How Can We Support Educators in Adopting Example-Based Learning in Software Engineering Education? An Exploratory Study

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Abstract

Example-Based Learning (EBL) has been adopted in Software Engineering Education (SEE) to support conceptual understanding, knowledge transfer, and the connection between theory and practice. However, its adoption remains challenging because educators must design meaningful examples, select materials with adequate complexity, and align activities with learning objectives and feedback strategies. To address this challenge, we propose an approach that frames EBL adoption as a pedagogical planning process guided by instructional decisions. This paper presents an enhanced version of the web-based portal that operationalizes our approach as a digital pedagogical artifact. The portal supports educators through instructional planning workflows, resources for creating and reusing EBL-based lesson plans, an expanded repository of examples, and mechanisms for evaluating examples according to their pedagogical adequacy. We evaluated the portal through an exploratory study with Software Engineering educators. The study combined quantitative data from a questionnaire based on the Technology Acceptance Model (TAM) with qualitative data from semi-structured interviews analyzed through coding procedures. The quantitative results indicate positive perceptions regarding perceived usefulness, perceived ease of use, and intention to use. The qualitative findings complement these results by showing that educators valued the portal's support for organizing lesson planning, clarifying instructional workflows, and reducing the effort required to prepare EBL-based activities. Participants also identified limitations and improvement opportunities, including the need to expand the example repository and increase workflow flexibility. Overall, our findings suggest that the portal can support a more structured, sustainable, and pedagogically grounded adoption of EBL in SEE.

Keywords

Example-Based Learning, Worked Examples, Software Engineering Education, Educational Tool

1 Introduction

Software Engineering (SE) is dedicated to the application of systematic, disciplined, and quantifiable approaches to the development, operation, maintenance, and evolution of software [29], which makes it a field intrinsically connected to the practical demands of professional development [22]. Given this context, Software Engineering Education (SEE) plays a central role in preparing professionals capable of transferring theoretical concepts to real development contexts, articulating technical knowledge, analytical skills, and practical competencies [1, 11].

In this direction, restricting the educational process to approaches centered solely on content delivery becomes insufficient, especially in a field in which learning depends on understanding complex problems and making decisions in applied scenarios [12, 18]. This challenge has motivated the adoption of active methodologies in SEE, since such methodologies promote student participation in the learning process and contribute to the development of critical thinking, problem-solving, and decision-making skills [10, 17].

Among the active methodologies with potential for this scenario, Example-Based Learning (EBL) stands out. EBL supports learning through the observation of how a task can be performed, allowing students to understand not only the expected outcome but also the reasoning underlying the solution presented [31]. Previous studies have shown that EBL can strengthen conceptual understanding, foster knowledge transfer, and increase students' self-efficacy [2, 7, 13]. These results have motivated its use in areas that require articulation between theoretical foundations and practical application, including SE, where examples can support the understanding of abstract concepts, the analysis of solutions, and the development of skills relevant to the professional context [24, 25, 28, 33].

Despite this potential, the adoption of EBL in SEE still faces important limitations. Educators often use examples in an *ad hoc* manner, without sufficient methodological support to guide pedagogical planning and the selection of appropriate materials. Barriers reported in the literature include the effort required to design and adapt examples with appropriate complexity [8, 15, 35], the time required to construct erroneous examples [27], and the absence of structured support to integrate this methodology into teaching practices [25]. These challenges highlight the need for systematic approaches and support artifacts that assist educators in operationalizing EBL in SE courses.

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In this direction, the EXEMPLIFY-SEE approach was proposed to support the systematic adoption of EBL in SEE [4]. In that previous work, the approach was initially instantiated as a web-based prototype structured around pedagogical planning axes, providing workflows to guide educators in aligning conceptual exposition, example-based activities, and feedback strategies [4]. In addition, that initial version incorporated a repository of examples aimed at supporting the construction and reuse of EBL-based lesson plans [4]. Initial empirical evidence indicated positive educator perceptions of the approach's usefulness, clarity, and ease of use, especially for organizing lesson planning, structuring instructional decisions, and supporting less experienced educators in the design of EBL-oriented teaching activities [4].

As a continuation of this work, a web-based portal was developed to operationalize the approach and supports educators in planning EBL-oriented teaching activities. The portal integrates pedagogical planning workflows, structured sequences of instructional decisions for conceptual exposition, example-based activities, and feedback, together with a repository of examples designed to support the selection, adaptation, and reuse of teaching materials. In addition to these pedagogical resources, the portal provides functional mechanisms to enable practical adoption in educational settings, including user authentication, persistence of planning decisions, PDF export of lesson plans, interface translation, and mechanisms for evaluating repository examples. This combination of pedagogical and technical functionalities characterizes the portal presented and empirically evaluated in this article.

Thus, this study aims to evaluate the EXEMPLIFY-SEE portal and to provide additional empirical evidence on how educators can be supported in adopting EBL in SEE. To guide this investigation, we defined the following research questions:

- **RQ1)** To what extent do educators perceive the EXEMPLIFY-SEE portal as effective in supporting EBL-based lesson planning in SE education?, and
- **RQ2)** What contributions, limitations, and improvement opportunities do educators identify when using the EXEMPLIFY-SEE portal?

To answer these questions, we conducted an exploratory empirical study with educators, combining quantitative data from a questionnaire based on the Technology Acceptance Model (TAM) with qualitative data from semi-structured interviews analyzed through coding procedures. The quantitative results indicate positive perceptions regarding the portal's perceived usefulness, perceived ease of use, and intention to use. The qualitative findings complement these results by showing that educators valued the portal's support for organizing lesson planning, clarifying pedagogical workflows, and reducing the effort required to prepare EBL-based activities. At the same time, participants identified limitations and opportunities for improvement, including aspects related to workflow flexibility and the expansion of the example repository. Overall, the findings suggest that the portal can support a more structured, sustainable, and pedagogically grounded adoption of EBL in SE education. Therefore, the main contribution of this article is an empirical evaluation of the EXEMPLIFY-SEE portal from the perspective of educators, offering evidence of its potential to support the practical adoption of EBL in SE courses.

2 Example-Based Learning in Software Engineering Education

In the educational context, the relevance of EBL is associated with the possibility of making learning more practical by demonstrating how a given task can be performed, favoring conceptual understanding, the application of knowledge, and the observation of the reasoning involved in the solution presented [13, 31]. In addition, by offering a structured path for problem solving, this methodology can reduce extraneous cognitive load and support the construction of more robust knowledge schemas [23, 32].

In SEE, this potential is particularly relevant, since the field requires students not only to know concepts, methods, and notations, but also to be able to apply them in the analysis, construction, and evaluation of software artifacts [11, 19]. The results of a systematic mapping study [6] on the use of EBL in Software Engineering indicate benefits such as improved interpretation and application of concepts [25, 28], increased motivation [24], strengthened student confidence [33], and the development of skills relevant to professional practice [16].

Despite this potential, the mapping study also revealed important difficulties for the systematic adoption of EBL in SE. These include the additional effort required from educators [8], the difficulty of developing examples with adequate complexity [35], the need for more structured pedagogical support [15], and, in some cases, students' difficulty in understanding the context of examples or identifying errors in modeled artifacts [25, 28]. These results reinforce that progress in using EBL in SE depends not only on recognizing its pedagogical value, but also on the existence of approaches and artifacts that support its operationalization in educator planning.

