# Supporting Interdisciplinary Education in the Built Environment through Self- and Socially-Shared-Regulated Learning

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Tackling today's and tomorrow's societal, technological, and environmental challenges demands expertise that extends beyond the boundaries of any single discipline. Architects and engineers, in particular, must integrate knowledge and skills across domains while effectively communicating with professionals from diverse fields. In response, interdisciplinary education has gained momentum in built environment education, aiming to prepare students for this complexity by engaging them in challenges that mirror real-world problems. However, if experienced professionals struggle to navigate such complexities, how can students be expected to thrive in similarly demanding learning environments? This chapter addresses this question through the lens of self- and socially shared regulated learning (S-SRL). We begin by introducing a commonly used S-SRL model to provide a foundation for understanding how students regulate their learning individually and collectively. Building on this model, we explored the typical challenges students may encounter at various stages of interdisciplinary learning tasks. Furthermore, we review instructional tools and highlight their core design principles that help students overcome these challenges, while supporting the development of essential regulatory skills. In doing so, we offer educators practical insights into fostering personal and group responsibility for learning as well as the collaboration needed to achieve successful interdisciplinary education.

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# INTRODUCTION

“Leyla, an architecture graduate student, joins an interdisciplinary team of students with the aim to design emergency housing in a remote area of Türkiye that has recently been struck by a disastrous earthquake. The idea behind the project is not to simply restore buildings as they were, but to ‘build back better’. This means redesigning the emergency shelters in a sustainable and structurally resilient way while paying particular attention to climate adaptation, circular economy, recycling of available building materials, and mobilizing the local workforce - including their unique skills and know-how. The newest findings in the field of post-disaster urban renewal tell us that this novel interdisciplinary approach will contribute significantly to the region’s long-term urban and social resilience. Leyla is enthusiastic about the prospect of sharing her knowledge with the world – recently she did a first year Master (MSc1) group project on post-disaster emergency design, where she and her fellow students tested some prefabricated modular solutions. The main premise of her project was how to reconcile the somewhat generic appearance of these models with local aesthetics and culture, arguing that beauty is an essential human need, especially in times of great distress. Furthermore, her rich contact with local authorities and stakeholders makes it possible for her to test some ideas with real-life actors, before implementing them in the project.

Despite her enthusiasm, however, Leyla is uncertain about what to expect from this project. In the first team meeting, students who were assigned as the main designers presented a vision emphasizing architecture in context: small open courtyards with a shared garden, ample natural light, a facade made of traditional building materials, and a technologically sophisticated roof with power-generating solar cells. The enthusiasm quickly faded when the student responsible for building technology raised concerns about structural feasibility and cost. Another student, representing the urban planning perspective, pointed out that in real-world cases, zoning laws might limit building height or restrict the garden’s public use. Meanwhile, an environmental science student critiqued the design for its extensive use of glass, noting the potential for increased heat gain that could compromise energy efficiency. Although the discussion was lively, the team struggled to make progress. The architecture students defended the design, the engineers stressed feasibility, the planners raised spatial concerns, and the environmentalists emphasized sustainability – yet they seem to be talking past one another. Each discipline brings its own technical language and priorities, and it’s left to the group to bridge these knowledge gaps collaboratively. As Leyla leaves the meeting, she feels a growing sense of uncertainty about how the team will move forward and what success will look like in such a complex, interdisciplinary setting.

Leyla's challenges were not unique to the project. Such difficulties are common in built environment education, where students learn to address complex real-world problems (e.g., sustainable urban development). These problems require professionals to collaborate across disciplinary boundaries, integrating knowledge and expertise from fields such as architecture, civil engineering, and urban planning. However, traditional education often leaves students unprepared for this kind of collaboration, offering limited opportunities for interdisciplinary teamwork[1]. Against this background, interdisciplinary education has gained prominence in contemporary built environment curricula and engineering education in general, with learning environments increasingly designed to confront students with problems that transcend a single discipline, reflect the complexity of professional practice, and prepare engineers for problems of an unknown future[2, 3]. These environments emphasize collaboration among students from diverse academic backgrounds, requiring them to integrate multiple perspectives, communicate complex knowledge, and address multifaceted problems[4]. By simulating the realities of professional practice, interdisciplinary education aims to equip students with the independent and empathic thinking needed to solve wicked social and technological problems of the future.

