

Software Standards in Action: A Complaint-Driven Game Inspired by Real Project Failures

Sevgi Koyuncu Tunç

Çankaya University

Software Engineering Dept., Faculty of Engineering Yukarıyurtçu Mahallesi

Mimar Sinan Caddesi No:4 06790 Etimesgut/Ankara, Türkiye

sevgik@cankaya.edu.tr

Abstract. *Complaint to Compliance is a classroom-based game teaching ISO/IEC/IEEE 12207 standards through real-world complaint-driven scenarios. Grounded in experiential learning, its low-tech, card-based design fosters active learning via guided discussion. A qualitative case study (n=21) analyzed student perceptions, revealing: (1) conceptual bridging of theory and practice, (2) professional identity development, and (3) enhanced engagement through gamification. The accessible design offers a scalable model for standards education. Preliminary findings suggest pedagogical value for information systems education, with further cross-cultural validation needed.*

Keywords. ISO/IEC/IEEE 12207, software engineering education, gamification, serious games, process standards, classroom activity, empirical study, curriculum innovation.

1 Introduction

International standards are essential to ensuring the quality, reliability, and maturity of software systems. Among them, ISO/IEC/IEEE 12207 serves as a comprehensive framework for software lifecycle processes, encompassing acquisition, development, operation, support, and maintenance. The standard defines a unified structure for software engineering activities, applicable across diverse domains and organizational contexts.

Despite its foundational role, ISO/IEC/IEEE 12207 is often taught through traditional lectures and passive methods, limiting students' ability to apply its principles in practice. This pedagogical gap is well-documented: Calderón and Ruiz (2016) stress the need to integrate process-oriented frameworks into curricula, while Sánchez-Gordón (2016) highlights the value of exposing students to real-world standards. Aydan et al. (2017) and Calderón et al. (2018b) further argue that abstract instruction fails to prepare students for industry roles, advocating instead for authentic, experiential learning environments. Recent work by Koyuncu Tunç et al. (2024) underscores these

challenges in Türkiye, where standards education remains disconnected from practical contexts.

While gamified learning (e.g., AI-supported platforms [Zhang et al., 2023]) shows promise, low-tech, scalable methods for teaching ISO/IEC/IEEE 12207 are underexplored. This study addresses that gap by presenting Complaint to Compliance, a case study of an innovative, complaint-driven game that bridges theory and practice. Grounded in experiential learning theory, the game uses real-world project failures to contextualize standard processes, fostering active engagement through collaborative problem-solving.

Through qualitative analysis of student perceptions (*n* = 21), this research examines the game's design and pedagogical utility, offering educators a replicable model for standards education. By reframing ISO/IEC/IEEE 12207 as a tool to diagnose and mitigate project risks, the intervention aims to shift student perspectives—from viewing standards as bureaucratic constraints to valuing their practical role in software engineering.

2 Background

2.1 ISO/IEC/IEEE 12207

The 2017 revision of ISO/IEC/IEEE 12207 reorganized its process model to align with ISO/IEC/IEEE 15288, enhancing consistency across systems and software engineering standards. It defines four main process categories:

1. Agreement Processes
2. Organizational Project-Enabling Processes
3. Technical Management Processes
4. Technical Processes

This structured categorization promotes both flexibility and rigor, allowing for implementation across various domains (see Fig. 1). However, its complexity poses significant instructional challenges in academic settings. Students often struggle to internalize the standard's abstract terminology and multifaceted process structure, highlighting the need for more engaging and context-aware teaching methods.

