Simplifying road to defining a scientific problem and hypothesis through gamified and storytelling-enhanced teaching of requirements engineering

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Abstract

The transition from structured coursework to independent research poses significant challenges for students, particularly in mastering the design science method required for thesis work. To address this issue, the paper proposes implementing gamified learning strategies within a Requirements Engineering course to enhance student readiness for thesis projects. A detailed course outline is provided, demonstrating how gamification, storytelling, and the design science method can be effectively embedded in the curriculum. By integrating these multifaceted teaching methods, the course aims to manage the complexity of preparing students for independent research and thesis writing. The course design refers to Bloom's taxonomy to ensure comprehensive learning outcomes across multiple cognitive levels, thereby fostering a deeper understanding and application of the design science method in engineering education.

Keywords

Gamified teaching, storytelling-enhanced teaching, requirements engineering

1. Introduction

Design science is a research paradigm focused on creating and evaluating artifacts intended to solve identified organizational problems [1]. The design science method is essential for research, and students must master it to complete their theses successfully. However, many students struggle with this transition due to a lack of engaging and practical learning experiences. Gamification, which involves adding game elements to non-game contexts, has been shown to boost motivation and learning outcomes [2]. Storytelling, on the other hand, makes learning more relatable and memorable [3]. This paper discusses the opportunity for using gamified learning and storytelling to teach the elements of design science within a Requirements Engineering course.

The proposed approach for preparing students for thesis writing through requirements engineering course involves managing the complexity of not only understanding the design

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science method but also effectively combining it with the principles of Requirements Engineering. The proposed course design addresses this complexity by integrating gamification and storytelling, creating a holistic educational experience that simplifies complex concepts and enhances student engagement. By embedding the design science method within the context of Requirements Engineering through interactive and narrative-based learning, students could better meet the multifaceted challenges of thesis preparation. This approach helps students develop some of the essential skills needed to conduct independent research, analyze data, and present their findings.

2. Background

This section briefly discusses the "ingredients" of the proposed approach and motivates the use of each ingredient. Section 2.1 discusses the potential benefits of the use of scientific method elements in studying different study courses, not only those that are exclusively devoted to the scientific method. Section 2.2 puts in focus gamification in teaching, while Section 2.3 focuses on storytelling. Section 2.4 points to the similarities between issues in requirements engineering and in design science research.

2.1. Integration of design science method training

Research shows a significant gap in student readiness for conducting scientific research during their thesis work. Many students lack the necessary knowledge and skills in the application of the design science method, which is essential for successful thesis completion. Poor supervision and training in scientific hypothesis formulation and writing are common issues that negatively impact students' research abilities [4]. This lack of preparedness often results in students struggling to create research questions, design experiments, and analyze data effectively [5]. Moreover, the mentoring relationship between students and supervisors plays a critical role. Inaccessible mentors or insufficient psychosocial support can limit the development of students' scientific self-efficacy, which is essential for successful research outcomes [6].

Adding design science method training and research practice early in the academic curriculum has proven to be an effective strategy. Early exposure to research methodologies within other courses improves students' understanding and mastery of scientific research by the time they begin their thesis work [6]. This approach ensures that students have a solid foundation in research skills, allowing them to transition smoothly into independent research projects. In this context, several educational strategies can be employed to train students in the design science method effectively. These strategies include undergraduate research experiences (UREs), problem-based learning, and inductive learning.

UREs involve students actively participating in research projects under the guidance of faculty mentors. These experiences help students develop a sophisticated understanding of experimental design, data analysis, and the nature of scientific knowledge. UREs improve students' comprehension of the scientific research process and provide hands-on experience and mentoring that are important for developing research skills and scientific thinking [7], [8]. Despite the recognized benefits, UREs are often underutilized or inadequately implemented, leaving many students underprepared [8], [9].

Problem-based learning involves presenting students with real-world problems that require them to apply various aspects of the design science method, including hypothesis formulation, solution design, and evaluation. This educational strategy encourages self-directed learning and critical thinking, which are essential components of the design science method. Through problem-based learning, students gain hands-on experience in scientific research, enhancing their understanding and retention of scientific concepts [10], [11].

