualization, iterative prototyping, peer critique, reflective synthesis, and assessment of both team products and individual systems reasoning.

3. Review of Literature

3.1 Systems Thinking as an Interdisciplinary Higher-Education Competence

Systems thinking refers broadly to forms of reasoning that focus on relationships, interdependence, system structure, feedback, boundaries, change over time, and behavior emerging from interactions among system components. Although terminology varies across disciplines, contemporary scholarship continues to identify systems thinking as an important cognitive resource for understanding complex systems. A 2026 multidisciplinary review of systems-thinking scholarship emphasizes that definitions and uses differ across disciplinary communities, which itself demonstrates why interdisciplinary educational settings can be valuable for exposing students to alternative systems perspectives.

Within sustainability education, Wiek, Withycombe, and Redman's competency framework positioned systems thinking alongside anticipatory, normative, strategic, and interpersonal competencies. Their work helped establish systems thinking as a capability relevant to complex sustainability problem solving and academic-program development. Demssie and colleagues subsequently examined pedagogical strategies for fostering systems-thinking competence and emphasized understanding relationships among social, environmental, and economic dimensions.

Recent higher-education scholarship continues to move systems thinking toward applied pedagogy. Peretz and colleagues describe real-world interdisciplinary scenarios as one means of making systems thinking teachable rather than leaving it as an abstract concept. Khajuria and colleagues' 2026 work similarly argues that systems thinking can strengthen circular-economy education by enabling learners to understand material, social, economic, and governance relationships rather than optimizing isolated waste-management variables.

These approaches share an important implication: systems thinking is demonstrated through how students organize relationships, not merely through whether they know systems terminology. Students need opportunities to define boundaries, identify stakeholders, map causal relationships, compare timescales, and examine how an intervention may generate secondary effects.

3.2 Interdisciplinary Project-Based Learning and Knowledge Integration

Project-based learning can expose students to problems whose solution requires knowledge from several disciplines. Chang and colleagues' interdisciplinary, project-oriented problem-based curriculum required undergraduates to address climate and urban issues, illustrating the educational potential of organizing learning around complex challenges rather than disciplinary exercises. Interdisciplinary project environments can stimulate creative thinking because teams must combine concepts and methods that would not ordinarily be placed together.

However, interdisciplinary teams can experience what may be called parallel disciplinarity. Each student contributes the portion that matches their specialization, but meaningful integration occurs only superficially. Research comparing interdisciplinary problem-based and project-based learning found that interdisciplinary competence depends strongly on instructional processes that encourage perspective taking, reflection, and integration.

This distinction is particularly important for systems thinking. An engineer may design a technically effective intervention, an economist may calculate cost, a policy student may discuss regulation, and a designer may improve the interface. Yet the final proposal can still be nonsystemic if the team never examines how these dimensions affect one another.

Project pedagogy should therefore include explicit integration events. These may involve common problem-framing workshops, shared causal maps, cross-disciplinary evidence reviews, stakeholder sessions, trade-off discussions, and team explanations in which members must articulate how one discipline's assumption changes another discipline's proposed solution.

3.3 Studio Pedagogy, Critique, Iteration, and Complex Problem Solving

Studio pedagogy is distinctive because knowledge remains visible through work in progress. Students develop artifacts, diagrams, prototypes, concepts, or models that can be examined by peers and instructors before they are complete. Ryan and colleagues' studio-based responsible-management model emphasizes experiential and iterative processes in which critique and prototyping are central learning mechanisms. Contemporary architectural and design-studio research similarly describes studios as active learning environments emphasizing interdisciplinary collaboration, iteration, industry or stakeholder engagement, and reflective practice.

This structure is highly compatible with systems thinking because students' representations can be criticized before the solution becomes fixed. A causal map can reveal a missing stakeholder. A prototype can expose an assumed behavior that does not occur. A peer from another discipline can identify an omitted environmental or financial consequence. Critique can therefore operate not only on the quality of a design but on the quality of the underlying system model.

Studio iteration also supports learning from unintended consequences. Students can first propose an intervention, then simulate or discuss what would happen if the system responded differently from expectation. This encourages movement away from linear reasoning of the form "problem → solution" toward a more systemic cycle of "structure → intervention → response → feedback → adaptation."

The studio becomes particularly powerful when critique is interdisciplinary. Students are required to defend assumptions in language understandable outside their own discipline. This process makes disciplinary blind spots more visible and transforms collaboration from task division into negotiated knowledge integration.

4. Research Methodology

4.1 Simulation Design and Studio Conditions

The study adopts a simulation-based comparative research design. A synthetic cohort of 640 students was created and allocated equally across four instructional conditions, producing 160 modeled students per condition.