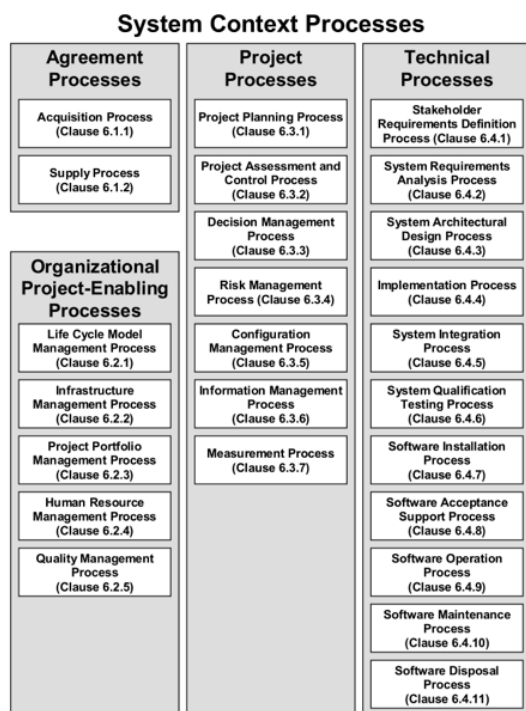


Figure 1. ISO/IEC/IEEE 12207 Processes

2.2 Serious Games in Software Engineering Education

Serious games—defined as games designed primarily for educational or training purposes—have gained traction in software engineering education. They offer immersive experiences where learners engage in simulated scenarios, interactive problem-solving, and context-driven decision-making.

Calderón et al. (2018a) conducted a multivocal literature review, concluding that serious games significantly enhance student engagement, motivation, and learning outcomes. Other studies support these findings: Garcia et al. (2020) and Calderón et al. (2017a) successfully applied game-based learning to teach ISO/IEC/IEEE 29148 and ISO/IEC 29110, respectively. Herranz et al. (2016) reported improved comprehension of software process concepts when gamification was introduced alongside traditional methods.

Several games have been developed to support standards instruction. Mesquida and Mas (2018) created MiProJOC, simulating ISO/IEC/IEEE 12207 project planning and task management. Garcia et al. (2025) introduced the Metric Cake Shop game to teach ISO/IEC/IEEE 15939, focusing on metrics and measurement. Aydan et al. (2015, 2017) proposed early-stage games aimed at making ISO/IEC/IEEE 12207 more accessible to students. Calderón et al. (2017b, 2018b) extended the concept to ISO 21500, emphasizing project management competencies.

While these efforts illustrate the potential of gamification in standards education, few games

explicitly target ISO/IEC/IEEE 12207, and even fewer utilize complaint-driven, case-based analysis rooted in real industry issues. This study aims to fill that gap by designing and evaluating a game that builds students' process literacy through the analysis of authentic project complaints.

3 Research Methodology

This study aims to evaluate the pedagogical effectiveness of a complaint-driven game designed to teach the ISO/IEC/IEEE 12207 standard. Two research questions guide the investigation:

RQ1: To what extent does the complaint-matching game enhance students' understanding of ISO/IEC/IEEE 12207 lifecycle processes?

RQ2: How do students perceive the relevance, engagement, and educational value of the game-based learning approach?

These questions address both cognitive outcomes and learner perceptions, enabling a comprehensive evaluation of the instructional intervention.

3.1 Research Design

This study adopts a qualitative case study design, examining the implementation of the Complaint to Compliance game in a naturalistic classroom setting. Thematic analysis (Braun & Clarke, 2006) of student reflections and instructor observations serves as the primary method to evaluate pedagogical utility, aligning with the study's goal of exploring how gamification bridges standards theory and practice.

3.2 Participants and Intervention Description

Twenty-nine undergraduate students enrolled in the Software Process Management course at XXX University, participated in this study as an integrated component of their formal coursework. Their participation reflected authentic engagement with the course content, providing a naturalistic setting for evaluating the intervention's impact on learning outcomes and professional awareness.

The game was implemented in a Software Process Management course at [University xxx], where students (*n* = 21) had no prior formal instruction on ISO/IEC/IEEE 12207. Due to the real-world constraints of classroom settings, participation was non-randomized. While absent students (*n* = 8) provided incidental comparison data, their exclusion from the intervention reflects typical attendance dynamics rather than experimental design. As such, quantitative differences in exam scores are interpreted as supplementary descriptive trends, not causal evidence—a limitation explicitly acknowledged in Section 6.4.

3.4 Data Collection

Triangulated data sources given in Table 1 ensured methodological rigor:

Table 1. Data collection methods

Data Type	Data Source	Collection Phase
Observational	Facilitator field notes	During gameplay session
Qualitative	Structured reflections (Google Forms)	Post-game Immediately
Quantitative	Scenario-based exam questions	1-week follow-up