Similarly to problem-based methods, inductive learning methods, such as inquiry-based and project-based learning, involve students uncovering principles through practical work, identifying problems and questions, and finding solutions. Unlike traditional deductive learning, where principles are provided at the beginning and then applied, inductive learning emphasizes discovery and exploration. This practical approach aligns closely with the design science process. Through inductive learning, students may actively engage in the scientific process, fostering a deep understanding of research methods and principles [11].

An integral component of the design science method can be also the experimentation. By understanding and applying principles of the design of experiments, students can design more effective experiments, analyze data more accurately, and draw more reliable conclusions [12].

The methods and skills discussed above are a part of ones applied in requirements engineering, which makes it promising to purposely design a requirements engineering course in way that it contributes to skills of scientific research.

2.2. Benefits of gamified learning

Gamification of learning has been shown to significantly improve educational outcomes by increasing student engagement and motivation. Gamified learning experiences make educational activities more interactive and enjoyable, leading to a deeper understanding of complex concepts [13]. Studies confirm that gamification positively affects motivation and engagement in learning, supporting its use in educational settings [14].

Gamified learning can increase students' intrinsic motivation by making learning activities more enjoyable and satisfying. A meta-analysis found that gamification has a small but significant positive effect on intrinsic motivation, primarily through enhancing students' perceptions of autonomy and relatedness [15]. Additionally, providing students with choices in assignments can enhance their sense of autonomy, leading to higher intrinsic motivation [16].

Gamification can make learning more efficient by providing immediate feedback and clear goals, which help maintain student interest and drive [17]. Additionally, studies show that gamification can improve students' ability to perform complex or repetitive activities by incorporating elements that challenge and engage them [18].

Despite its benefits, gamification must be carefully designed to avoid potential negative effects. Leaderboards can create a sense of embarrassment for students who rank low, and poorly designed tasks can undermine students' competence needs by being too easy or too difficult [15]. There is a need for rigorous primary study designs to better understand the impact of gamification on different learning outcomes [19].

Nevertheless, gamification helps to address complexity and engage in solving complex problems autonomously and in a team.

2.3. Learning through storytelling

Storytelling has emerged as a powerful tool for enhancing learning experiences, particularly in online environments. Storytelling makes learning more engaging by presenting information in a narrative format that students find interesting and relatable. Stories provide context for learned information, making it easier for students to understand and retain new concepts [3]. Narratives also help students relate to the material on a personal level, thereby enhancing comprehension and recall. Key storytelling principles are conflict, authenticity, and entertainment. These principles help instructional designers capture students' interest and facilitate deeper cognitive and emotional connections to the learning material [20].

The experiments show that incorporating storytelling, for instance, into project-based learning allows students to apply their knowledge in practical, real-world scenarios. In this context, project-based learning involves students creating digital stories related to specific case studies within the course content. The project is the process of creating these digital stories, where students are required to research, design, and present their narratives to apply and represent their understanding of the subject matter. This method has been shown to improve learning motivation and competence by providing a creative and engaging way for students to demonstrate their understanding [21].

One of the storytelling approaches is digital storytelling, which involves using multimedia elements such as images, videos, and audio to create engaging narratives. These videos provide a dynamic and immersive learning experience that can capture students' interest more effectively than traditional text-based materials [22]. The use of interactive digital storytelling videos has been found to promote student engagement and learning in hybrid courses. These videos provide a dynamic and immersive learning experience that can capture students' interest more effectively than traditional text-based materials [23].

Interactive digital storytelling typically includes a mix of video, audio, and narrative content, with embedded interactive elements such as quizzes, questions, or decision points that require student participation. The main goal is to enhance student engagement, motivation, and comprehension by making the learning experience more dynamic and immersive. This is particularly important in online learning environments where maintaining student interest can be challenging [24]. Integrating gamified elements with storytelling can further enhance student engagement and motivation. This approach combines the interactive and motivational aspects of games with the emotional and cognitive benefits of storytelling [2].

2.4. The IREB requirements engineering framework

The IREB framework [25] is widely recognized and provides best practices and methodologies that ensure the development of high-quality software systems. The International Requirements Engineering Board (IREB) framework provides a structured approach to Requirements Engineering, covering key activities such as elicitation, documentation, validation and verification, and management of requirements:

- **Elicitation:** Techniques for gathering requirements from stakeholders.