2.1 The EXEMPLIFY-SEE Approach

In response to the difficulties of adopting EBL in SE education, the EXEMPLIFY-SEE approach was proposed, conceived to support educators in planning example-based classes [3, 4]. Its formulation was grounded in evidence on the use of EBL in SE, including benefits, difficulties, types of examples, and pedagogical practices reported in the literature [6]. Based on this body of evidence, pedagogical requirements were established to guide the structuring of the approach and its subsequent operationalization in a web portal.

In general, the approach organizes educator planning into stages that articulate theory teaching, definition of the activity format, selection of the type of example, and feedback strategies. This organization seeks to offer educators a more structured workflow for adopting EBL, reducing dependence on *ad hoc* decisions and fostering greater coherence among teaching objectives, the class profile, and the available pedagogical resources [4]. In addition, the approach does not lead to a single fixed plan, but rather guides different planning possibilities based on the choices made by educators throughout the process, such as students' level of knowledge, the intended type of activity, and the pedagogical resources to be employed. Thus, the sequence of steps and the elements that compose the planning may vary according to the didactic context considered. The approach is not tied to a specific curriculum or to a predefined sequence of Software Engineering topics. In its initial conception, the approach prioritized the cognitive perspective of EBL, especially through the use of Worked Examples and Erroneous

Worked Examples, with a focus on supporting lesson planning in Software Engineering [4].

To enable the initial evaluation of the EXEMPLIFY-SEE approach, a functional prototype was created to instantiate the process of planning example-based classes proposed in the approach [4]. In this initial instantiation, the prototype was organized to support educators in defining strategies for theoretical classes, activities, and feedback, in addition to providing a repository populated with some examples to assist in preparing SE classes. The prototype's main objective was to illustrate that it is possible to reduce practical barriers to the adoption of EBL by offering more systematic guidance for educator planning.

The preliminary evidence associated with this instantiation indicated positive perceptions regarding the potential of the portal prototype to support lesson planning. Among the aspects highlighted were the usefulness of the proposal, the clarity of the workflows, ease of use, and the support offered to educators in organizing strategies for adopting EBL in SE [4]. These results suggest that the initial instantiation of the portal contributed to making the approach more accessible to teaching practice, especially by offering an explicit structure for planning classes supported by examples.

Although the initial instantiation of the EXEMPLIFY-SEE approach through the prototype made it possible to identify positive preliminary evidence, it still did not offer sufficient support for the complete adoption of the approach in situations of continuous use. Its main limitation lay in the incompleteness of its computational support, since functionalities planned to support the use of the approach were not available in the prototype, restricting the operationalization of the approach and the user experience.

Among the aspects that required improvement, usability enhancements and the incorporation of mechanisms that would favor continuity of use stood out, such as user authentication, persistence of the choices made during the construction of the lesson plan, export of lesson plans in PDF format, and availability of an English version of the portal. The need for additional resources for the example repository also became evident, including evaluation mechanisms and better support for organizing and reusing materials. Together, these elements indicated that the advancement of the approach depended mainly on improving its computational instantiation, which motivated the development of the portal aimed at strengthening support for planning example-based classes in SE education, which is the core of the present work.

3 The EXEMPLIFY-SEE Portal

The portal for supporting educator planning with EBL [1] was developed to expand support for planning classes with EBL in SE education, preserving the pedagogical basis of the approach and concentrating the modifications on its computational instantiation. In this sense, the portal aims to offer better conditions for educators to organize didactic planning, revisit previously made decisions, and continuously use the resources associated with the approach. To this end, the environment brings together **organized planning workflows** for theoretical classes, activities, and feedback, as well as a **repository of examples** intended to support the selection and reuse of materials during class preparation. The repository organizes examples gathered from previous studies, books, repositories, and online SEE materials to support EBL-based lesson planning. Figure **??** presents the tutorial screen of the portal, in which these workflows are operationalized through the axes of the approach, customization questions, and step suggestions. The interface illustrates how the choices made by educators are converted into guidance for constructing activities with EBL. In addition to the workflow guided by the tutorial, the sidebar menu allows direct access to the steps of the approach, the repository of examples, and the English version of the portal.

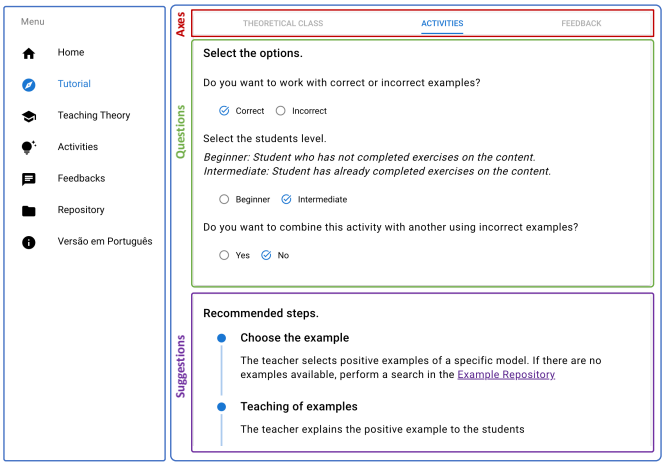

Figure 1: Annotated screen of the EXEMPLIFY-SEE portal

In this context, the portal offers **user authentication** resources, with support for login, registration, and access through a Google account, as well as mechanisms for the **persistence of choices made during planning**. As a result, the portal began to allow continuous and individualized use, enabling educators to later resume the decisions recorded in the environment. Associated with this process, the portal allows the **export of the lesson plan in PDF format**, enabling the planning constructed in the portal to be converted into an artifact directly usable in teaching practice. These functionalities respond to limitations of the prototype, which still offered only partial support for recurrent use of the environment and for consolidating the planning prepared by educators.

The portal also offers an **English version**, expanding the possibilities of access to the environment and reducing a restriction present in the prototype, whose interface was limited to Portuguese. In addition, the repository now includes a **larger number of examples**, strengthening support for educators in selecting and reusing materials for planning classes with EBL. This aspect is particularly relevant because the availability of appropriate examples constitutes one of the central elements for sustaining the operationalization of the approach in the context of didactic planning.

Finally, the repository offers a mechanism for the **star-based evaluation of examples** available in the repository. This functionality offers an additional form of interaction between educators and the cataloged materials, allowing them to assign evaluations to the examples consulted during planning. Thus, in addition to making materials available, the repository includes a resource that

[1] The EXEMPLIFY-SEE portal can be accessed at: «omitted for blind review».

can assist educators in identifying examples that are potentially more useful for planning classes with EBL. Together, these modifications contribute to expanding the conditions for operationalizing the approach through the portal, reinforcing its role as support for educator planning in SE.

To make the type of support offered by the portal more concrete, Table 1 presents an excerpt from a lesson plan prepared by one of the study participants, focusing on the elements structured with support from the portal. In the case presented, the portal was used to define the sequence of class steps and to select, from the repository available in the environment, an example of a hospital management system to be used during the activity. The complete link to this example is available in the study's supplementary material [5]. The table shows how the portal supports the organization of planning with EBL by presenting a predefined sequence of steps, whose composition is shaped by the choices made by the educator throughout the planning workflow, such as the type of activity, the use of examples, and feedback strategies.