1. The instructor documented observational notes on participation, group dynamics, and problem-solving strategies.
2. Following the game, students were prompted to reflect on the activity through questions. With these prompts and guidance, students were invited to complete a brief post-session survey designed to evaluate the perceived educational value of the activity. The survey consisted of three Likert-scale items and one open-ended reflection question. Students rated their agreement with statements on a five-point scale (1 = Strongly Disagree to 5 = Strongly Agree), reflecting on: (1) whether real-life project complaints helped them understand the importance of clearly defined processes, (2) whether the game format supported their focus and engagement, and (3) the extent to which the activity improved their understanding of team dynamics in software development. The open-ended question invited students to share additional feedback yielding diverse and authentic perspectives.
3. To evaluate learning outcomes, all students completed an exam one week after the intervention. The exam included scenario-based and multiple-choice questions targeting core ISO/IEC/IEEE 12207 concepts, including lifecycle processes, terminology, and process roles. This served as a post-test for both groups. Students' exam scores were recorded alongside their attendance status. Based on this, participants were categorized into the intervention or non-intervention group for subsequent analysis.

3.5 Qualitative Analysis (Primary Focus)

Thematic analysis of student reflections followed Braun and Clarke's (2006) six-phase approach to ensure methodological rigor:

1. Familiarization: All responses (n=21) were read multiple times while noting initial patterns.

2. Initial Coding: Data were coded line-by-line to identify meaningful units related to learning outcomes.
3. Theme Development: Codes were clustered into potential themes through iterative comparison.
4. Theme Review: Themes were checked against the dataset for consistency and relevance.
5. Theme Definition: Clear names and definitions were established for each theme.
6. Report Production: Selected exemplar quotes were chosen to illustrate each theme.

The following steps were employed to enhance trustworthiness:

- Peer validation: Two independent coders achieved $\kappa=0.85$ inter-rater reliability on 30% of responses
- Negative case analysis: Actively seeking disconfirming evidence (e.g., Student7's hierarchy confusion)
- Reflexive journaling: Documenting analytical decisions throughout the process

This process yielded three robust themes regarding the game's educational impact, as detailed in Section 5.

3.6 Quantitative Analysis

Performance data were analysed descriptively given sample limitations:

- Effect size caution: Cohen's d reported but interpreted conservatively
- Score distributions were visualized via boxplots to highlight variability.
- Statistical tests: Independent samples t-test noted as exploratory.

4 Game Design

To enhance students' understanding of ISO/IEC/IEEE 12207 in a practical and engaging manner, a classroom activity titled "Complaint to Compliance" was developed. The game was grounded in authentic scenarios frequently encountered in real-world software projects (see Table2) and aimed to foster experiential learning through structured peer discussion and guided analysis.

The initial complaint statements were drafted based on the author's extensive industry experience, having worked on more than 25 medium- and large-scale private sector and e-government software projects since 2005. Drawing on insights from all stages of the software development lifecycle (SDLC), the author compiled a set of 74 statements reflecting common project issues, communication breakdowns, and process deficiencies.

Table 2. Examples of complaints and relevant processes in the game

Team Member Complaint	Associated Standard Process
Tom (Technical Team Lead): “I requested vacation time for March, but I don’t see it reflected in the project schedule.”	6.3.1 Project Planning
Mary (Developer): “Harry (Developer), how did you decide to use this third-party library for map integration? Did you consult with the Team Lead?”	6.3.3 Decision Management
Susan (Project Manager): “We’ve exceeded the pessimistic estimate for the first milestone and are now one week behind schedule.”	6.3.2 Project Assessment and Control

To validate and refine the game design, the activity was piloted in two settings: the author’s home university and a workshop at a Belgian university during Spring 2024 (Fig. 2). Feedback from students and facilitators in both implementations informed iterative improvements to the original 74 complaint statements. Through this process, unclear, context-dependent, or overly complex prompts were eliminated, resulting in a finalized set of 57 streamlined scenarios. These carefully curated complaints reflect authentic, recurring challenges in software projects while maintaining pedagogical clarity. Each scenario was attributed to realistic team roles (e.g., project managers, developers, devops) to enhance relatability and discussion value. The refined version was subsequently implemented at the home university in 2025, with data from this session serving as the basis for the final assessment.

Each complaint was printed on a card and randomly distributed among the students. During the activity, the instructor introduced the ISO/IEC/IEEE 12207 lifecycle processes’ purposes, inputs, outputs and actions one by one.