- **Documentation:** Practices for recording requirements in a clear and structured manner.
- **Validation and verification:** Methods for ensuring that the documented requirements meet stakeholder needs and are feasible for implementation.
- **Management:** Strategies for maintaining and updating requirements throughout the project lifecycle.

These practices are intended to create and manage requirements for the identified problem or goal and proposed solution, aligning closely with the design science method's focus on artifact creation and evaluation. Requirements Engineering naturally incorporates steps similar to the design science method, making it an appropriate domain for teaching these skills. Both fields emphasize problem-solving and the development of practical solutions through systematic processes. In Requirements Engineering, students observe real-world needs, formulate hypotheses about system requirements, and develop artifacts to meet those needs. This process mirrors the steps of the design science method: problem identification, solution definition, solution design, and solution demonstration and evaluation [26].

Design science focuses on artifact creation within the scope of information systems research. This involves developing constructs, models, methods, and instantiations that solve specific organizational problems and evaluating their utility and effectiveness [1]. By teaching Requirements Engineering with a focus on the design science method, students not only learn to manage and document requirements but also gain hands-on experience in creating and evaluating artifacts. This dual focus prepares students for their thesis work, where they must apply these principles to conduct independent research and contribute to the field of information systems.

3. Methodology

This study follows the hypothesis that it is possible to teach design science method by combining traditional academic training with gamified tasks and storytelling in requirements engineering. To prove this hypothesis, a requirements engineering course design is proposed. The course is based on the IREB Requirements Engineering framework, incorporating gamified elements, storytelling techniques, and mini-projects that simulate various application scenarios of the design science method.

The proposed research approach itself follows the design science research principles by applying its steps as discussed below (Figure 1):

1. **Problem identification:** Identifying the lack of design science training as a barrier to student preparedness for thesis work and the need for more engaging learning methods.
2. **Solution definition:** Hypothesizing that combining gamified learning, traditional training, and design science will enhance student engagement, motivation, and understanding of the design science method, thereby improving readiness for thesis work.

3. **Solution design:** Developing course modules with gamified tasks and storytelling elements aligned with learning objectives, incorporating design science principles.
4. **Solution demonstration:** Conducting pilot implementations to test the course and observe its impact on student learning and engagement.
5. **Evaluation:** Assessing student performance through mini-projects and traditional assessments to evaluate the effectiveness of the gamified and storytelling approach. This involves collecting and analyzing data on engagement, motivation, and understanding of the design science method.

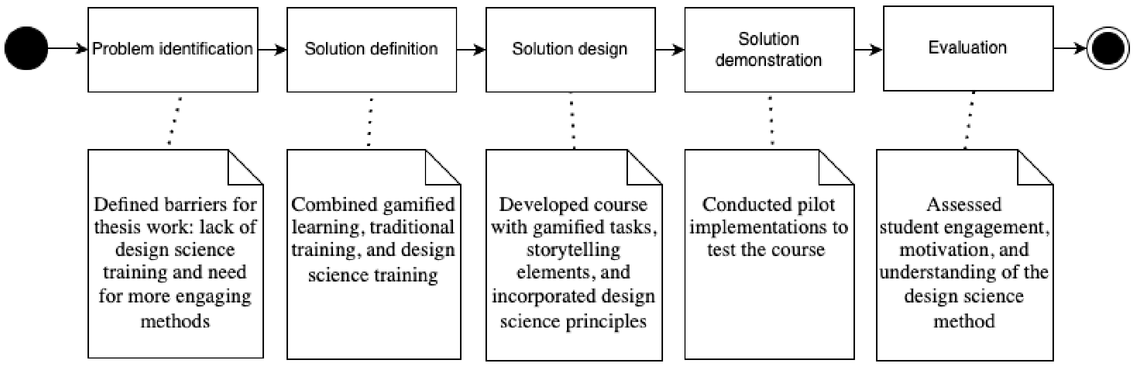

Figure 1: Research Methodology

This paper focuses on the first three steps of the design science method: problem identification, solution definition, and solution design.

Future research should focus on the full implementation of the course (including comprehensive data collection and analysis) and evaluating whether the collected data supports the hypothesis, to make recommendations for future course improvements and research.

