Serious Games for Vocational Training

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Abstract: The research project 'SG4BB' (Serious Games for Vocational Education and Training; abbr.: VET) has developed an integrated platform for the description, search, retrieval, integration, and utilization of educational games. This paper summarizes project outcomes, including platform concepts, software components, and – as focus – practical insights derived from a case study involving the educational game 'Corrugated' as simulation and training environment for service technicians. SG4BB has followed a user-centered design in an interdisciplinary project team: Two learning providers specified their requirements for VET in their specific application domains. Based on those requirements, game developers, learning solution providers and researchers for VET have conceptualized and prototypically implemented both an integrated learning platform (SG4BB platform) and two case studies of Serious Games for VET: 'Corrugated' for service technicians and an IT security game. The platform follows a process pipeline: For search and retrieval of educational games for VET, an application profile for VET based on the standardized 'Serious Games Metadata Format' (DIN/SPEC 91380) has been elaborated. This format builds the semantic basis for the metadata-based catalog system 'Serious Games Information Center' (SG-IC) with filter functionality for VET. Learning providers and developers can use the SG-IC portal to describe and promote their educational games, enabling users to identify suitable games for their learning needs and integrate them via learning infrastructure. Educational games can interact with the backend (Learning Management System and Learning Record Store) through a middleware based on the xAPI standard, allowing for personalized gameplay and data collection for game-based learning analytics. The final evaluation of the SG4BB project focused on the utilization of the educational game 'Corrugated', targeting problem-solving skills for service technicians in the corrugated cardboard industry. Data from 26 participants playing the game for 60 minutes, along with problem-solving tests and user experience feedback, were analyzed to validate game-based assessment and to assess learning impact. Initial results reveal insights into specific game missions, playtimes, and success rates, indicating that participant behavior during gameplay influenced perceived learning progress, leading to varied learning paths. This paper provides valuable insights and technical information for VET practitioners on using educational games for training. Game interactions and learning outcomes can be monitored via a dashboard within the learning infrastructure, offering visualizations for user behavior (during play) and (learning) progress.

Keywords: Serious Games, Vocational Education And Training, Metadata, Middleware, Case Study and Evaluation.

1. Introduction

Stakeholders in continuous vocational education and training are required to provide appropriate and suitable (digital) learning opportunities that can be used to develop the needed skills induced by technological change and thereto affected changes in type of jobs, skill needs, task content and other economic effects (Frey and Osborne, 2017). In light of this, serious games have enormous potential, as they can simulate complex real-life situations without disrupting operations, but in a playful and motivating way, and with adaption to the individual needs of the users. The problem is to find high-quality learning games for a specific job and skill level, and to integrate them in an existing learning management system.

In this contribution we investigated the practical question of which serious games exist for diverse occupational fields, what quality they possess, and how they can be integrated into professional development. We developed an innovative and standardized system to find appropriate games matching the skill needs, job tasks and interests of potential users/customers in continuous vocational education and training (Rotter et al, 2022; Göbel et al, 2018).

2. Project Description and use Case 'Corrugated'

Within the research project SG4BB (Serious Games for Continuous Vocational Education and Training) funded by the German Ministry for Science and Education, a platform has been developed based on existing components to discover, integrate, test, and evaluate appropriate serious games and playful learning offerings in vocational education and training: the Serious Games-Information Center (SG-IC, a classical web-based information system in form of a portal) and its underlying Serious Games Metadata Format (SG-MDF; DIN SPEC 91380, as semantic basis for the description and retrieval of serious games) are evolving into a search engine for target group-specific description and search for suitable learning games in VET on the level 4 to 7 of the European Qualifications Framework (EQF; European Union, 2017). Figure 1 illustrates the process pipeline for the usage of the SG4BB platform.

Figure 1: SG4BB process pipeline: Input parameters for application fields and user characteristics, search and retrieval of appropriate educational games based on metadata, integration of educational games into learning infrastructures, usage and evaluation of learning effects.

Through the search engine, educational stakeholders (e.g. teachers, coaches or trainers in VET settings, end users/learners etc.) can identify suitable game-based learning opportunities for their target groups in their specific occupational fields. Users as well as educational providers can download these educational games via a marketplace and integrate them into their own learning management system (LMS). The components of the platform, including the technical interfaces based on standards (xAPI) between the SG4BB middleware, the LMS, and the game, were tested through the collaboration of research, development, and practice using the serious game 'Corrugated'. The insights of the project are presented in the next sub-chapters.