However, adapting to the demands of interdisciplinary education can be challenging for many students[5]. Such environments not only require students to demonstrate expertise across multiple disciplines, but also place greater demands on their ability to monitor and control both their own learning and their team's collective progress[6]. For instance, in a project requiring civil engineering, architecture, and environmental science students to collaboratively design a sustainable urban district, teams may experience content-oriented challenges, such as applying (inter)disciplinary knowledge to address the technical aspects of the design. Simultaneously, they may encounter process-oriented challenges, such as aligning project goals, building shared understanding, coordinating task distribution, and adapting plans in response to feedback and evolving needs. In our view, for interdisciplinary education to achieve its intended outcomes, it is imperative that students receive targeted support that addresses both the content and process-oriented demands of such projects.

In educational science, self-shared-regulated learning (S-SRL) are two frameworks that offers valuable insights into how students can be supported in navigating content- and process-oriented challenges. Self-regulated learning describes an intentional, goal-oriented process in which students direct their own learning by identifying goals, planning activities, monitoring progress, and adjusting strategies to achieve their objectives[7]. Socially shared-regulated learning extends this understanding to group settings, describing how students jointly establish learning goals, coordinate efforts, and respond to emerging challenges[8]. However, in interdisciplinary higher education, particularly in the built environment, S-SRL frameworks are not widely used to inform educational design, which, in turn, leads educators to miss important opportunities to design learning experiences that actively support students in managing the complex demands of interdisciplinary education. Accordingly, this chapter introduces the S-SRL framework in the context of built environment education, particularly for educators interested in designing interdisciplinary learning experiences. First, we define S-SRL and outline its key components. We then examine how interdisciplinary settings create conditions in which students may need support to overcome various challenges. Finally, we discuss practical tools for providing such support, aiming to contribute to a more responsive and well-aligned interdisciplinary education in the built environment.

## Self and Socially Shared Regulated Learning

Researchers in educational science and psychology have long sought to understand why some students engage deeply with learning materials, persist through challenges, and adapt their approaches over time, whereas others struggle to sustain effort or rely heavily on external guidance[9,10]. This pursuit has led to the development of various theories and models that emphasize the role of students as active participants in their learning. A particularly influential line of research in this area is self-regulated learning (SRL), which focuses on how students exercise control over their cognitive (thoughts), motivational (beliefs), behavioral (strategies), and emotional (feelings) processes to achieve their learning goals[11]. Several theoretical models have been proposed to better understand how students self-regulate their learning. Although these models emphasize different aspects, they share significant overlaps, particularly in describing self-regulation as a cyclical and dynamic process[12]. Here, we defer Zimmerman's cyclical model of SRL[7] as it is widely recognized and offers a clear framework for understanding how students regulate their learning over time.

According to Zimmerman[7], SRL unfolds across three fundamental phases: forethought, performance, and self-reflection. In the forethought phase, students' task understanding and motivation laid the foundation for their subsequent learning activities. During this phase, students analyzed the task, set learning goals, and formulated plans to achieve those goals. Crucially, students' motivation, such as their interest in the task and the value they attach to learning, strongly influences their approach, including the strategies they employ to execute learning tasks; thereby influencing their performance[13,14]. In the performance phase, students put their plans into action by engaging in a learning task. Central to this phase are (a) the strategies students employ and (b) their ongoing self-monitoring of progress[15]. For instance, when preparing for an exam, students might rely on strategies such as rereading notes, creating flashcards, or summarizing key concepts[16]. Simultaneously, they monitored their progress by checking their understanding, assessing the effectiveness of their strategies, and adjusting their approach as needed. Finally, in the self-reflection phase, students evaluate their performance and make attributions; they interpret their success or failure by linking them to internal or external factors[17]. For example, students might attribute a high grade to their diligent study efforts (internal), or a poor result to what they perceive as an unfair exam (external). Completing the cycle, these reflections shaped students' motivation and planning for future tasks, potentially strengthening or undermining their self-regulatory efforts.

While earlier models of SRL, such as Zimmerman's cyclical model, focused on individuals regulating their own learning, they offer limited insight into the contexts in which multiple students learn together when they influence and are influenced by others (e.g., peers), such as during collaborative learning tasks, where any type of action is a product of negotiation between multiple individuals. Accordingly, the concept of SRL has been expanded to include co-regulation and socially shared regulation of learning, which accounts for how regulation can emerge and develop within social interactions[8,18]. Co-regulation refers to temporary, interactive forms of regulation in which one individual, often a more capable peer, guides or scaffolds another's regulation until the learner gradually internalizes those strategies. For instance, during a group assignment, a student may overlook monitoring whether their understanding of the task is sufficient. At this moment, a peer or tutor can prompt the student to pause and check their comprehension, encouraging them to reflect on what they know and identify any gaps. In contrast, socially shared-regulated learning describes a more reciprocal and collective process in which group members work together to regulate their joint learning. This involves identifying and establishing shared learning goals, creating a plan, monitoring learning at both the individual and group level, and adjusting their approach in response to evolving needs[19]. For instance, at the outset of a group project, team members might work together to clarify the task requirements, ensure that they have a shared understanding of the goals, and develop a joint plan for dividing responsibilities. Although both co-regulation and shared regulation represent forms of social regulation, the key difference lies in the direction and ownership of the regulatory processes: co-regulation involves one individual guiding another's regulation, whereas shared regulation refers to group members collectively managing their joint learning[8].