The hypothetical cohort represented engineering, design, business, environmental science, social science, and public-policy backgrounds. Teams worked on semester-long challenges involving urban mobility, community energy transition, public-health access, food-system waste, digital public services, and climate-resilient neighborhoods.

The semester was modeled over 16 weeks, including problem framing, stakeholder exploration, system mapping, intervention design, critique, prototyping, iteration, and final synthesis.

Table 1: Simulated Interdisciplinary Project-Studio Conditions

Instructional Condition	Team Structure	Systems-Thinking Tools	Critique and Iteration	Principal Learning Characteristic
Disciplinary project teams	Students primarily from one field	No explicit systems tools	Conventional instructor feedback	Strong disciplinary application
Interdisciplinary project teams	Mixed academic backgrounds	Informal stakeholder discussion	Mid-project and final feedback	Cross-disciplinary collaboration
Interdisciplinary studio + systems mapping	Mixed teams	Boundary maps, stakeholder maps, causal relationships, feedback identification	Recurring studio critiques	Explicit system representation
Integrated studio + critique + iteration	Mixed teams plus stakeholder input	Systems maps, causal loops, temporal effects, trade-off matrices, leverage-point analysis	Repeated peer critique, prototype testing, reframing, reflective synthesis	Systems reasoning embedded throughout project lifecycle

4.2 Systems-Thinking Competence Measures

Eight dimensions were evaluated on a standardized 0–100 scale.

- System-boundary framing represented the student's ability to determine what should be included within the problem system and justify exclusions.
- Interdependency recognition measured identification of meaningful relationships among technical, social, environmental, economic, and institutional elements.
- Feedback-loop reasoning measured recognition that system outputs can influence later inputs and behavior.
- Temporal reasoning represented understanding of delays, cumulative effects, and short- versus long-term consequences.
- Trade-off analysis measured the ability to identify situations in which improvement in one dimension creates costs or risks elsewhere.

Leverage-point identification represented the ability to identify interventions capable of influencing wider system behavior rather than merely addressing visible symptoms.

Interdisciplinary integration assessed whether the final reasoning synthesized disciplinary perspectives rather than placing them side by side.

Collaborative decision quality measured the coherence of team decisions under competing evidence, stakeholder interests, and uncertainty.

4.3 Studio Learning Cycle and Assessment Procedure

The integrated studio condition followed seven recurring activities. Students first framed the problem and explicitly stated the boundary of the system under investigation. Teams then identified stakeholders and disciplinary assumptions before constructing an initial relationship map.

The third stage involved investigation of causal relationships, feedback effects, delays, and competing system objectives. Students then proposed potential leverage points rather than immediately selecting a final intervention.

During studio critique, other teams and instructors challenged assumptions, missing variables, weak causal claims, and potential unintended consequences. Students subsequently developed prototypes or intervention scenarios and revised the original system map in response to evidence.

The final stages required reflective synthesis. Each student explained how their understanding of the problem had changed, which disciplinary assumption had been revised, and what system consequences remained uncertain.

5. Analysis

5.1 Comparative Systems-Thinking Outcomes

The disciplinary project-team condition produced a simulated systems-thinking composite of 58. Students demonstrated relatively strong technical problem solving within their own fields but weaker scores in feedback reasoning and interdisciplinary integration.

Interdisciplinary project teams increased the composite to 70, demonstrating that exposure to multiple disciplinary perspectives provided a meaningful benefit. However, teams still showed uneven integration.

Adding explicit systems mapping increased the composite to 82. Improvements were particularly strong in system-boundary framing, interdependency recognition, and feedback-loop reasoning.

The integrated studio condition produced the strongest composite score at 91.

Table 2: Simulated Systems-Thinking Outcomes Across Project-Studio Models

Project-Studio Model	Boundary Framing	Interdependencies	Feedback Loops	Temporal Reasoning	Trade-Off Analysis	Leverage Points	Interdisciplinary Integration	Collaborative Decision Quality	Composite
Disciplinary project teams	63	61	49	55	60	51	48	77	58
Interdisciplinary project	72	75	62	66	73	64	72	76	70

Project-Studio Model	Boundary Framing	Interdependencies	Feedback Loops	Temporal Reasoning	Trade-Off Analysis	Leverage Points	Interdisciplinary Integration	Collaborative Decision Quality	Composite
teams									
Interdisciplinary studio + systems mapping	84	88	79	78	84	78	83	82	82
Integrated studio + critique + iteration	93	95	90	88	92	91	94	85	91

5.2 Why Interdisciplinary Teams Alone Are Insufficient

The comparison between the second and third conditions provides the most important result.
Interdisciplinary teams improved system understanding relative to disciplinary teams, but simply combining academic backgrounds did not consistently produce feedback-loop or leverage-point reasoning.