Figure 2. “Complaint to Compliance” Game as a workshop for Engineering Students- 2024

While listening to the instructor, students were asked to match their assigned complaints to the ISO/IEC/IEEE 12207 process they believed addressed the issue. When a student identified a relevant process, they read their complaint aloud and pinned it under the corresponding category on the classroom board (see

Fig. 3). In cases where matches were uncertain or debatable, the instructor facilitated open-ended discussions to encourage critical thinking and collaborative reasoning.

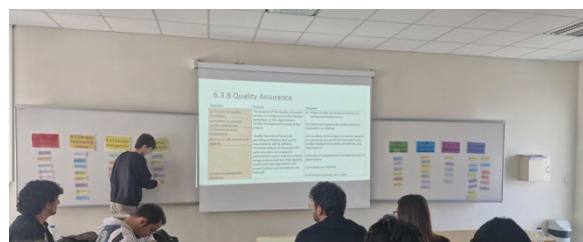


Figure 3. “Complaint to Compliance” Game as a part of Software Process Management Course - 2025

The game supported multiple valid interpretations for certain complaints—for example, a scenario could be justifiably linked to either Information Management or Configuration Management. In such cases, students were invited to justify their decisions and consider alternative perspectives, promoting flexibility in process reasoning.

The 60-minute interactive session was systematically documented through instructor field notes capturing participation dynamics and problem-solving behaviours. Post-intervention data collection employed a mixed-format survey instrument evaluating perceived utility of complaint scenarios for understanding process formalization, game format’s effectiveness in maintaining engagement, and enhanced awareness of software team dynamics. Open-ended responses complemented these quantitative measures, enabling triangulation of cognitive gains and affective outcomes. This dual-method approach aligned with Kirkpatrick’s (1996) framework for evaluating training interventions, assessing both immediate reactions and conceptual understanding.

5 Results

This section presents the findings from the in-class observations, post-survey and an exam for evaluating the impact of the complaint-driven instructional game on students.

5.1 Behavioral Observations

Field observations during gameplay sessions revealed striking contrasts with traditional lecture-based instruction. Participants exhibited sustained cognitive engagement, with lively peer debates emerging organically around ambiguous complaint classifications — particularly those involving cross-process dependencies. The instructor’s role shifted markedly from content deliverer to facilitator, with interventions primarily focused on clarifying nuanced process boundaries in the ISO/IEC/IEEE 12207

framework. Most notably, the competitive yet collaborative dynamic fostered immediate knowledge co-construction, as students collectively reasoned through real-world scenarios while challenging each other's interpretations. This stood in sharp relief to observed passive note-taking behaviours during conventional standards instruction, suggesting the game's effectiveness in promoting active learning. Several participants spontaneously drew connections to prior project failures, indicating early development of professional diagnostic reasoning skills.

5.2 Post-Survey Results

5.2.1 Likert-scale survey results (n=21)

Survey responses revealed strong consensus regarding the intervention's pedagogical value, with near-universal endorsement of its effectiveness in bridging theoretical and practical understanding as can be seen in Fig. 4. Participants overwhelmingly agreed that the real-world complaint scenarios elucidated the necessity of formalized processes ($M = 4.9/5$), with qualitative reflections emphasizing how tangible examples—such as mismanaged third-party library integrations—transformed abstract clauses into actionable knowledge. The game-based format was similarly praised for sustaining engagement ($M = 4.7/5$), with multiple respondents contrasting its dynamic nature favourably against traditional lecture-based standards instruction. Notably, many students reported heightened awareness of role-specific challenges in software development ($M = 4.5/5$), suggesting the activity's utility in fostering professional mindset development.

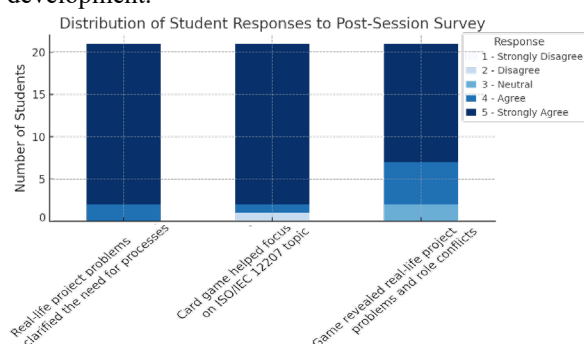


Figure 4. Distribution of student responses to post session survey

These quantitative findings were reinforced by open-ended responses, in which participants frequently described the experience as “revelatory” in connecting ISO/IEC/IEEE 12207 processes to authentic project pain points. The consistency between high Likert-scale ratings and unsolicited qualitative remarks underscores the intervention's success in making standards education both accessible and professionally relevant.