Notably, while much of the research on S-SRL has focused on how students monitor and control their cognitive processes, students can also regulate their motivation[20] and emotional processes[21]. For instance, students may sustain their motivation by reminding themselves of the personal relevance of a task (e.g., utility value interventions)[22] or manage their frustration when facing difficulties by reframing setbacks as opportunities to learn (e.g., cognitive reappraisals)[23]. These forms of regulation are particularly important in collaborative and interdisciplinary settings where students must navigate complex tasks, coordinate with peers from different backgrounds, and sustain their motivation over time. The following chapter explores how S-SRL unfolds in interdisciplinary education in built environments, highlighting the ways in which students may individually and jointly regulate their cognitive, motivational, and emotional processes to tackle shared challenges.

## Interdisciplinary Education: Definitions and Instructional Approaches

Interdisciplinary education engages students in learning conditions that extend beyond the boundaries of a single discipline and exposes them to knowledge, skills, and methodologies from multiple fields. While it shares similarities with other cross-disciplinary approaches such as multidisciplinary education, it is conceptually distinct. In multidisciplinary education, for instance, disciplines are placed side by side, with each contributing its own viewpoint to a shared topic, but typically without integration. By contrast, interdisciplinary education emphasizes the intentional integration of disciplinary insights and methods to create new understandings that bridge boundaries, aiming to develop a synthesized whole that goes beyond the sum of individual disciplines[2,24,25]. Interdisciplinary education also differs from transdisciplinary education, which goes a step further by engaging stakeholders beyond academia, such as community members, professionals, or policymakers, and seeking a fusion of knowledge that breaks down traditional disciplinary structures altogether. Here, our goal is not to suggest that one approach is more advanced than another but to highlight their similarities and distinctive characteristics, which may in turn shape course design and influence students' learning experiences.

How is interdisciplinary education being delivered? In practice, there is no single recipe for designing interdisciplinary education. The approach to interdisciplinarity may depend on various factors, including the learning tasks and the backgrounds of students and course designers[26,27]. In this view, it lies on a spectrum that incorporates diverse elements or approaches toward interdisciplinarity. For instance, a course on earthquake resilience in a built environment can be designed using varying approaches and styles of interdisciplinarity. In terms of student composition, for example, at a minimal level, students might come from the same discipline with limited opportunities for interaction with peers from other fields. However, the course itself could still incorporate highly interdisciplinary learning tasks co-designed by experts in architecture, civil engineering, geosciences, and urban planning. In such a setup, even if students share the same disciplinary background, they engage with complex interdisciplinary problems that require them to integrate knowledge from various domains, such as site analysis, material innovation, seismic risk assessment, and policy regulations. This conceptualization of interdisciplinarity allows flexible education that can be adapted based on course objectives, diversity of student backgrounds, and desired depth of disciplinary integration.

In classrooms, interdisciplinary education is often implemented through active and learner-centered approaches such as problem-based learning (PBL) and project-based learning (PjBL). While a detailed discussion of these approaches is beyond the scope of this chapter, both are problem-driven pedagogies that engage students in complex, authentic, and often ill-structured problems (i.e., unclear problems with many answers)[28]. These approaches also place greater responsibility on students, requiring them to work independently (e.g., identifying what they know, determining what they need to learn) and collectively (e.g., distributing tasks and roles, negotiating perspectives) over an extended period while positioning teachers primarily as facilitators rather than direct transmitters of knowledge.

Although PBL and PjBL are widely used to deliver interdisciplinary education, these instructional approaches may impose significant challenges on students. The demand for navigating unfamiliar disciplinary content, integrating diverse perspectives, and managing collaboration among peers with different disciplinary priorities and interests can be particularly intense in interdisciplinary contexts. In what follows, we examine some of the challenges that students may encounter in PBL and PjBL within the context of interdisciplinary education by a) focusing on how these challenges may manifest across the cyclical phases of S-SRL, and b) exploring instructional support mechanisms that can help students navigate them effectively.