4. Course overview

The proposed course is divided into seven modules, each focusing on key aspects of Requirements Engineering (RE) while integrating gamified learning tasks and practical projects designed to teach the design science method (Figure 2):

- **Gamified Tasks:** These are designed to make learning more interactive and enjoyable, helping students to practice and reinforce the knowledge gained in lectures and handle complexity.
- **Mini-Projects:** These projects will focus on the steps of problem identification and solution definition, teaching students to define hypotheses related to the identified problems and potential solutions through problem-based learning and other inductive learning approaches.

The selection of gamified mechanics for each module is based on the Learning Mechanics-Game Mechanics (LM-GM) model [27]. This model helps to map pedagogical goals to appropriate game mechanics to ensure that learning objectives are effectively met through engaging gameplay.

The storytelling elements incorporated into the mini-projects used in the course are selected based on the approach defined in [28]. These elements include point of view, a dramatic question, emotional content, the gift of your voice, the power of the soundtrack, economy, and pacing. By integrating these elements, the course aims to enhance student engagement and comprehension through compelling digital narratives, supporting the learning goals by making abstract concepts more relatable and memorable.

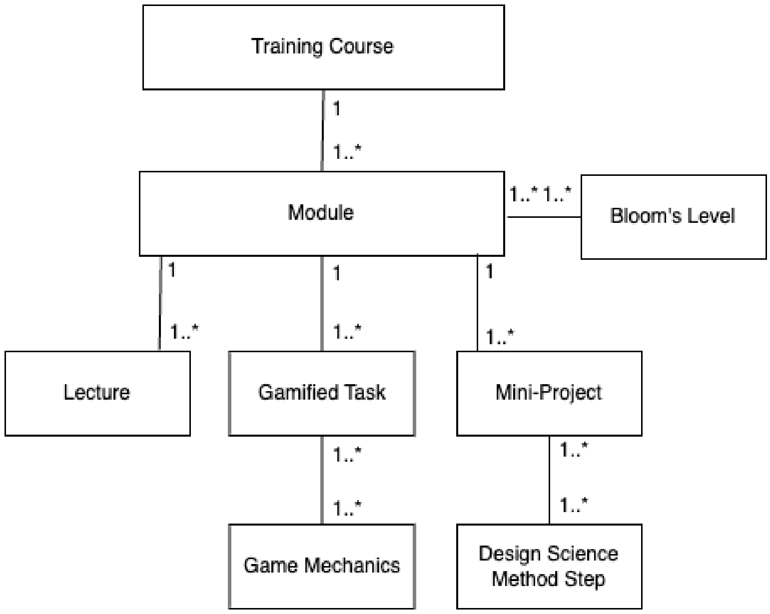

Figure 2: Training Course Structure

The course also aligns with Bloom's Taxonomy to ensure comprehensive cognitive skill development [29]. The activities/skills contributing to design science research are highlighted in Italic.

Module 1: Introduction and Overview of Requirements Engineering and the Design Science Method

- **Lecture:** Overview of Requirements Engineering (IREB framework) and the Design Science method.
- **Gamified Task:** Interactive quiz game about IREB and the design science method. **Game mechanics:** Points, leaderboards, and badges for correct answers.
- **Mini-Project (Problem identification):** Students will read a short story about a fictional company, TechSolutions, which is facing issues with their project management software. They will *identify and document the key problems* mentioned

in the story, such as missed deadlines, lack of collaboration features, and user dissatisfaction.
- **Bloom's Levels:** Remembering, understanding, applying, analyzing.

Module 2: Fundamental Principles of Requirements Engineering

- **Lecture:** Overview of fundamental principles in Requirements Engineering.
- **Gamified Task:** Role-playing game where students simulate stakeholder interviews to gather requirements. **Game mechanics:** Role-playing, scenarios, and feedback.
- **Mini-Project (Solution definition):** Based on the problems identified in Module 1, students will read a continuation of the TechSolutions story where they interview various stakeholders. They will *document the stakeholders' requirements for a new project management software solution*, such as improved collaboration tools, real-time updates, and user-friendly interfaces.
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating.