5.2.2 Thematic Analysis of Open-Ended Responses

Thematic analysis of student reflections revealed three dominant patterns, each with distinct pedagogical implications:

1. Conceptual Bridging (Theory-Practice Connections): Participants consistently emphasized how real-world complaints transformed their engagement with ISO/IEC/IEEE 12207.

This theme highlights how the game helped students bridge the gap between abstract ISO/IEC/IEEE 12207 concepts and their practical application in real-world scenarios. Students frequently mentioned how the game concretized their understanding. Here are some of the statements from students:

- "I think this game was very useful for learning the scope of the standards and experiencing their real-life application." (Student1)
- "Trying to figure out which ISO/IEC/IEEE 12207 process each card related to helped me put the theory I had learned into practice. This not only improved retention but also helped me better understand the logic behind the topic." (Student10)
- "For example, one card said the system was delivered without being tested, and I immediately thought of the verification process." (Student10)
- "I understood the concept of standards and why we need them after this game." (Student13)
- "I read my cards, figured out the problems and link them to the possible processes." (Student17)
- "The complaints on the cards made me understand how things can go wrong if people do not have written guides/processes that defines how to do a task." (Student20)
- "Made us connect ISO/IEC/IEEE 12207 standard processes with real life project cases." (Student21)

This theme underscores the game's success in reducing cognitive load (Sweller, 1988) by grounding standard clauses in concrete dilemmas.

2. Professional Identity Development: Many responses reflected growing empathy for industry roles. This theme highlights how the game led students to grasp the practical importance and value of structured processes and standards in professional software development. They moved beyond seeing standards as mere academic concepts to recognizing their crucial role in avoiding real-world project pitfalls.

- "This made me see standards as solutions." (Student14)
- "It also helps me see who is responsible for what in the team." (Student4)
- "I learned about problems in real software projects. I saw how people in different roles can have conflicts." (Student5)
- "We enjoyed the course, discussed lots of issues and started to understand difficulties that software development teams face." (Student12)

- "I understood the concept of standards and why we need them after this game." (Student13)
- "The complaints on the cards made me understand how things can go wrong if people do not have written guides/processes that defines how to do a task. And I didn't realize how many issues could arise from unclear responsibilities and poor planning. It made me see the value of having structured processes." (Student20)
- "When teacher said that we will learn about ISO/IEC/IEEE 12207 standard, I was expecting a lecture and a theoretical course that will be very hard to follow. Then she introduced the game. I was so ambitious to match my cards with the relevant processes as soon as possible correctly. So I listened the teacher and also read the slides on the projector to understand the purpose, actions, inputs, and outputs of each process." (Student21)
- "I think it was a very good and fun way to learn." (Student15)
- "This game motivated me about the course." (Student17)
- "The course was really interesting and fun." (Student19)
- "It was an interesting game. I did not see such an educational game before." (Student20)
- "So, it was really fun and engaging game that made us connect ISO/IEC/IEEE 12207 standard processes with real life project cases." (Student21)
- "Some of us were very competitive about matching all the cards correctly." (Student21)

Overall, the game helped bridge the gap between theoretical instruction and real-world complexity. It increased students' readiness for professional practice by promoting structured reasoning, practical awareness, and an appreciation of software process standards as actionable tools—not bureaucratic.

Such comments suggest the intervention fostered situated learning (Lave & Wenger, 1991), bridging academic and professional mindsets.

3. Engagement through Gamification: This theme encapsulates how the game's interactive, intrinsic motivation, and novel format enhanced student motivation and participation, transforming a potentially dry topic into an enjoyable learning experience. Students consistently highlighted the element of play and its impact on their engagement. Here are some examples from student reflections:

- "The fact that it was gamified was both fun and educational." (Student2)
- "It is a fun and interactive way to learn a complex standard. Instead of only reading the theory, we get to think about real problems and discuss them together." (Student4)
- "I liked the 'Complaints To Compliance' card game. The game was fun and easy." (Student5)
- "Had fun and learned a lot of best practices in this course." (Student6)
- "I think it was an interactive and fun game that really helped us learn a relatively boring topic easier." (Student8)
- "Having concrete examples from real life made the learning process enjoyable by allowing us to imagine the situations rather than overloading our minds with existing documents." (Student9)
- "Normally, classes tend to be quite monotonous, but this activity made the lesson much more interactive." (Student10)
- "It was like we were playing a game, not like we were doing a lesson. This gave me a different enthusiasm and motivation. It was nice to learn by having fun and having fun without getting bored." (Student11)
- "We enjoyed the course, discussed lots of issues..." (Student12)
- "I hope we can have more gamified courses for this type of text-based content. Otherwise, it is hard to keep my concentration while listening the professors." (Student14)