## S-SRL in interdisciplinary education: An interdisciplinary approach to earthquake recovery

We based our discussion on a design studio on earthquake recovery in a built environment. It brings students from architecture, civil engineering, urban planning, industrial design, and geoscience programs to collaborate on the PjBL problem. Students were invited to form teams involving at least one member from each discipline. Teaching activities included workshops and lectures led by experts from various fields in the architecture, engineering, and construction industries. The course lasts 10 weeks and includes collaborative, design-based research, and assignments, where teams iteratively develop, test, and refine designs that address earthquake resilience. For example, a team can develop a post-earthquake recovery hub and shelter system in which students design a modular and scalable structure that can function as a temporary housing and community hub after an earthquake. By attending this course, students are expected to develop both content-related knowledge and expertise, as well as professional competencies, such as:

- Analyze the post-disaster context in relation to the different actors that determine the production of architecture in that context.
- Designing a sustainable and resilient architectural project in collaboration with selected experts.
- Evaluate the emerging architecture, instruments, and methods employed in its design and construction in relation to the collaborative process.

The assessment is based on submitted design projects, team and individual presentations, and individual reflection reports.

## Supporting students during the forethought phase of S-SRL

One of the first challenges that students may face in our example arises from the process of establishing shared learning goals and building a shared understanding of the task, both of which are central to the forethought phase of S-SRL. Specifically, students from different fields bring diverse perspectives, disciplinary priorities, and professional identities, which can make it difficult to align expectations and agree on a common approach to problem-solving. Consider an example of designing a post-earthquake recovery hub and shelter system. Students must collectively determine not only what they are aiming to achieve, such as prioritizing modularity for rapid deployment, ensuring cultural appropriateness for community acceptance, integrating with urban infrastructure, or optimizing seismic resistance, but also how they interpret the scope, constraints, and success criteria of the task itself. These decisions require negotiation, mutual understanding of disciplinary contributions, clarification of assumptions, and coordination of goals and subgoals. However, these processes often do not come naturally to students with little or no experience in interdisciplinary teamwork, and misunderstandings at this early stage can hinder collaboration throughout the project, if left unaddressed.

In our view, such a diverse group of students, most likely with no interdisciplinary learning experience, can benefit from structured guidance and support. Järvelä et al.[29] proposed three key principles for designing instructional support: awareness, externalization, and prompting. First, a support mechanism should help students gain deeper insight into their thinking and motivational processes (i.e., awareness), both individually and as a group. This can involve reflecting on the personal goals, desired skills, and knowledge they want to develop, and self-assessments of their understanding and readiness for anticipated learning tasks. Second, students should have opportunities to externalize and share these insights with their group members (i.e., externalization), often through tangible outputs such as drawings and 3D models. Finally, an instructional support tool should prompt and activate students to translate their reflections into concrete next steps (i.e., prompting), keeping in mind both their individual learning and the group's collective work.

Radar and Our Planner are two tools commonly used in the literature to support students in group-learning activities. A radar is a visual diagram with multiple axes, which is derived from students' ratings of their individual and group-level cognitive, motivational, and emotional processes[29,30]. For example, students assessed their understanding of task demands (e.g., How well do you know what is expected of you?), and their confidence in their group's ability to complete the task successfully (e.g., Does your group have the necessary knowledge and skills?). These self-assessments are represented through a two-dimensional chart (a form of spider web, Figure 1) and serve as the foundation for reflection and group negotiations. Note that the dimensions of radar can be adapted, expanded, or reduced depending on the learning objectives or interdisciplinary nature of the task. For instance, in our case, an additional dimension could assess interdisciplinary competencies, such as students' appreciation of different disciplinary perspectives[25].


Figure 1. Our Radar adapted from Jarvela et al. 2016 (No further use allowed)

Note. Sample questions per dimension: Clarity of task goals: Do I clearly understand what needs to be accomplished? Clarity of roles: Do I understand what I expect to do? Individual Motivation: How motivated is I to engage in this task? Group Motivation: How committed is our group to doing well? Trust and Safety: Do I feel safe in expressing my questions, concerns, and options?

Similarly, Our Planner[29] is a structured planning tool designed to help students externalize and coordinate their individual and collective learning activities. Although similar tools have been proposed in the literature, such as the Individual Planner and Group Planner by Miller and Hadwin[31], they prompt students to respond to key questions related to various aspects of task understanding, goal setting, and action planning.

- Defining roles within the team (e.g., Who is responsible for which task?)
- Clarifying task demands (e.g., what are the key requirements and constraints of this project?)
- Setting goals (e.g., what do I aim to achieve in this phase?)
- Establishing a timeline (e.g., what are my/our deadlines and how will progress be tracked?)