Table 1: Excerpt of the planning elements structured with support from the EXEMPLIFY-SEE portal

Lesson plan characterization: Class on Class Diagram, planned for the Software Engineering I course, in an undergraduate Information Systems program, with a workload of 4 class hours.
Sequence of steps defined with support from the portal: **(1) Lecture:** presentation of the fundamental concepts of object-oriented software modeling and the importance of the class diagram in UML, with prior sharing of supporting material. **(2) Explain examples of the concepts taught:** use of practical examples to illustrate the application of the concepts discussed, relating the content to concrete situations. **(3) Choose the example:** selection of a practical example to be demonstrated to students. **(4) Demonstration:** demonstration of how to construct the class diagram for the chosen example, showing how to identify classes, attributes, methods, and relationships. **(5) Present a domain:** presentation of a specific domain for modeling, with a description of the system's operation and the entities involved. **(6) Perform the modeling:** students perform the modeling of the class diagram for the domain provided. **(7) Demonstration of the correct modeling:** presentation of the correct modeling for the proposed domain, after the activity performed by the students. **(8) Diagram correction:** correction of the diagrams by students based on the demonstration performed. **(9) Feedback:** submission of the corrected diagrams and provision of individualized feedback.

4 Research Methodology

This study aimed to analyze educators' perceptions of the EXEMPLIFY-SEE portal as support for planning classes with EBL in SE education. To this end, the following research questions were defined:

- **RQ1 – To what extent do educators perceive the EXEMPLIFY-SEE portal as effective in supporting EBL-based lesson planning in SE education?** This question seeks to investigate whether educators consider that the portal provides effective support for organizing didactic planning with EBL.
- **RQ2 – What contributions, limitations, and improvement opportunities do educators identify when using the EXEMPLIFY-SEE portal?** This question seeks to identify positive and negative perceptions of the portal, as well as improvement suggestions related to its use as support for planning classes with EBL.

To answer these questions, an exploratory study was conducted in which educators used the portal to prepare a lesson plan and then answered a questionnaire based on the Technology Acceptance Model (TAM) and participated in a feedback interview. This design made it possible to gather quantitative and qualitative evidence on the support offered by the new version of the portal for planning classes with EBL.

4.1 Participants

The participants in this study were educators invited by email and selected by convenience, according to their availability to participate in the proposed activities. The evaluation was conducted remotely, and participants received instructions for carrying out each stage of the study. The sample did not require prior experience with EBL, since the proposal also seeks to support educators with less familiarity with this active methodology. On the other hand, participants were required to work in higher education courses in the Computing area, especially in contexts related to SE education and software modeling.

In total, eight educators participated, affiliated with seven public universities located in six Brazilian states. The complete characterization of the participants is presented in the supplementary material [5]. Regarding experience teaching software modeling, most participants had a consolidated trajectory in the area, with 62.5% (5/8) having ten or more years of experience. Participants were also characterized in terms of their previous use of active methodologies and EBL. In this respect, the sample was observed to be composed mostly of educators with experience in active methodologies, corresponding to 87.5% (7/8) of the participants. On the other hand, only 12.5% (1/8) reported prior experience with EBL, which is particularly relevant given the portal's objective of supporting lesson planning with this methodology.

4.2 Study Protocol

After accepting the consent form and completing the characterization form, the educators proceeded to the execution of the study. The adopted protocol comprised the stages presented in Figure **??**: instructional video, lesson plan construction, TAM questionnaire, feedback interview, and analysis of the results. All stages were conducted remotely.

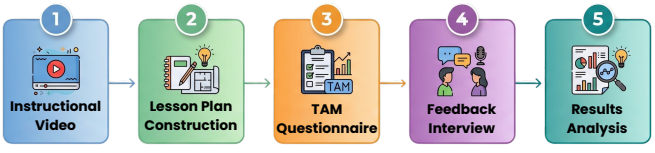

Figure 2: Sequence of Activities in the Exploratory Study

Instructional video: In the first stage, participants watched a video with guidance on the approach and on the use of the portal. This material aimed to present the main elements necessary for educators to use the environment in planning classes with EBL.

Lesson plan construction: Next, the educators used the portal to prepare a lesson plan focused on teaching software modeling. In this stage, participants went through the workflows available in the portal and selected the options most appropriate to their

didactic context. During this activity, there was no direct interaction between the researchers and the participants.

TAM Evaluation Questionnaire: After constructing the lesson plan, participants answered a questionnaire based on the TAM, proposed by Davis et al. [9]. The instrument was organized into three indicators. The first, Perceived Usefulness (PU), consisted of four statements aimed at analyzing the extent to which participants perceived that the portal could improve their performance in planning classes with EBL. The second, Perceived Ease of Use (PEU), also with four statements, sought to analyze educators' perceptions of the effort required to use the technology. The third, Perceived Intention to Use (IU), consisted of three statements related to the future intention to use the portal. Responses were recorded on a five-point Likert scale, ranging from "Strongly agree" to "Strongly disagree." The complete set of statements used in the questionnaire is available as supplementary material in [5].

Feedback Interview: After completing the evaluation questionnaire, the educators participated in a semi-structured interview, conducted remotely via Google Meet, recorded, and later transcribed for analysis. The interview addressed participants' perceptions of the use of EBL in teaching software modeling, as well as positive and negative aspects observed in the use of the portal, difficulties encountered, and suggestions for improvement. The complete interview script and the anonymized interview transcripts are available in the supplementary material in [5].

Results Analysis: The qualitative data from the interviews were analyzed based on the coding procedures proposed by Strauss and Corbin [30]. The objective of this stage was to code, categorize, and synthesize the data in order to identify positive aspects, limitations, and suggestions perceived by educators after using the portal. Initially, the interview recordings were fully transcribed. Then, the Taguette tool was used to support the organization and synthesis of the data. The analysis began with the application of open coding to the transcripts. The coding process was conducted by one researcher and later discussed in meetings with the research team, with the objective of reducing possible interpretive biases. An illustrative example of the coding procedure is also available in the supplementary material in [5].

5 Results

5.1 Quantitative Results

Figure **??** presents the educators' perceptions obtained from the responses to the TAM questionnaire. Items PU1 to PU4 of the questionnaire are related to the **Perceived Usefulness** of the portal. All items associated with this indicator showed 75% or more agreement ("Strongly agree" and "Agree"). This indicates that participants perceived the portal as a useful resource to support lesson planning with EBL in the context of SE education. The item with the highest level of agreement was PU2, with 100% agreement ("Strongly agree" and "Agree"). This item assesses the extent to which educators perceive that the portal can increase their productivity in adopting EBL. This result suggests that the portal was perceived as a resource capable of making the preparation of classes with this methodology more efficient. Items PU1, PU3, and PU4 showed 75% agreement, indicating that most educators also perceived the portal as useful for improving planning performance, understanding aspects of their own teaching experience with EBL, and supporting the reporting of this experience. Taken together, these results suggest that the portal was perceived as useful for supporting different dimensions of educator planning with EBL.