Module 3: Work Products and Documentation Practices

- **Lecture:** Work products in RE, documentation practices, and documentation structures.
- **Gamified Task:** Documentation scavenger hunt where students *find and categorize different types of documentation*. **Game mechanics:** Scavenger hunt, rewards for completion, and time-based challenges.
- **Mini-Project (Solution design):** In the next part of the TechSolutions story, students will be provided with a basic outline of a new software design. They will quickly sketch a wireframe or mock-up for one key feature of the software, such as the dashboard interface, using simple tools like paper and pencil or a basic wireframing tool.
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating, creating.

Module 4: Practices for Requirements Elaboration

- **Lecture:** Techniques for eliciting requirements, resolving conflicts, and validating requirements.
- **Gamified Task:** Puzzle-solving game where students resolve conflicting requirements. **Game mechanics:** Puzzles, levels, and hints.
- **Mini-Project (Solution demonstration):** Students will read about a conflict between TechSolutions' development and marketing teams regarding a feature's implementation. They will then present their solution to an imaginary stakeholder (e.g., the Marketing Manager) and receive feedback. Students will use a provided checklist to *conduct their own review of the solution* based on factors such as usability, feasibility, and alignment with stakeholder requirements.
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating, creating.

Module 5: Process and Working Structure

- **Lecture:** Configuring and managing Requirements Engineering processes.
- **Gamified Task:** Simulation game where students configure and manage a project using Requirements Engineering processes. **Game mechanics:** Simulation, strategy, and progress tracking.
- **Mini-Project (Solution evaluation):** Students will reflect on their work in the previous modules and identify lessons learned from their project experiences. They will then read a new scenario about TechSolutions planning a follow-up project. Based on the previous project's characteristics and outcomes, students will map out a tailored *Requirements Engineering process for the new project*.
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating, creating.

Module 6: Management Practices for Requirements

- **Lecture:** Requirements management, including lifecycle management, prioritization, and traceability.
- **Gamified Task:** Management game where students prioritize and trace requirements through different project stages. **Game mechanics:** Resource management, strategic planning, and scoreboards.
- **Mini-Project (Full process):** Based on a provided hypothetical context for TechSolutions, students will define a comprehensive Requirements Engineering process tailored to the project's specific needs. *They will cover all aspects of the design science process: problem identification (define the key issues and requirements), solution definition (outline the process and steps), partial solution design (create a draft of process documentation and workflow), and evaluation (propose criteria for assessing the effectiveness of the RE process).*
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating.

Module 7: Tool Support

- **Lecture:** Overview of tools in Requirements Engineering.
- **Gamified Task:** Tool exploration challenge where students use different Requirements Engineering tools to complete tasks. **Game mechanics:** Challenges, achievements, and exploration.
- **Mini-Project (Full process):** Students will research and select the most effective set of tools for managing requirements, project tracking, and collaboration for the TechSolutions project. *They will define the problem (e.g., existing tools' inefficiencies), provide a solution definition (selecting the most suitable tools), partial solution design (drafting a configuration and usage plan for the selected tools), and conduct a partial evaluation (propose criteria and methods for evaluating the tools' effectiveness in the project context).*
- **Bloom's Levels:** Understanding, applying, analyzing, evaluating.

5. Conclusions

This paper argues that integrating the design science method's elements within a Requirements Engineering course prepares students for thesis work by systematically teaching them essential research skills through practical, hands-on projects. This approach reinforces theoretical knowledge and develops the critical skills necessary for successful research endeavors. Additionally, incorporating gamification and storytelling enhances student engagement, motivation, and comprehension of complex concepts. Gamification makes learning interactive and enjoyable, while storytelling provides contextual and relatable narratives, helping students internalize and effectively apply their learning. By addressing the multifaceted challenges of preparing students for thesis writing, this course design offers a framework for managing educational complexity behind the thesis work. It supports a deeper understanding and application of the design science method in engineering education, contributing to improved student readiness for independent research. Future research should focus on the implementation of this course, with data collection and analysis to validate the combined effectiveness of gamification and storytelling in enhancing educational outcomes.

The limitation of current course design is that it does not directly address the analysis of scientific works. However, in contemporary requirements engineering it is also an essential component in innovative product design, Therefore this component can be indirectly included in stories and gamified tasks of the course.

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