By making these elements explicit and shared among peers, Our Planner helps students reflect on their own contributions, while also aligning expectations and strategies within the group. Overall, this dual focus on S-SRL may enable students to proactively plan, negotiate responsibilities, and adjust their approach as needed, thereby fostering more effective interdisciplinary collaboration.

## Supporting students during the performance phase of S-SRL

The performance phase of S-SRL refers to how students perform learning activities (individually or collectively), while monitoring and adjusting their strategies as needed. In interdisciplinary education, this phase presents challenges owing to the complexity and unfamiliarity of the learning context. Students are often required to engage in cognitively demanding tasks such as conducting independent research, synthesizing knowledge from diverse fields, and learning to use specialized tools or software. In other words, interdisciplinary education, by design, immerses students in multifaceted problems spanning multiple domains of knowledge. To succeed, students must draw on a broad repertoire of learning strategies that support knowledge acquisition, skill development, and transfer of learning. However, research shows that many students struggle with selecting and applying effective strategies during their self-study, which is a major part of PBL and PjBL, thereby limiting their own learning[32,33]. To this end, research in cognitive and educational psychology has identified several evidence-based techniques that enhance learning[16]. These techniques include, but are not limited to, retrieval practice, spaced practice, and interleaved practice, so-called desirably difficult learning conditions–learning processes that impose higher mental effort on students, drop immediate performance, and benefit learning in the long run[34].

An individual study program that incorporates elements of desirably difficult strategies is illustrated in Figure 2. In a nutshell, retrieval practice involves engaging in learning activities that require students to recall information from their long-term memory without referring to learning materials. This can be achieved through various methods such as self-testing with flashcards, explaining concepts to themselves or their peers, or solving problems without immediate access to reference materials. These strategies strengthen memory retention, promote deeper understanding, and facilitate knowledge transfer across situations[35]. For instance, in the context of our interdisciplinary project, a student might use retrieval practice by sketching out a design principle discussed in a lecture, explaining the seismic load distribution to their peers, or mentally rehearsing how different materials respond to stress under earthquake conditions. Although these learning activities may initially impose higher mental effort and feel less productive, they ultimately enhance knowledge retention and support the transfer of learning across situations, key demands in complex interdisciplinary tasks.

Second, spaced practice refers to distributing study sessions over time rather than concentrating on all study efforts in a single session. This contrasts with cramming, where students attempt to complete their learning activities in the last minute, often through intensive and prolonged study sessions. In our example, students might space their efforts by revisiting site data at different project stages, refining structural calculations across multiple meetings, or periodically reviewing team feedback on the design drafts. Note that spaced practice does not require additional study time; rather, it ensures that the same total study time is distributed across timely intervals, allowing students to revisit the material periodically, strengthen their memory traces, and reduce forgetting.

Finally, interleaved practice involves alternating between different, yet related concepts, categories, or skills within a study session. This approach contrasts with blocked practice, in which students repeatedly focus on one topic or skill before moving on to the next. Interleaved practice is particularly beneficial because it encourages students to compare and contrast concepts, helps them recognize key differences, identifies underlying principles, and makes meaningful connections across topics[36,37]. For instance, in our interdisciplinary project, a civil engineering or architecture student might compare and sketch two structural solutions for seismic zones, such as reinforced concrete frames with shear walls versus light timber frames with cross-bracing. This form of practice helps students identify critical differences in material behavior, structural logic, and design implications while also deepening their understanding of how each solution performs under earthquake conditions. However, without instructional support, students may default on blocked practice because it is easier or more efficient, despite being less effective for long-term learning and transfer.

| Day | Morning | Afternoon | Evening |
|---|---|---|---|
| Monday | | Course session: Expert lecture on Structural Design Considerations in Earth-quake recovery | Prepare flashcards and self-quiz on design constraints in post-earthquake contexts:<br>• Without reading notes, describe at least four structural and contextual constraints introduced during the lecture. |
| Tuesday | Compare and sketch two structural solutions for seismic zones.<br>• Reinforced concrete frames with Shear walls<br>• Light timber frame with cross bracing | Gym | Sketch site layout ideas based on Monday's session |
| Wednesday | Course session: Workshop on simulation tools | | Team chat: How can we use what we learned in our design? |
| Thursday | Compare two post-disaster housing design approach-es.<br>• Lightweight, modular housing used in rural Nepal<br>• Reinforced concrete shelters deployed in urban Turkey | Revise initial design sketch | Dinner with friends |
| Friday | Revisit flashcards on key design constraints in post-earthquake architec-ture.<br>Write a summary describing key similarities and differ-ences between structural solutions for seismic zones. | Plan next week's goals | |

Figure 2. A sample weekly study plan using retrieval, spaced, and interleaved practice.