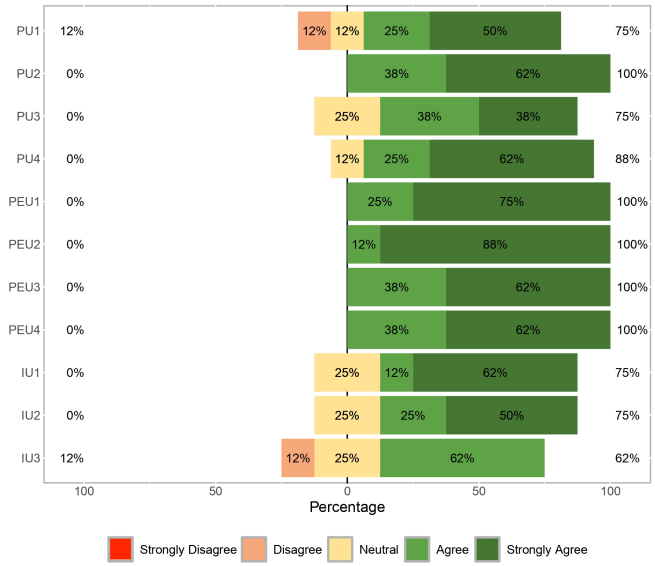

Figure 3: Educators' perceptions of the portal

Items PEU1 to PEU4 of the questionnaire are related to the **Perceived Ease of Use** of the portal. All these items showed 100% agreement ("Strongly agree" and "Agree"), indicating that participants perceived the portal as easy to use. The item with the highest percentage of "Strongly agree" responses was PEU2, related to the mental effort required to use the portal, with 88% of responses in this category. Items PEU1, PEU3, and PEU4 also showed high levels of agreement, suggesting that educators perceived the portal as clear, understandable, and intuitive to use. These results indicate that the portal was perceived as accessible in terms of interaction, which is particularly relevant in a proposal aimed at supporting educators with different levels of familiarity with EBL.

Items IU1 to IU3 of the questionnaire assess the **Perceived Intention to Use** of the portal. All items in this category showed 62% or more agreement, indicating that most participants expressed an intention to use the portal to plan classes with EBL. Items IU1 and IU2, which address the intention and likelihood of use assuming that educators have access to the portal, reached 75% agreement. This suggests that most participants consider using the portal in future didactic planning situations. Item IU3, related to the intention to use it in the next month, showed the lowest level of agreement, with 62%. This result suggests that, although most educators demonstrated a favorable predisposition toward using the portal, some of them may have restrictions or uncertainties regarding the immediate use of the tool, possibly due to contextual factors related to the academic calendar, course planning, or time availability.

5.2 Qualitative Results

The categories presented in this section were derived from the codes identified during the interview coding process. Figure **??** summarizes the main positive aspects, limitations, and improvement

suggestions mentioned by the educators. Although these findings were initially coded according to their positive, negative, or suggestive polarity, their presentation in this section was reorganized into two analytical dimensions. The first brings together perceptions related to usability and the interaction experience with the portal. The second groups perceptions related to the pedagogical support offered to educators in planning classes with EBL. This reorganization makes it possible to show more clearly how the portal was perceived both as a computational artifact and as a resource to support educator planning.

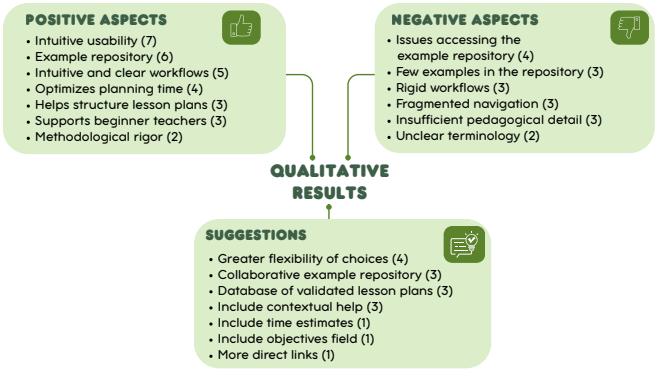

Figure 4: Summary of positive aspects, negative aspects, and suggestions based on educators' perceptions.

5.2.1 ***Usability and interaction experience with the portal.*** A first dimension of the qualitative results refers to usability and the interaction experience with the portal. The portal's **intuitive usability** was the most recurring positive aspect. Participants reported that the environment is simple to use, pleasant, and easy to navigate, which contributed to an interaction experience without significant difficulties. In one statement, the tool was described as *"simple to use, super pleasant"* – P01; in another, the navigation flow was characterized as *"very smooth"* – P08. These results converge with the quantitative findings related to perceived ease of use and reinforce the positive evaluation of the portal in terms of interaction. In addition to general usability, another frequently mentioned positive aspect was the presence of **intuitive and clear workflows**. Participants reported that the step-by-step process is easy to follow and makes sense for preparing classes with EBL. One educator stated that *"the flow of questions that lead you to the plan is very straightforward"* – P1. Similarly, another participant highlighted: *"I liked the flow that is here"* and added that *"this guide that guides us with these questions is very interesting"* – P4. It was also reported that *"the workflows help organize ideas"* – P6 and that they *"constitute a step-by-step process that is intuitive for classroom application"* – P7. These reports suggest that the clarity of the workflows was perceived as an important contribution, both for guiding planning and for making the proposal more understandable to educators.

Despite this positive evaluation, the educators also identified limitations related to the interaction experience. Among the reported limitations, **problems accessing the example repository** appeared recurrently. In the portal, the repository made materials available through external links, and participants mentioned difficulties in accessing some of these resources, mainly due to broken links or incorrect redirects. In one statement, an educator reported that *"there was a diagram that did not open"* and that, in another case, *"the link was wrong"* – P1. These reports indicate that, although the repository was perceived as a relevant component, its use was still hindered by failures in external access to part of the materials made available.

Problems related to **unclear terms** were also reported, especially in items of the workflow and in concepts presented in the environment. Participants indicated that some names used in the portal made it difficult to immediately understand what was being requested or explained. One educator, for example, stated that they found the use of the term *"tutorial"* strange in that context – P5, while another reported difficulty understanding expressions such as *"socio-cognitive perspective"* – P4, indicating that certain concepts were not immediately clear at first contact. These reports indicate that part of the difficulties in use was associated less with the general logic of the proposal and more with the way certain elements were named and presented. This perception is connected to an aspect also mentioned in the interviews, described here as **fragmented navigation**. In this case, participants reported difficulties in better understanding the sequencing between stages and in following, in a more integrated way, the construction of the lesson plan throughout navigation. One educator observed that, at certain moments, *"this sequencing is not very good"* and questioned the excessive division into tabs, stating that they could not clearly perceive *"how my plan as a whole is changing"* – P01. These reports suggest that, for some educators, interaction with the portal still presented points of discontinuity that affected the fluidity of planning.

The educators' suggestions reinforce this interpretation. Improvements were proposed, such as the **inclusion of contextual help and explanation of terms**. In this case, participants suggested mechanisms that would make some concepts and questions presented in the portal workflow clearer. One participant reported initial difficulty in understanding expressions such as socio-cognitive perspective, noting that the meaning only became clearer when additional information about this point was presented – P4. Based on this experience, the same participant suggested including *"a help item or icon just explaining the question better"* – P4. Similarly, another educator indicated that, *"although complementary readings may be useful, it would be important for the portal itself to provide a little more beyond this text that you placed there"* – P6. These reports suggest that the inclusion of contextual help and additional explanations within the environment itself can make the use of the portal clearer and more accessible to educators. Another suggestion was the inclusion of **more direct links throughout the navigation flow**. In this case, participants proposed that materials, examples, and resources mentioned in the step-by-step process could be accessed without requiring additional searches in other parts of the portal or outside it. One educator stated that *"it would be better to place the links in the middle of the step-by-step process so that the teacher could follow the planning more directly"* – P5. This suggestion indicates that punctual improvements in the integration between the workflow and support resources can make the user experience more fluid.