Students could recognize that several dimensions were relevant while still reasoning about those dimensions separately.

Systems mapping changed the task. Teams were required to demonstrate how one variable influenced another. A proposed change in public transport, for example, could alter accessibility, traffic demand, emissions, operating cost, land-use patterns, public acceptance, and future investment.
This requirement turned disciplinary contributions into relationships.

The studio critique process produced a further improvement because system maps were not treated as final representations. Peers were expected to challenge the boundary, question causal claims, identify missing stakeholders, and propose alternative feedback pathways.

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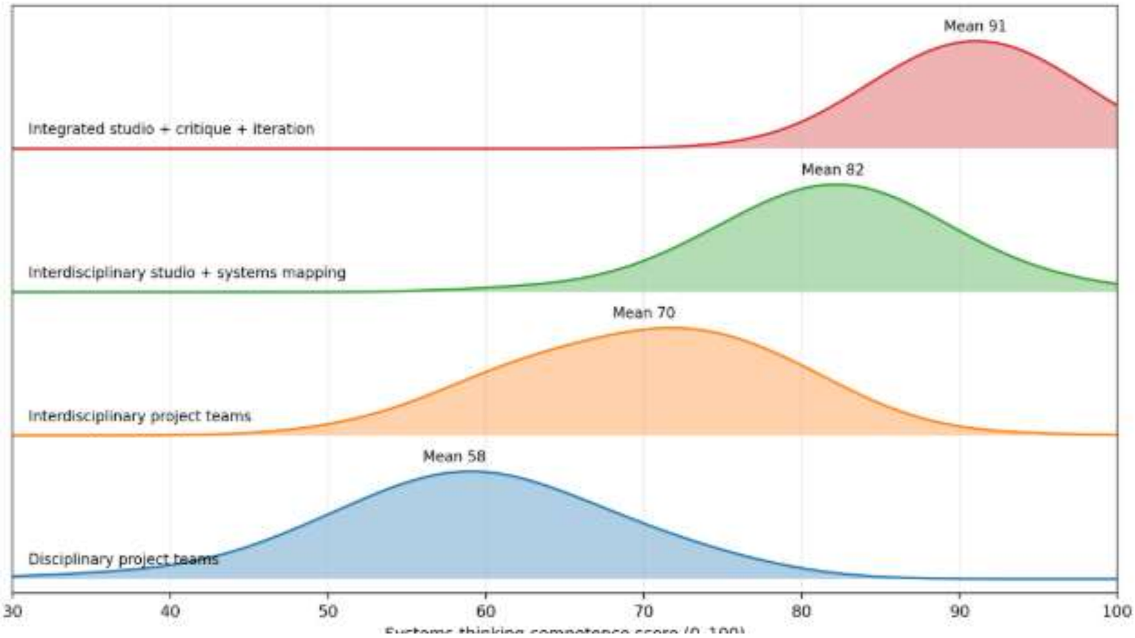
5.3 Distribution of Systems-Thinking Competence

Graph 1: Simulated Distribution of Systems-Thinking Competence Across Project-Studio Models



The ridgeline graph shows the full synthetic distribution of systems-thinking competence rather than only group averages.

The disciplinary project condition is concentrated around a mean score of approximately 58. The interdisciplinary project condition shifts the distribution toward 70, demonstrating the contribution of multiple disciplinary perspectives.

The central analytical finding is therefore that interdisciplinary exposure creates potential for systems thinking, but explicit system representation, critique, and iteration are what convert that potential into sustained systems competence.

6. Discussion

6.1 Systems Thinking Emerges When Disciplinary Knowledge Becomes Relational

The simulation suggests that systems thinking develops when students stop treating disciplinary knowledge as separate contributions and begin using those contributions to explain relationships. This distinction is fundamental. An interdisciplinary group can contain significant expertise without possessing an integrated understanding of the system. Brassler and Dettmers' research similarly demonstrates that interdisciplinary competence depends on educational processes that support reflection and integration rather than merely assembling multiple disciplines. The present framework extends that logic by making relationships themselves the object of learning.

System mapping functions as a boundary object through which students can negotiate different disciplinary interpretations. An economics student may represent an intervention through incentives, an engineer through physical infrastructure, a social scientist through behavior and institutions, and a designer through user interaction. Requiring the team to create one shared causal representation forces these views into conversation. The value of the map therefore lies less in producing a perfectly accurate diagram and more in making assumptions visible enough to be challenged.