As mentioned, survey studies indicate that effective study techniques, including retrieval, spaced, and interleaved practices, are often underutilized by students[32,33]. Several factors may contribute to this issue, including a lack of knowledge and awareness of the effectiveness of these study techniques, as well as metacognitive illusions that arise from their desirably difficult nature[38]. Specifically, while effortful strategies often lead to better long-term retention, students may misinterpret increased difficulty as a sign of inefficacy, leading them to favor less-demanding but suboptimal study techniques[39,40]. Additionally, motivational barriers may play a role; students may perceive the effort required for these techniques to be unjustified given their low interest, limited time, or uncertainty about the long-term benefits[38,41].

From the instructor's perspective, a pressing question is: How can students be encouraged to engage in these effective study techniques more frequently? To address this challenge, several strategy training programs have been developed, such as Study Smart[42] and interventions based on the Knowledge, Beliefs, Commitment, and Planning (KBCP) framework[43]. While we refer interested readers to these specific studies, what these programs share is their emphasis on direct instruction, which helps students adopt more effective learning strategies.

- Closing knowledge and awareness gaps: Educating students about how learning happens, warning them about metacognitive illusions, providing explicit instruction on what different study techniques entail, when to use them, and why they work.
- Fostering students' confidence in these strategies: Helping students believe that these techniques will actually work for them by creating low-stakes learning opportunities where they can practice effective study strategies with their own learning materials without fear of academic consequences.
- Providing repeated practice and feedback: Encouraging students to engage in these strategies consistently over time, with guided practice, feedback, and reinforcement to help them integrate these techniques into their regular study habits.

At first glance, the design principles underlying effective strategy training appear to differ from those proposed by Järvelä et al.[29]. However, closer examination revealed a substantial overlap between the two approaches. For example, closing students' knowledge gaps and addressing misconceptions through direct instruction align clearly with the awareness principle. By contrast, the principle of externalization may seem less straightforward. Yet, it is effectively supported by training such as Study Smart, in which students are encouraged to engage in peer discussion and share their own experiences with strategy use. Such activities make thinking processes and experiences visible and socially grounded, adhering to the core features of externalization. Finally, creating repeated opportunities for practice directly supports the prompting principle, helping students translate new knowledge into action and experience the benefits of these strategies first. Together, these design principles offer practical guidance for educators aiming to design instructional support and interventions to help students overcome the challenges of S-SRL.

## Supporting students during the self-reflection phase of S-SRL

Central to the self-reflection phase are students' assessments of their individual and collective learning efforts and their reactions to these assessments, wherein they make causal attributions about their successes and failures by linking them to internal or external factors[15]. Here, we identify two common challenges encountered by students. First, they may underappreciate or overlook the value of self- and group-related assessments. This process requires students to compare their current state of learning or performance against a benchmark – be it internal (personal goals or prior performance) or external (e.g., grading rubrics). While recognizing discrepancies between the current state and the desired state can create opportunities for improvement, it can also trigger negative emotions, such as anxiety, self-doubt, or frustration[44], particularly in summative and high-stake situations, where self- and group-assessment significantly impact grades. In such cases, students may view assessment as a threat to their competence and self-worth rather than a tool for personal growth, eventually hindering their engagement in self-regulated assessment activities.

Second, even students who recognize the value of assessment may struggle to accurately evaluate their individual and group-learning processes. Interdisciplinary education exposes students to unfamiliar disciplinary content, tools, and ways of thinking outside their academic training. As they work on complex, multifaceted problems, such as those involved in designing a post-earthquake recovery hub, they may find it difficult to judge whether they truly understand key concepts from other fields or whether their learning is progressing adequately. This difficulty is amplified by the limited time available to build foundational knowledge in unfamiliar areas, which can ultimately lead to students misjudging their learning, overestimating their comprehension, or feeling lost without knowing what is next. This metacognitive shortcoming, in turn, may prevent students from making necessary improvements in their learning at both the individual and group levels.