5.3 Quantitative Analysis

A total of 29 students completed the exam. Among them, 21 students attended the game session (Intervention Group), while 8 were absent (Non-Intervention Group). The exam, administered one week after the intervention, served as a post-test to assess learning outcomes. Although participants achieved higher exam scores, these findings remain exploratory given the study's naturalistic design and small sample size. The top 20 performers all attended the game, suggesting a strong positive impact. Students who did not participate are clustered in the lower score range, with no one exceeding 62. The quantitative patterns (see Table 3) align with qualitative findings, though the study design precludes causal claims.

Table 3. Group level statistics

Group	N	Mean	Std. Dev	Min	Max
Attended the Game	21	69.0	13.56	37	94
Did Not Attend	8	45.3	13.73	28	67

The boxplot in Fig. 5 illustrates the tighter score distribution and higher median among students who participated in the game.

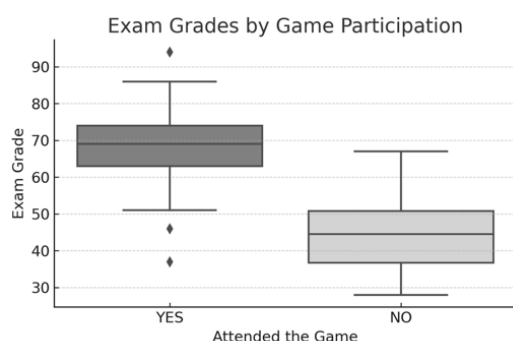


Figure 5. Distribution of Exam Grades by Game Participation

6 Discussion

6.1 Innovation in Design

The Complaint to Compliance game introduces three key innovations in standards education:

1. **Authentic Scenario Design:** Grounded in 20 years of industry experience (25+ projects), the game's 57 complaint cards operationalize *situated cognition* (Greeno, 1998) by embedding ISO/IEC/IEEE 12207 processes in tangible project failures. Unlike abstract examples (e.g., Calderón et al., 2018a), these scenarios mirror what Herranz et al. (2016) term the "simulation gap" — the disconnect between standards and their real-world consequences.
2. **Multi-Dimensional Mapping:** The game intentionally includes complaints spanning multiple standard clauses (e.g., Configuration Management and Quality Assurance), reflecting the interconnected nature of software processes in practice. This design choice cultivates *systems thinking* (Senge, 1990), a skill critical for professional practice but neglected in conventional standards pedagogy.
3. **Low-Tech Accessibility:** By leveraging physical cards and peer debate instead of digital interfaces, the intervention achieves scalability while addressing resource constraints noted in global engineering education (Koyuncu Tunç, 2024). This aligns with García et al.'s (2020) calls for "pedagogical minimalism" in standards instruction.

The design embodies Lave and Wenger's (1991) legitimate peripheral participation by positioning students as analysts diagnosing authentic process breakdowns — a significant departure from passive, lecture-based standards training.

6.2 Comparison with Related Work

The Complaint to Compliance game advances beyond existing serious games for standards education through

three key distinctions, while maintaining alignment with their shared pedagogical goals:

1. **Diagnostic vs. Procedural Focus:** While MiProJOC (Mesquida & Mas, 2018) trains students in planned process execution (e.g., ISO/IEC 12207 project scheduling), this game emphasizes retrospective failure analysis—a higher-order cognitive skill (Bloom, 1956) critical for process improvement in industry. This addresses Sánchez-Gordón's (2016) observed gap in "abstraction-to-application" transitions.
2. **Scalability:** Unlike Metric Cake Shop (García et al., 2025), which requires specialized measurement tools, this card-based design achieves comparable engagement ($M=4.7/5$) with minimal resources—validating Calderón et al.'s (2018a) argument for scalable interventions in resource-constrained institutions.
3. **Professional Relevance:** Where Aydan et al. (2017) teach standard components in isolation, this complaint-driven approach demonstrates their practical utility in mitigating project risks (e.g., untested deliveries linking to Verification Processes). This directly tackles Calderón et al.'s (2018a) finding that students dismiss standards as "bureaucratic" without real-world context.