5.2.2 ***Pedagogical support for educator planning with EBL***. The second dimension of the qualitative results refers to the pedagogical support offered by the portal for educator planning with EBL. This dimension brings together the findings most directly associated with the objective of the portal, that is, supporting educators in organizing example-based classes in SE education. Among the positive aspects perceived by educators, **helps script the class** was one of the most recurrent. Participants associated the portal with the possibility of better organizing ideas, structuring the planning stages, and making more explicit the elements that need to be considered when preparing classes with EBL. In one statement, an educator highlighted that the proposal *"allows us to outline a script... it facilitates the teacher's work"* – P02, while another stated that the portal *"already brings you an organization of ideas, of how you should do it"*. – P06. This perception also appeared linked to the idea of **methodological rigor**, although less frequently. For one participant, the step-by-step process provided by the portal contributes to keeping class preparation more aligned with the principles of EBL, reducing uncertainties about how to apply the methodology consistently. One educator stated that this was *"the main point of the approach"*, because it represented *"a guarantee that I am following the example-based learning process in the formal way"* – P05. This result suggests that the portal was perceived not only as a resource to support the organization of educators' work, but also as support for methodologically oriented planning.

Educators also reported that the portal **optimizes planning time**. This aspect was associated with the fact that the portal offers a more direct path for class preparation, preventing educators from having to search on their own, across different sources, for how to apply the methodology. One participant stated that having *"a well-defined step-by-step process made it faster"* – P05, while another highlighted that, without this support, they would have to "spend time, search, investigate." – P08. This result suggests that the portal was perceived as a resource capable of making planning more agile, without giving up methodological support. The usefulness of the portal was also associated with the fact that it **supports novice educators**. Participants emphasized that the portal can be particularly useful for teachers with little experience, whether in teaching in general or in preparing lesson plans with EBL. In different statements, the tool was associated with more explicit guidance on how to structure the class. One participant observed that it is *"very useful especially for those who are starting to teach"* – P01, while another highlighted that it *"helps a lot, especially for those who do not have much experience creating lesson plans"* – P07. The portal was perceived as a support resource that can reduce initial insecurity and provide greater direction in the class preparation.

In this same dimension, participants emphasized the presence of a **repository of examples** as an important positive aspect. This resource was associated with the possibility of accessing examples more immediately during planning, reducing the need for external searches for materials. One educator observed that *"many times we end up looking for other examples, but they are not so readily available"* – P06, while another highlighted as a positive point the fact that the portal already provides a repository in which it is possible to *"go directly there to check the example"* – P08. These reports indicate that the repository was perceived as a relevant component of the pedagogical support offered by the portal, supporting the selection of materials consistent with the EBL proposal.

Despite these positive aspects, educators also pointed out limitations directly related to pedagogical support. One of them was the presence of **few examples in the repository**. Participants reported that the number of available materials was still limited, which restricted the possibilities for consulting and selecting examples during the planning of classes with EBL. One educator highlighted as a negative point that *"the environment is still lacking several other examples"* – P5. Similarly, another participant observed that *"it would be important to have more examples"*, although she also recognized the difficulty of populating this type of database – P7. These reports suggest that, although the repository is perceived as useful, its coverage was still considered insufficient to broadly meet educators' needs. The presence of **rigid workflows** was also reported, associated with the perception that the portal offers limited possibilities for combining pedagogical choices. Participants reported that, at certain moments, planning decisions were restricted to binary answers or to only one option per stage, which reduced educators' flexibility to compose the class according to their needs. In one statement, an educator observed that some questions could *"have more options that were not simply yes or no"* – P1. Reports such as this indicate that the portal still presents limitations regarding the flexibility offered to educators during class preparation.

Another negative aspect identified was the **insufficient pedagogical detailing** in some points of the planning process. Participants reported the absence of elements that could make the lesson plan more specific from a pedagogical point of view, such as fields for specifying objectives or more concrete support for defining the workload. One educator observed that *"there is no plan without objectives"* – P1. Another highlighted that, for early-career teachers, *"estimating the appropriate duration of each stage can be difficult"* – P5. These reports indicate that, although the portal organizes planning, there is still room to expand the pedagogical detailing offered to educators.

The improvement suggestions reinforce this reading. Among the suggestions, one of the most recurrent was the need for **greater flexibility of choices** throughout planning. Participants suggested that the portal should allow alternatives to be combined within the same stage, as well as allow certain elements of the workflow to be reorganized according to educators' needs. In one statement, an educator proposed *"giving the teacher the chance to reorder the steps"* – P1. Similarly, another participant suggested *"allowing more than one choice in situations in which the teacher wishes to combine strategies such as individual presentation and seminar"* – P5. Together, these reports indicate that expanding the flexibility of the workflow can make planning more adherent to different didactic contexts.

Another important suggestion was the **inclusion of time estimates and objectives** in the lesson plan. Participants indicated that these elements could make planning more complete and more usable in teaching practice. One educator suggested the *"inclusion of a specific field to record the objectives of the class"* – P1. In the same direction, another participant proposed *"implementing this issue of workload for the example and presenting, at the end, a sum of the expected time for the activities"* – P5. These reports suggest that making objectives explicit and supporting the temporal distribution of stages can make the lesson plan more concrete and more

useful for educators. Participants also suggested the **creation of a collaborative repository of examples**. This proposal appeared associated with the possibility of increasing the amount of available materials and reducing dependencies on access to external links. One educator suggested *"opening this repository so that people can submit examples used in the classroom"* – P8. In addition, there was the suggestion to *"make the materials available in spaces such as Drive or GitHub, to make it easier for us to access them and not run the risk of them going offline"* – P7. These statements indicate that participants envision a more dynamic repository, expanded collaboratively and with more stable forms of access.

Finally, another relevant suggestion was the **availability of a repository of validated lesson plans**. Participants indicated that examples of already completed plans, produced by other educators, could serve as concrete references to support the use of the portal and the preparation of classes with EBL. One educator suggested *"an example of a template of a lesson plan from a real case already completed in the system"* – P2. Another participant proposed that the plans should remain in an internal repository, accompanied by comments from the educators themselves about their use – P6. Similarly, it was also suggested to *"make an example lesson plan available within your platform"* – P8. Together, these statements suggest that making already prepared plans available can offer additional support to educators, especially in situations of lower familiarity with the methodology or with the portal itself.

6 Discussion

6.1 Educators' perceptions of support for lesson planning with EBL (RQ1)

The results for **Perceived Usefulness** indicate that educators considered the portal useful for planning classes with EBL. All items associated with this indicator showed 75% or more agreement, with emphasis on PU2, which reached 100% agreement and refers to increased productivity in using the portal. These results suggest that the EXEMPLIFY-SEE portal was perceived as a resource capable of supporting different dimensions of didactic planning, including class organization, understanding one's own experience with the methodology, and more efficient preparation of activities with EBL.