How can we encourage students to assess their learning and equip them to do so accurately? In their attempts to integrate Assessment for Learning and S-SRL research, Panadero et al.[45] highlighted the necessity of incorporating self- and peer-group assessment activities as a formalized component of instructional design rather than optional or informal practices. Additionally, Panadero and colleagues summarized several principles (Table 1), mainly derived from the Assessment for Learning literature, to implement self- and peer-assessment in classrooms.

| Self-Assessment | Peer Assessment |
|---|---|
| Define the criteria by which students assess their work | Clarify the purpose of peer assessment |
| Teach students how to apply the criteria | Involve students in developing and clarifying assessment criteria |
| Give students feedback on their self-assessments | Determine the assessment format and mode of student interaction |
| Give students help in using self-assessment data to improve performance | Provide quality assessment training |
| Provide sufficient time for revision | Provide sufficient support for assessment |
| Do not turn self-assessment into evaluation by counting towards grades | Specify assessment activities and timetable |
| - | Monitor the assessment process and coach students |

Table 1. Principles to implement self- and peer assessment trainings in classrooms.

Synthesizing and reflecting on these principles, together with those introduced earlier in this chapter, we agree that students should first be provided with clear instructions regarding the purpose and rationale behind self- and group-assessment activities, emphasizing their role in learning (i.e., assessment for learning rather than assessment of learning), following the awareness-principle. This introductory session can take place in one of the initial sessions, where students are introduced to course objectives as well as teaching and learning activities. During this session, students and instructors can also make agreements regarding the mode and function of these assessments, for example, whether or to the extent that they can be counted towards grades.

Second, it is essential to provide students with clear and valid standards for assessing both their individual and group learning processes. To this end, students can be given scripts or rubrics to structure their assessments and ensure consistent and valid evaluations. Scripts can take the form of structured prompts or step-by-step guidelines that lead students through the assessment process[46]. For example, in the recovery hub project, a self-assessment script might include prompts such as What disciplinary knowledge did I contribute to the team's design decisions on structural safety? To what extent did I engage with or learn from other fields? A group-assessment script might ask, Did we communicate effectively during the site analysis phase? How did we manage differences when selecting structural systems or materials? Unlike scripts, a self-assessment rubric might present specific dimensions of learning (e.g., goal setting, strategy use, and features of a quality product) with explanations that distinguish between different levels of proficiency (e.g., developing, sufficient, and proficient). In our example, a peer-assessment rubric might include dimensions such as collaboration during prototyping, constructive use of feedback, or efforts to bridge disciplinary gaps, each with clear performance descriptors, defining what constitutes weak versus strong performance. Note of caution: Students might come to see rubrics as checklists solely used for grading. It is therefore critical to link rubrics back to awareness principles, emphasizing their role in learning rather than assessment. Additionally, it is equally important to support externalization, encouraging students to make their thinking, assessments, and judgments visible and share them with their team members. Together, scripts and rubrics help students make more objective, accurate, and actionable assessments, reducing bias in their self- and group-assessments[46,47].

Finally, it is unlikely that students will immediately master how to assess themselves or the learning processes of their groups. Ideally, they should receive structured training on how to implement self- and group assessment, aligning with the prompting-principle. One way to facilitate this learning is through video modeling, in which students observe an expert or a more knowledgeable peer demonstrating and verbalizing the assessment process[48]. Research suggests that observational learning can help students develop a clearer understanding of assessment criteria and reflection techniques[48,49]. However, in practice, time and resource constraints often limit the feasibility of direct training methods. An alternative approach is to incorporate regular self- and group-assessment opportunities into coursework, ensuring that students develop these skills progressively through experience and feedback. By engaging in repeated assessment cycles, students can refine and improve their ability to evaluate their own and their peers' work, specifically when supported through scripts and rubrics. Where possible, providing feedback on students' assessments can accelerate this process and help them calibrate their judgments against more reliable standards. Additionally, repeated assessment opportunities are crucial to allow students to see tangible improvements in their work over time. Overall, this iterative process not only reinforces the importance of assessment as a learning tool but also contributes to the long-term development of self-regulatory skills.

## Conclusion

Leyla's story and the challenges she encountered in her education highlight an important reality: neither the built environment nor the ways we teach about it through interdisciplinary approaches are shaped by architects or architectural students alone. Accordingly, preparing students for this reality requires more than relaying discipline-specific expertise, which is the focus of the traditional approach to the built environment education. Instead, this reality and the surrounding complexities call for the ability to work across domains, synthesize and integrate knowledge and skills from multiple disciplines, and communicate effectively, the so-called transversal skills that interdisciplinary education may (and aims) foster[24]. However, interdisciplinary education presents its own challenges, specifically for students navigating unfamiliar content, roles, and collaboration demands. In this chapter, we explore the challenges that students may encounter in interdisciplinary learning environments, focusing on them from the lens of self- and socially shared-regulated learning (S-SRL). Additionally, we examined some of the instructional support tools and mechanisms designed to help students overcome these challenges while gradually developing the knowledge and skills needed to address them independently.