Convergence: All approaches successfully leverage gamification to overcome Sánchez-Gordón's (2016) "abstraction barrier," but this method uniquely combines:

- Cognitive authenticity (diagnosing real project failures)
- Accessibility (low-tech materials)
- Professional framing (standards as preventive tools)

6.3 Practical Implications and Transferability

The game's design offers several practical implications:

1. **Curriculum Integration:** The Complaint to Compliance game offers versatile implementation across educational and professional contexts. Its 60-minute format fits standard class periods, serving effectively as either an introductory engagement activity or capstone exercise, addressing common scheduling constraints in software engineering curricula (Calderón et al., 2018b).
2. **Adaptability:** The framework's adaptable methodology extends to other standards like ISO/IEC 29110 (for small entities) through tailored complaint sets, with a replicable process for deriving scenarios from project retrospectives (García et al., 2020).
3. **Professional Training:** Pilot workshops demonstrate its value for industry onboarding and audit training, particularly in emerging economies

where Koyuncu Tunç (2024) identified gaps between academic standards education and industry needs.

Successful implementation across diverse contexts - from Belgian university workshops to Turkish undergraduate courses - confirms its scalability. The minimal resource requirements further enhance adoption potential for both academic and corporate training environments.

6.4 Limitations

Three key limitations warrant consideration. First, while implemented at two universities, the cultural context limits generalizability to diverse educational settings. Second, the absence of longitudinal data prevents assessment of long-term knowledge retention and professional application - a critical gap given the study's emphasis on real-world relevance. Third, the small control group (n=8) and non-randomized design, though methodologically justified for this exploratory study, constrain causal claims about effectiveness. As a case study, this research prioritizes rich contextual insights over generalizability. The lack of randomized controls and small sample size prevent causal inferences, but the qualitative findings provide valuable pedagogical insights.

6.5 Future Enhancements

Future research should pursue: (1) multi-institutional validation across different cultural contexts, particularly in developing economies where standards education faces unique challenges (Koyuncu Tunç, 2024); (2) longitudinal tracking of students into industry roles; and (3) controlled studies with larger samples. Technical enhancements could include a digital platform for asynchronous play and AI-generated scenarios (Zhang et al., 2023), while maintaining the low-tech option's accessibility.

These limitations notwithstanding, the qualitative findings suggest the game's potential for making standards tangible. The game's success in making ISO/IEC/IEEE 12207 tangible suggests a promising foundation for broader adoption.

7 Conclusion

This study presents Complaint to Compliance, an innovative low-tech game that transforms ISO/IEC/IEEE 12207 standards education from abstract theory to engaged practice. Through qualitative analysis of student experiences, we identified three key pedagogical benefits: (1) strengthened connections between theoretical standards and practical applications, (2) development

of professional identity through process-aware thinking, and (3) enhanced engagement via collaborative problem-solving.

The game's significance lies in its dual accessibility:

- **Conceptual:** Making complex standards tangible through real-world project failures
- **Logistical:** Requiring only printed materials for implementation

The findings suggest this approach successfully addresses two critical gaps in engineering education:

- The relevance gap identified by Koyuncu Tunç (2024), where students struggle to see standards as practical tools
- The resource gap in emerging economies, where high-tech solutions may be impractical

For educators, this work offers:

- A ready-to-implement template for standards education
- Evidence that low-tech gamification can achieve high engagement
- A model for developing professional mindset alongside technical knowledge

Future research should explore:

- Longitudinal studies to assess knowledge retention
- Multi-institutional implementations across cultural contexts
- Potential integrations with digital tools (e.g., AI-generated scenarios)

This study ultimately demonstrates that effective standards education requires moving beyond passive instruction to active, context-rich experiences. By positioning students as problem-solvers analysing real project challenges, we prepare them not just to know standards, but to use them as instruments for quality in professional practice.

Acknowledgments

I sincerely thank Prof. Dr. Hayri Sever for encouraging me to teach the Software Process Management and Quality Standards courses. His trust and support motivated me to approach these subjects creatively and explore new methods in education. I also thank my students for their active participation and valuable contributions to this research.

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