The qualitative results complement this interpretation by showing how this support was perceived in practice. In the dimension of pedagogical support for educator planning, participants highlighted that the portal **helps script the class**, **optimizes planning time**, **supports novice educators**, and **contributes to greater methodological rigor**. Taken together, these findings suggest that the portal was perceived as a relevant pedagogical support for transforming planning into a more structured process that is less dependent on improvised decisions. This point is particularly important because it suggests that the approach remained stable as the pedagogical core, while the portal strengthened its operationalization by offering greater clarity, continuity, and direction to the planning process.

The results suggest that the portal supports planning with EBL by offering structure, methodological guidance, and support for organizing educators' pedagogical decisions.

The **repository of examples** also contributes to this perception of effectiveness. Although it can be seen as a functionality of the portal, the qualitative reports indicate that educators understood it as a pedagogical support resource for planning, as it reduces the need for external searches for materials and favors the selection of examples during class preparation. Thus, the repository acts as a relevant component of the support offered by the portal, especially because the availability of appropriate examples is an important condition for adopting EBL in SE education.

The dimension of usability and interaction experience reinforces this interpretation, but in a complementary role. The results for **Perceived Ease of Use** show that all items in this category reached 100% agreement, indicating that participants perceived the portal as clear, understandable, and intuitive. The qualitative results also indicate that the workflows were perceived as **intuitive and clear**, favoring an initial understanding of how the portal works. Thus, positive usability contributed to enabling educators to focus on pedagogical planning, rather than facing operational difficulties in using the environment.

The results indicate that the portal's positive usability favors its adoption by reducing interaction barriers during educator planning.

Regarding **Perceived Intention to Use**, the results showed a favorable, although more moderate, predisposition toward future use of the portal. Items IU1 and IU2, related to the intention and likelihood of using the portal, reached 75% agreement, while IU3, which assesses the intention to use the portal in the short term, showed 62%. This result suggests that, although educators recognized value in the portal and considered its use plausible in future planning situations, the more immediate incorporation of the portal was not yet equally consolidated. The qualitative results help explain this difference. Aspects such as rigid workflows, unclear terms, problems accessing the repository, and insufficient pedagogical detailing indicate that the user experience, although generally positive, still presents points that may restrict the prompt and continuous adoption of the environment. Thus, the lower agreement in IU3 suggests that the portal, despite its advances, still requires refinements to become more fluid, flexible, and complete as support for planning with EBL.

The results suggest that educators perceived the portal as offering relevant support for planning with EBL, although its immediate adoption may still depend on greater flexibility, pedagogical detailing, and stability of the available resources.

Answer to RQ1: Educators perceived the EXEMPLIFY-SEE portal as effective in supporting lesson planning with EBL in SE. The quantitative evidence shows positive perceptions of usefulness, ease of use, and a favorable predisposition toward future use, while the qualitative results indicate that the portal contributes to structuring planning, guiding educators, and especially supporting educators with less experience. At the same time, the lower intention to use it in the short term and the negative aspects identified show that there are still opportunities for refinement to strengthen this support.

6.2 Contributions, limitations, and opportunities for improving the EXEMPLIFY-SEE portal (RQ2)

The results indicate that the portal was perceived positively, especially in two complementary dimensions. The first refers to usability and the interaction experience with the environment. The second refers to the pedagogical support offered to educators during lesson planning with EBL. This distinction makes it possible to understand that the portal was evaluated both as a computational artifact and as a resource to support educator planning. In the dimension of **usability and interaction experience**, educators perceived the portal predominantly positively. This interpretation is supported both by the quantitative results, which indicated positive evaluations of **perceived ease of use**, and by the qualitative results, in which categories such as **intuitive usability** and **intuitive and clear workflows** stood out. Taken together, these findings suggest that the portal was perceived as a clear, accessible, and understandable environment, capable of supporting educators in navigating the planning workflows.

At the same time, the results also show that this dimension still presents limitations. Perceptions of **unclear terms**, **fragmented navigation**, and **problems accessing the repository** indicate that strengthening the computational support did not eliminate all points of friction in the user experience. These results suggest that the portal expanded the conditions for operationalizing the approach, but that there is still room to make the interaction more fluid, clear, and integrated.

> The results suggest that the portal was perceived as clear and intuitive, although adjustments to navigation, terminology, and access to resources could still improve the user experience.

In the dimension of **pedagogical support**, the results appeared less as a change in the basis of the approach and more as a strengthening of the support offered to educators during planning. Categories such as **helps script the class**, **optimizes planning time**, **supports novice educators**, and **methodological rigor** indicate that participants perceived the portal as a resource that makes stages explicit, guides decisions, and reduces the initial effort required to adopt EBL, especially in contexts in which educators do not yet have a consolidated repertoire for this type of planning. Thus, the results suggest that the portal contributed to making the operationalization of the approach clearer, more directed, and more sustainable in teaching practice.

> The results suggest that the portal offers structured support for planning with EBL, strengthening the pedagogical support offered to educators and reducing the initial effort required to adopt the methodology.

The **repository of examples** also composes this pedagogical dimension, as it was perceived by educators as a resource to support the selection and reuse of materials during planning. Participants valued the possibility of accessing examples more directly, which may reduce part of the effort required to prepare activities with EBL. This is particularly relevant because one of the fronts of portal evolution focused on the repository, with the inclusion of new examples and evaluation mechanisms. The qualitative reports therefore show that this advancement was perceived, but that it was still not sufficient to fully resolve issues of access, stability, and diversity of the materials made available.

This same pattern appears in other dimensions of planning. Although the portal advanced by incorporating mechanisms for persistence and export of the lesson plan, reports on **insufficient pedagogical detailing** show that the consolidation of the plan can still be improved, especially with regard to making objectives explicit and distributing the time of activities. Similarly, perceptions of **rigid workflows** indicate that the portal can still offer greater flexibility so that educators can combine strategies, reorganize stages, and adapt planning to different didactic contexts.

The improvement suggestions detail more clearly how educators envision this next stage of evolution. The proposals for greater flexibility of choices, inclusion of time estimates and objectives, contextual help and explanation of terms, a collaborative repository of examples, and a repository of validated lesson plans indicate that participants do not see the portal as a finished artifact, but as a promising basis for future development. This point is important because it reinforces the interpretation that the approach remained stable as the pedagogical core, while the portal is configured as a means of expanding its applicability and adherence to the real needs of educator planning.

> The limitations and suggestions identified show that the portal expanded the support offered for planning with EBL, but that components such as the repository, workflow flexibility, plan consolidation, and contextual help can still be improved in future versions.

Answer to RQ2: Educators perceived the second version of the EXEMPLIFY-SEE portal positively, especially regarding support for planning, the clarity of the workflows, and the usability of the environment. Considering the limitations identified in the prototype, the results suggest that the portal strengthened the operationalization of the approach, especially by expanding the support offered to educators during the preparation of classes with EBL. At the same time, participants identified limitations related to the repository, workflow flexibility, clarity of terms, and pedagogical detailing, in addition to suggesting concrete improvements for future versions. Taken together, these results indicate that the portal expanded the computational and pedagogical support for the approach, although important opportunities for refinement remain to strengthen its flexibility, its integration with the repository, and its adherence to the real needs of educator planning.