We presented some of the common challenges that students may encounter during interdisciplinary learning situated within the forethought, performance, and self-reflection phases[15]. In the forethought phase, we highlight the difficulties that may result from understanding interdisciplinary learning tasks, establishing shared learning goals, and engaging in effective planning. In other words, reaching consensus on a joint roadmap, outlining both individual and collective learning activities, can be particularly challenging when students come from diverse disciplinary backgrounds (or take different roles in teamwork) and hold differing assumptions about the task. In the performance phase, we focused on the study techniques that students could select and use. Students often rely on familiar but suboptimal study techniques (e.g., highlighting or note-taking) that do not support deep understanding. Given the complexity of interdisciplinary tasks, which require rote memorization, as well as the synthesis and transfer of knowledge, it is essential that students use evidence-informed study techniques that enhance knowledge acquisition and transfer. Finally, in the self-reflection phase, we pointed out the challenges that may arise when students fail to evaluate their learning or are unable to do so accurately because of a lack of clear criteria or valid standards. This can hinder their ability to identify strengths and weaknesses, adjust strategies, and learn from experience, which are critical opportunities for their development as self-regulated learners.

Two important points should be acknowledged regarding the aforementioned challenges. First, these challenges are not necessarily unique to interdisciplinary contexts. However, the complexity and demands of interdisciplinary learning environments can intensify their prevalence or make them more visible. For example, establishing a shared understanding may be more straightforward in a mono-disciplinary project than in an interdisciplinary project, in which students must navigate differing assumptions, terminologies, and perspectives. Second, these challenges were neither exhaustive nor mutually exclusive. For example, in the forethought phase, students' task understanding is critical, but so are their motivational beliefs, such as self-efficacy and collective efficacy regarding their individual and group ability to succeed. Likewise, during the performance phase, students may already have difficulties typically associated with the self-reflection phase, such as neglecting to monitor their task understanding or evaluating individual and group performance. In this chapter, we primarily focus on the challenges that are (meta)cognitive and relational in nature, while setting aside a deeper discussion of the motivational and emotional challenges. We encourage future research to further investigate these dimensions and examine how they intersect the cognitive and social aspects of regulation in interdisciplinary learning.

Additionally, to address the challenges that students may encounter during interdisciplinary learning, we reviewed some pedagogical tools (e.g., Our Radar) and instructional approaches (e.g., the use of self-assessments). While each of these support mechanisms has been shown to effectively address specific challenges, such as planning, using effective study techniques, or engaging in self-reflection, our aim is not merely to present them as isolated interventions. Rather, we sought to highlight the common instructional principles that underpin these tools, particularly those that support the development of S-SRL. The first principle, introduced by Järvelä et al.[29], is awareness, which helps students recognize and understand the importance of approaching both the learning task and their individual and collective learning processes (e.g., thinking, motivation, and behaviors). The second principle is externalization, which is critical when students learn and work together. While students may reflect on their individual learning processes, if these reflections remain tacit or are not well communicated to their peers, they may miss out on the benefits of their awareness. The third principle is prompting – inducing students to take concrete action in response to the challenges and plans identified through awareness and explication. While we agree with Järvelä et al. on these principles, we further propose that external prompts (or any other support mechanism) should gradually fade away, enabling students to act independently over time. Crucially, this shift toward self-regulated actions is unlikely to occur through isolated or one-off interventions. Instead, students need repeated and sustained opportunities to engage with new strategies, tools, and ways of thinking while external support is gradually reduced. Accordingly, the fourth principle we propose is continuity: ensuring that support for S-SRL is not limited to a single activity or moment, but is embedded consistently across the learning experience. Together, these four principles provide a foundation for designing instructional support that helps students overcome the challenges commonly observed in interdisciplinary education while also enabling them to develop the essential regulatory skills needed to navigate complex, collaborative learning environments. By embedding these principles into interdisciplinary courses, educators can create conditions that not only support students but also prepare them to become skilled professionals.

In closing, the goal of this chapter is to introduce self- and socially shared regulation of learning (S-SRL) as a relevant and practical lens for both understanding common challenges and guiding instructional design in interdisciplinary education. By bridging research and practice and by highlighting actionable design principles, we hope this chapter offers educators a useful foundation for creating more supportive, responsive, and evidence-informed interdisciplinary learning environments.

**The authors contribution:**

Conceptualization: EO, SA, AS.

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**Conflict of Interest**

The authors declare no conflict of interest.

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