Systems thinking also changes what counts as a good solution. A narrowly optimized intervention can produce local improvement while worsening another part of the system. Contemporary systems-thinking education increasingly emphasizes complex interrelationships and the need to move beyond isolated technical optimization. Students therefore need assessment criteria that reward consideration of consequences, feedback, and trade-offs rather than only solution novelty or technical feasibility.

The integrated studio creates this expectation repeatedly. Students cannot move directly from problem statement to final design. They must show what system structure they believe produces the problem and how the proposed intervention is expected to alter that structure.

6.2 Studio Critique Converts Complexity Into a Learnable Process

The second implication is that complexity becomes educationally manageable when students are allowed to externalize incomplete thinking. Traditional assessments often evaluate knowledge after the student has already produced a final answer. Studio pedagogy makes work visible while it is still developing. Ryan and colleagues emphasize critique, prototyping, iteration, and peer-led learning as characteristic strengths of studio-based education.

This process is particularly valuable for systems thinking because first interpretations of complex problems are almost always incomplete. A team may initially exclude an important stakeholder, assume a linear causal relationship, overlook a time delay, or treat a social response as fixed. Critique identifies these weaknesses before they become embedded in the final solution.

Iteration then gives students the opportunity to demonstrate learning by changing the model. The revised map becomes evidence that the team has incorporated another perspective or recognized an unintended consequence. In this sense, correction is not failure; it is a central studio outcome.

Peer critique also distributes expertise. Students learn not only from instructors but from disciplinary differences within and across teams. A public-policy student may identify a regulatory barrier overlooked by engineers, while an environmental student may identify rebound effects ignored by a business team. Interdisciplinary critique therefore turns difference into an instructional resource.

6.3 Assessment Should Reward System Understanding, Not Only Project Completion

The third implication concerns assessment. Project-based education can unintentionally reward students for producing attractive final products even when the underlying reasoning remains weak. A successful prototype may appear to demonstrate deep learning while concealing narrow problem framing or unsupported assumptions.

Systems-thinking assessment should therefore evaluate both the final intervention and the reasoning architecture that produced it. Students should receive credit for defining boundaries, mapping relationships, recognizing feedback, comparing time horizons, identifying trade-offs, evaluating leverage points, and revising assumptions.

This approach also protects disciplines from becoming superficial. Interdisciplinary education does not require students to become experts in every participating field. Instead, they need sufficient disciplinary literacy to recognize when another field changes the structure of the problem. The objective is integration, not disciplinary dilution.

Recent higher-education literature continues to emphasize that authentic project-based learning can strengthen transferable and interdisciplinary capabilities, but implementation quality and scaffolding remain decisive. The studio should therefore include faculty or mentors capable of asking discipline-specific questions while also facilitating integration.

Future empirical research should investigate whether systems thinking developed in a studio transfers beyond the original project. Students should be presented with unfamiliar systems problems after completion of the course and evaluated on whether they spontaneously identify boundaries, feedback, delays, and leverage points without being explicitly instructed to use a particular mapping tool. Transfer would provide stronger evidence that the studio has developed a durable mode of reasoning rather than temporary proficiency with systems diagrams.

7. Conclusion

Interdisciplinary project studios offer a promising environment for developing systems thinking because they bring together three pedagogical conditions that are often separated in higher education: authentic complex problems, disciplinary diversity, and iterative critique. The simulation presented in this paper indicates that interdisciplinary participation alone can improve students' recognition of multiple perspectives but may remain insufficient for deep systemic reasoning.

The synthetic systems-thinking composite increased from 58 under disciplinary project teams to 70 under interdisciplinary teams, 82 when systems mapping was added, and 91 under the integrated studio model. These scores do not represent measured educational outcomes. Their purpose is to demonstrate a comparative framework through which systems-thinking pedagogy can be evaluated empirically.

The principal contribution is the Interdisciplinary Systems Project Studio, in which students repeatedly move through problem framing, stakeholder exploration, system mapping, leverage analysis, prototyping, critique, iteration, and reflective synthesis. This structure prevents interdisciplinary work from becoming a simple division of labor. Every disciplinary contribution must eventually become part of a shared explanation of how the system behaves.

The broader educational conclusion is that students develop systems thinking not by being told that the world is complex but by being required to work responsibly inside that complexity. They need opportunities to make assumptions visible, discover contradictions, revise system boundaries, encounter unintended consequences, and defend interventions against perspectives different from their own. An effective interdisciplinary studio therefore does more than help students solve complex problems; it teaches them to recognize why those problems behave as systems in the first place.