7 Threats to Validity

Regarding **internal validity**, participants knew they were evaluating a portal developed by the researchers, which may have influenced their responses. To mitigate this threat, the study followed standardized instructions, confidentiality was assured, and the interviews used open-ended questions. Moreover, participants

reported limitations, difficulties, and improvement suggestions, indicating that they were able to critically evaluate the portal.

Regarding **external validity**, the study involved eight educators selected by convenience, affiliated with Brazilian public universities, and the evaluation focused on planning software modeling classes. Although the participants had different levels of teaching experience and most had no prior experience with EBL, the results should not be generalized to all SE educators, institutions, countries, or SE topics.

Regarding **construct validity**, the study relied on a TAM questionnaire and semi-structured interviews to capture educators' perceptions of usefulness, ease of use, intention to use, contributions, and limitations. Thus, the results should not be interpreted as evidence of objective pedagogical effectiveness, learning gains, or measured improvement in the quality of lesson plans.

Regarding **conclusion validity**, the small sample and the use of descriptive quantitative analysis limit the strength of the conclusions. In addition, qualitative analysis involves researcher interpretation. interpretation. This threat was mitigated by the use of systematic coding procedures, based on [30], and by discussions among the researchers throughout the analytical process. Therefore, the findings should be interpreted as exploratory evidence of educators' perceptions of the portal.

8 Related Work

The literature on EBL in SE still presents few tools directly aimed at supporting educators in preparing classes. There are different computational artifacts that support teaching with EBL, such as portals, repositories, web applications, and integrated environments [6]. However, when specifically considering support for educators, the number of initiatives is more limited.

Within this scope, one of the closest works is that of Tonhão et al. [34], which proposes a portal to catalog and structure Worked Examples extracted from open-source projects. This portal was designed to provide instructors with resources and references to incorporate examples into their classes, serving as a centralized platform through which SE educators can consult, access, and reuse the cataloged examples. Another relevant initiative is OpenSMALS, a repository that offers strategies and scenarios for teaching UML, seeking to guide educators in preparing activities in this specific context [26]. DEPTHS (Design Patterns Teaching Help System) [14], in turn, integrates modeling resources, feedback, collaborative annotation, and an online repository of patterns, offering a more comprehensive environment to support teaching.

Other platforms support active learning methodologies from broader perspectives. OpenPBL supports Problem-Based Learning by helping educators organize PBL activities in a web-based environment [21]. OpenMAIC, in turn, uses LLM-driven agents to create interactive learning experiences, including classes, quizzes, simulations, discussions, and project-based activities [20]. Although these platforms provide relevant support for active learning, they differ from EXEMPLIFY-SEE in scope and pedagogical focus. OpenPBL focuses on organizing PBL activities, and OpenMAIC focuses on AI-generated interactive learning experiences, whereas EXEMPLIFY-SEE specifically supports the adoption of EBL in SEE through structured pedagogical workflows, lesson-planning support, and a repository of SE examples.

Together, these works show relevant contributions to the provision, organization, and reuse of examples in SE education, as well as to the broader support of active learning methodologies. Even so, support for the pedagogical planning of EBL remains limited. In this sense, the EXEMPLIFY-SEE approach and its portal differ by supporting educators both in accessing examples and in the structured definition of steps for the class, integrating these different elements into an educator-oriented workflow.

9 Conclusion

In this paper, we discussed the EXEMPLIFY-SEE portal, based on the previously proposed approach to support EBL in SE education [4]. This portal was developed to expand the support offered to educators in planning classes with EBL. To evaluate it, we conducted an exploratory study with eight educators from different Brazilian universities, who used the portal to prepare a lesson plan and then evaluated it through a TAM questionnaire and a feedback interview. The results showed positive perceptions regarding usefulness, ease of use, and potential support for educator planning, especially with regard to class organization, clarity of the workflows, optimization of preparation time, and support for educators with less prior experience with EBL.

On the other hand, the results also showed that there is still room for improvement in the portal. Among the main points identified are limitations related to the repository of examples, workflow flexibility, clarity of some terms, and pedagogical detailing of the lesson plan. The suggestions raised by the participants include greater flexibility of choices, inclusion of contextual help, expansion and strengthening of the repository, as well as the availability of validated lesson plans. As future work, we intend to incorporate these improvements into new versions of the portal, as well as to advance mechanisms that expand the sustainability of use of the environment and the support offered to educator planning, as well as to investigate the use of large language models (LLMs) as complementary support for educator planning, especially in generating drafts of lesson plans and in recommending and creating examples aligned with the didactic objectives defined by educators. We also consider as a future direction investigating the use of the portal in other SE education contexts and analyzing, in a more objective way, its effects on the quality of the lesson plans produced and on students' learning.

Artifact Availability

The artifacts are available in an anonymized repository [5]. The material includes the data collection instruments, the TAM questionnaire, the interview script, the anonymized interview transcripts, an example lesson plan, and an example of the coding procedure.

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References

[1] Isaque Alves and Carla Rocha. 2021. Qualifying software engineers undergraduates in DevOps - challenges of introducing technical and non-technical concepts in a project-oriented course *(ICSE-JSEET '21)*. IEEE Press, 144–153. doi:10.1109/ICSE-SEET52601.2021.00024

[2] Maik Beege, Sascha Schneider, Steve Nebel, Justus Zimm, Sarah Windisch, and Günter Daniel Rey. 2021. Learning programming from erroneous worked-examples. Which type of error is beneficial for learning? *Learning and Instruction* 75 (2021), 101497. doi:10.1016/j.learninstruc.2021.101497

[3] Tiago Piperno Bonetti, Matheus Molina Dias, Williamson Silva, and Thelma Elita Colanzi. 2023. Students' Perception of Example-Based Learning in Software Modeling Education. In *Proceedings of the XXXVII Brazilian Symposium on Software Engineering* (Campo Grande, Brazil) *(SBES '23)*. Association for Computing Machinery, New York, NY, USA, 67–76. doi:10.1145/3613372.3614195

[4] Tiago P. Bonetti, Matheus M. Dias, Williamson Silva, and Thelma E. Colanzi. 2026. EXEMPLIFY-SEE: A Structured Approach and Portal for Example-Based Learning in Software Engineering Education. In *Proceedings of the 2026 IEEE/ACM 48th International Conference on Software Engineering: Software Engineering Education and Training* (Rio de Janeiro, Brazil) *(ICSE-SEET '26)*. Association for Computing Machinery, New York, NY, USA, 12. doi:10.1145/3786580.3786975

[5] Tiago P. Bonetti, Matheus M. Dias, W. Silva, and T. E. Colanzi. 2026. Supplementary Material. https://figshare.com/s/efce01d4439301a1c883.

[6] Tiago P. Bonetti, W. Silva, and T. E. Colanzi. 2025. Example-Based learning in Software Engineering Education: a systematic mapping study. *Computer Science Education* (2025), 1–37. doi:10.1080/08993408.2025.2543095

[7] Xingliang Chen, Antonija Mitrovic, and Moffat Mathews. 2020. Learning From Worked Examples, Erroneous Examples, and Problem Solving: Toward Adaptive Selection of Learning Activities. *IEEE Transactions on Learning Technologies* 13, 1 (2020), 135–149. doi:10.1109/TLT.2019.2896080

[8] Marian Daun, Andrea Salmon, Thorsten Weyer, Klaus Pohl, and Bastian Tenbergen. 2016. Project-Based Learning with Examples from Industry in University Courses: An Experience Report from an Undergraduate Requirements Engineering Course. In *2016 IEEE 29th International Conference on Software Engineering Education and Training (CSEET)*. IEEE, Dallas, TX, USA, 184–193. doi:10.1109/CSEET.2016.15

[9] Fred D. Davis, Richard P. Bagozzi, and Paul R. Warshaw. 1989. User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science* 35 (1989), 982–1003.