2.1 Target Group Learner in Vocational Training

The goal was to develop a concept for the recommendation of relevant educational games in VET. Therefore, a literature review of established and well-founded national and international classification systems was conducted to identify fitting criteria and databases (Rotter et al, 2022). The research focus was on continuous vocational education and training in Germany, but with correspondence to international systems, such as International Standard Classification of Occupations 2008 (ISCO-08). Matching criteria were derived to propose appropriate educational games for VET, tailored to the potential users' professional context and educational aspirations. This process resulted in a collection of occupational fields as defined by the German Federal Institute for Vocational Education and Training (BIBB; Tiemann, 2018), and main activity as defined by the microcensus, the largest annual household survey of official statistics in Germany, annotated with metadata and a matrix, mapping occupation fields with educational games. Now, educational stakeholders (i.e. learning providers, coaches, or individual learners) can use the search engine to find appropriate game-based learning offerings tailored to specific occupations or job tasks.

As a result, we developed the application profile 'vocational education and training' as an added 'variant' of the SG-MDF. Hereto, serious games are matched with a database of occupational fields (or major occupational fields) as defined by the Federal Institute for Vocational Education and Training (BIBB; Tiemann, 2018), and main tasks and duties as defined by the microcensus.

2.2 Content Discovery via SG-IC

The Serious Games-Information Center (SG-IC, see https://seriousgames-portal.org/) is a web-based portal providing a free search engine that has been completely redesigned by the Serious Games research group at TU Darmstadt to incorporate the 'application profile for vocational education and training", tailored to the characteristics and needs in the field of VET. This profile is an extension of the underlying Serious Games Metadata Format (SG-MDF, DIN SPEC 91380), which serves as the semantic basis for describing and retrieving serious games via the SG-IC (Göbel et al., 2018) or other systems and portals.

The SG-IC can be used to formulate queries for serious games or educational games designed for game-based learning, applying filters such as specific occupational fields, primary activities, target age groups, or game genres. The retrieval process generates a list of candidates — educational games that meet the query's criteria

— presented in the SG-IC. Interested educational providers and individuals can then analyze these candidates in detail, accessing all available metadata information in the standardized SG-MDF format for each game.

2.3 Download and Integration via Middleware

Within the distribution section of the SG-MDF, users can access information on where the original games are available, including potential downloads from Skillfire.info or other platforms. Educational providers can integrate these games into their learning environments, provided they operate their own LMS and use the SG4BB plugin (middleware) developed in the project for integration. For example, in SG4BB, an interface has been established between the SG-IC and the 'Skillfire' platform, a 'steam-like' distribution platform for game-based learning and training material.

The Skillfire marketplace offers both free and paid (gamified) learning offerings for vocational education and training, facilitating integration into moodle-based LMS via SG4BB middleware with license management capabilities. Skillfire.info has transitioned to the new domain, serving as gamified learning platform in the Business-to-Business (B2B) sector. Additionally, a mobile app ('skillfire app') under the previous domain www.skillfire.io will focus on training personal and professional soft skills for end-users in the Business-to-consumer (B2C) sector.

MasterSolution, an IT service provider, has developed a middleware (SG4BB plugin) for connecting gamified learning applications to LMS using the xAPI standard. This middleware is freely available and can be accessed via MasterSolution's Git repository, linked on the SG4BB website. Detailed guidance on integrating and using the middleware by educational providers is available in project documents, i.e. 'Deliverable D4' (particularly Section D4.2 xAPI for the integration of learning games into LMS). Additionally, 'Deliverable D5' outlines the development process for development studios creating gamified learning offerings, emphasizing the design requirements for xAPI integration into the LMS.

2.4 Testing and Rating

The components of the platform, including the technical interfaces based on standards (xAPI) between the SG4BB middleware, the LMS, and the game, were tested through the collaboration of research, development, and practice using the serious game 'Corrugated': In the first development cycle, integration with the moodle-based LMS was tested; subsequently, the game was expanded and finally tested. Core activities of the SG4BB project focused on the development and testing of AI-supported (personalized, adaptive) playful learning offerings. Therefore, a requirements analysis was conducted in the first project phase to determine the needs of application partners and address open technical issues of technology providers. The outcome of this phase leads to a requirements specification, a concept for iterative and agile development and testing, which serves as the basis for networking and further development of the components of the SG4BB platform. The project proceeded iteratively in two development cycles following the paradigm of agile software development.