References

1. Kordova, S. (2020). Developing systems thinking in a project-based learning environment. *International Journal of Engineering Education, 2*(1), 63–81. https://doi.org/10.14710/ijee.2.1.63-81.
2. Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research, 102*, 101586. https://doi.org/10.1016/j.ijer.2020.101586.
3. Cummings, C. M., & Cummings, T. M. (2020). Teaching non-majors hydroponics: PBL in higher education. *College Teaching*, *69*(1), 1–8. https://doi.org/10.1080/87567555.2020.1791036.
4. Warr, M., & West, R. E. (2020). Bridging academic disciplines with interdisciplinary project-based learning: Challenges and opportunities. *Interdisciplinary Journal of Problem-Based Learning, 14*(1). https://doi.org/10.14434/ijpbl.v14i1.28590.
5. Hart, J. L. (2019). Interdisciplinary project-based learning as a means of developing employability skills in undergraduate science degree programs. *Journal of Teaching and Learning for Graduate Employability*, *10*(2), 50–66. https://doi.org/10.21153/jtlge2019vol10no2art827.
6. Brassler, M., & Dettmers, J. (2017). How to enhance interdisciplinary competence—Interdisciplinary problem-based learning versus interdisciplinary project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 11*(2). https://doi.org/10.7771/1541-5015.1686.
7. Kordova, S., Frank, M., & Miller, A. N. (2018). Systems thinking education—Seeing the forest through the trees. *Systems, 6*(3), 29. https://doi.org/10.3390/systems6030029.
8. Grohs, J. R., Kirk, K. B., Soledad, M. M., & Knight, D. B. (2018). Assessing systems thinking: A tool to measure complex reasoning through ill-structured problems. *Thinking Skills and Creativity, 28*, 110–130. https://doi.org/10.1016/j.tsc.2018.03.003.
9. Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science*, *44*, 669–678. https://doi.org/10.1016/j.procs.2015.03.050.
10. Frank, M. (2000). Engineering systems thinking and systems thinking. *Systems Engineering, 3*(3), 163–168.
11. Sweeney, L. B., & Sterman, J. D. (2007). Thinking about systems: Student and teacher conceptions of natural and social systems. *System Dynamics Review, 23*(2–3), 285–311. https://doi.org/10.1002/sdr.366.
12. Booth Sweeney, L., & Meadows, D. (2010). *The Systems Thinking Playbook: Exercises to Stretch and Build Learning and Systems Thinking Capabilities*. Chelsea Green Publishing.
13. Gero, A., & Danino, O. (2016). High-school course on engineering design: Enhancement of students' motivation and development of systems thinking skills. *International Journal of Engineering Education, 32*(1), 100–110.
14. Weaver, J., & Kleinke, D. (2016). A flipped classroom approach to conveying the basics of systems thinking to engineering undergraduates. *Proceedings of the ASME 2016 International Mechanical Engineering Congress and Exposition*. https://doi.org/10.1115/IMECE2016-66069.
15. Yurtseven, M. K., & Buchanan, W. W. (2016). Decision making and systems thinking: Educational issues. *American Journal of Engineering Education, 7*(1), 19–28.

16. Dhukuram, A. V., Sgouropoulou, C., Feldman, G., & Amini, A. (2018). Higher education provision using systems thinking approach—Case studies. *European Journal of Engineering Education, 43*(1), 1–23. https://doi.org/10.1080/03043797.2016.1210569.
17. Yueh, H.-P., Liu, Y.-L., & Lin, W. (2015). Fostering interdisciplinary learning in a smart living technology course through a PBL approach. *International Journal of Engineering Education, 31*(1), 220–228.
18. Stozhko, N. Y., Bortnik, B., Mironova, L. I., Tchernysheva, A., & Podshivalova, E. (2015). Interdisciplinary project-based learning: Technology for improving student cognition. *Research in Learning Technology, 23*, 27577. https://doi.org/10.3402/rlt.v23.27577.
19. Adya, M., Temple, B. K., & Hepburn, D. M. (2015). Distant yet near: Promoting interdisciplinary learning in significantly diverse teams through socially responsible projects. *Decision Sciences Journal of Innovative Education, 13*, 121–149. https://doi.org/10.1111/dsji.12058.
20. Hart, J. L. (2019). Interdisciplinary project-based learning and the development of communication, teamwork, critical-thinking and problem-solving skills in undergraduate science education. *Journal of Teaching and Learning for Graduate Employability*, *10*(2), 50–66.