[10] Víctor M. Fonseca and Jesica Gómez. 2017. Applying Active Methodologies for Teaching Software Engineering in Computer Engineering. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje* 12, 3 (2017), 147–155. doi:10.1109/RITA.2017.2738178

[11] Vahid Garousi, Gorkem Giray, Eray Tuzun, Cagatay Catal, and Michael Felderer. 2020. Closing the Gap Between Software Engineering Education and Industrial Needs. *IEEE Software* 37, 2 (2020), 68–77. doi:10.1109/MS.2018.2880823

[12] Bhuvana Gopal and Stephen Cooper. 2021. Peer Instruction in Software Engineering - Findings from Fine-grained Clicker Data. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 115–121. doi:10.1145/3408877.3432405

[13] Xiaoxia Huang. 2017. Example-based learning: Effects of different types of examples on student performance, cognitive load and self-efficacy in a statistical learning task. *Interactive Learning Environments* 25 (4 2017), 283–294. Issue 3. doi:10.1080/10494820.2015.1121154

[14] Zoran Jeremić, Jelena Jovanović, and Dragan Gašević. 2009. Semantic Web Technologies for the Integration of Learning Tools and Context-Aware Educational Services. In *The Semantic Web - ISWC 2009*. Vol. 5823. Springer Berlin Heidelberg, Berlin, Heidelberg, 860–875. doi:10.1007/978-3-642-04930-9_54 Series Title: Lecture Notes in Computer Science.

[15] Paula Kotzé, Karen Renaud, and Judy van Biljon. 2008. Don't do this – Pitfalls in using anti-patterns in teaching human–computer interaction principles. *Computers & Education* 50, 3 (April 2008), 979–1008. doi:10.1016/j.compedu.2006.10.003

[16] C Kussmaul. 2009. Software projects using free and open-source software: Opportunities, challenges, and lessons learned. In *ASEE Annual Conference and Exposition, Conference Proceedings*. American Society for Engineering Education. ISSN: 21535965.

[17] José Lima, Fernanda Alencar, and Wylliams Santos. 2021. A Preliminary Guide for Assertive Selection of Active Methodologies in Software Engineering Education. *Brazilian Symposium on Software Engineering* 10 (9 2021), 170–179. Issue 21. doi:10.1145/3474624.3476976

[18] Kate Lockwood and Rachel Esselstein. 2013. The inverted classroom and the CS curriculum. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education* (Denver, Colorado, USA) *(SIGCSE '13)*. Association for Computing Machinery, New York, NY, USA, 113–118. doi:10.1145/2445196.2445236

[19] Maira R. Marques, Alcides Quispe, and Sergio F. Ochoa. 2014. A systematic mapping study on practical approaches to teaching software engineering. *2014 IEEE Frontiers in Education Conference (FIE) Proceedings* (10 2014), 1–8. doi:10.1109/FIE.2014.7044277

[20] OpenMAIC. 2026. OpenMAIC: Open Multi-Agent Interactive Classroom. https://openmaic.chat/. Accessed: 2026-07-13.

[21] OpenPBL. 2026. OpenPBL: Active Learning, PBL, Problem Based Learning. https://openpbl.org/. Accessed: 2026-07-13.

[22] Solal Pirelli. 2024. Scalable Teaching of Software Engineering Theory and Practice: An Experience Report. In *Proceedings of the 46th International Conference on Software Engineering: Software Engineering Education and Training* (Lisbon, Portugal) *(ICSE-SEET '24)*. Association for Computing Machinery, New York, NY, USA, 286–296. doi:10.1145/3639474.3640053

[23] Alexander Renkl, Tatjana Hilbert, and Silke Schworm. 2009. Example-based learning in heuristic domains: A cognitive load theory account. *Educational Psychology Review* 21, 1 (2009), 67–78.

[24] R Shmallo and T Shrot. 2020. Constructive Use of Errors in Teaching the UML Class Diagram in an IS Engineering Course. *Journal of Information Systems Education* 31, 4 (2020), 282 – 293. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101341765&partnerID=40&md5=e3e96a6bcb0780736e3fa56318238bed

[25] Fernanda Gomes Silva, Moara Sousa Brito, Jenifer Vieira Toledo Tavares, and Christina von Flach G. Chavez. 2019. FLOSS in Software Engineering Education: Supporting the Instructor in the Quest for Providing Real Experience for Students. In *Proceedings of the XXXIII Brazilian Symposium on Software Engineering*. ACM, Salvador Brazil, 234–243. doi:10.1145/3350768.3353815

[26] Williamson Silva, Bruno Gadelha, Igor Steinmacher, and Tayana Conte. 2020. Towards an Open Repository for Teaching Software Modeling applying Active Learning Strategies. In *2020 IEEE/ACM 42nd International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET)*. 162–172.

[27] Williamson Silva, Igor Steinmacher, and Tayana Conte. 2019. Students' and Instructors' Perceptions of Five Different Active Learning Strategies Used to Teach Software Modeling. *IEEE Access* 7 (2019), 184063–184077. doi:10.1109/ACCESS.2019.2929507

[28] Williamson Alison Freitas Silva, Igor Fabio Steinmacher, and Tayana Uchoa Conte. 2017. Is It Better to Learn from Problems or Erroneous Examples?. In *2017 IEEE 30th Conference on Software Engineering Education and Training (CSEE&T)*. IEEE, Savannah, GA, 222–231. doi:10.1109/CSEET.2017.42

[29] I. Sommerville. 2015. *Software Engineering*. Pearson Education.

[30] A. Strauss and J.M. Corbin. 1998. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. SAGE Publications.

[31] Nikol Rummel Tamara Van Gog. 2018. Example-Based Learning. In *International Handbook of the Learning Sciences*. Routledge. doi:10.4324/9781315617572-20

[32] Mustafa Tepgeç and Yasemin Demiraslan Çevik. 2025. An Experimental Evaluation of Worked Example Strategies for Efficient Programming Instruction. *Technology, Knowledge and Learning* (2025), 1–16.

[33] Simone Tonhão, Thelma Colanzi, and Igor Steinmacher. 2021. Using Real Worked Examples to Aid Software Engineering Teaching. In *Brazilian Symposium on Software Engineering* (New York, NY, USA). ACM, 133–142. doi:10.1145/3474624.3476970

[34] Simone Tonhão, Thelma Elita Colanzi, and Igor Steinmacher. 2020. A portal for cataloging worked examples extracted from open source software. In *Proceedings of the 34th Brazilian Symposium on Software Engineering*. ACM, Natal Brazil, 493–498. doi:10.1145/3422392.3422471

[35] Dina Zayan, Michał Antkiewicz, and Krzysztof Czarnecki. 2014. Effects of using examples on structural model comprehension: a controlled experiment. In *Proceedings of the 36th International Conference on Software Engineering*. ACM, Hyderabad India, 955–966. doi:10.1145/2568225.2568270