2.4.1 Use Case 'Corrugated"

In order to facilitate a deeper understanding of the individual components of the platform, including the technical interfaces and their interactions, 'Corrugated' ('SG4BB Corrugated Service Game') has been selected as a case study. This use case involves the examination of a prototype of a serious game, providing insights into the tested elements of the platform. . Initially, a target group-specific needs analysis was conducted to identify specific requirements and preferences of individuals within the target audience. The collected data, impressions, and requirements were integrated into the game's prototype conception, design, and content development. The prototype was developed iteratively in close collaboration with game developers (Nurogames), vocational education and training scientists, teaching staff, and subject matter experts from practice (UEBZO, BHS Corrugated) to ensure alignment with learning objectives and player experiences. The game concept is based on the theoretical framework of competence-based knowledge space theory (CbKST; Kickmeier-Rust et al, 2016) and evidence-centered design (ECD; Mislevy et al, 2003). A domain-specific competence model was created to enable personalization and adaptation within the learning game, structuring prerequisite relationships among learning content, competency facets, and gameplay behavior (learning progress). This approach should facilitate a non-invasive measurement of player actions within the game.

Corrugated is a single player 3D simulation game designed for the corrugated board industry, developed for mobile devices, and released in 2023 as a free app on common app stores (App Store - iOS and Google Play Store - Android). Players learn the game mechanics through a tutorial level at the beginning. Educational providers

can integrate the game into mobile devices via the SG4BB plugin integrated into their LMS interface, making it suitable for online training programs. This allows both learners and trainers to monitor learning progress and performance, even though the game can also be played independently without LMS integration. To effectively engage with the game, players require basic knowledge of corrugated board systems and manufacturing processes.

Players receive various missions simulating disruptions in the production process of a corrugated board system, requiring problem-solving skills for resolution. The overarching goal ('characterizing goal') of the game is to foster domain-specific problem-solving abilities in preparation for real-world training on corrugators. The game offers three difficulty levels, each designed in collaboration with training staff members to ensure appropriate challenge levels. Each mission is tailored to specific problem symptoms and appropriate maintenance tasks, reflecting real-world scenarios encountered by technicians in the corrugated board industry. The target audience for the game primarily includes inexperienced technicians specializing in maintenance and repair in the corrugated board industry. The game is classified within the domain of vocational training, specifically categorized under the VET application profile for technical occupations (main vocational field; Tiemann et al, 2018) focusing on monitoring, control of machines, plants, technical processes (activity field) (Hall and Rohrbach-Schmidt, 2020, 38).

2.4.2 Evaluation Studies

The system components and implementations of the SG4BB prototypes were tested in two iteration cycles. In the first cycle, an initial game version (version 1.5) was integrated into a training course on the moodle-based learning infrastructure using the SG4BB plugin and initial web services via xAPI standards and a learning record store (LRS) connection. This testing aimed to assess the correct functionality of all elements implemented in a test system environment from both a technical and user-friendly perspectives. Additionally, the study sought to identify gameplay barriers related to usability and playability issues, such as poor controls and interfaces, which can significantly impact the user experience (IJsselsteijn et al, 2007).

In a mixed method approach, representative participants (n=11) provided feedback on the game and its overall concept, including game design, selected content, and gameplay experience during a moderated test session. Participants played the game for 30 minutes while using the think-aloud protocol method, and their thoughts, feedback and interactions were recorded through audio and screen recordings. After gameplay, specific aspects of the user experience were explored in-depth through focused interviews to identify potential weaknesses and gameplay barriers. Finally, a semi-standardized questionnaire was used to collect data alongside demographic information.

Key findings highlighted the helpfulness of the tutorial at the beginning of the game, user-friendly game design, and ease of use as positive aspects. However, participants encountered significant difficulties with the first mission due to its non-intuitive nature, which required collection and evaluation a predetermined amount of information deemed relevant, not meeting user expectations. Participants expressed a desire for more supportive feedback on their performance during this phase. The feasibility of evaluating the test environment in a self-directed setting, where participants could download and test the game on their own mobile devices, was not examined due to technical restrictions of the test system.

Based on the results of the first iteration, the insights from these findings and potential improvements were deliberated and implemented. This involved rectifying bug fixing, adjusting incorrect content, expanding the player's scope of action when seeking information, and integrating additional educational feedback and assistance. Moreover, adjustments were made to refine the research methods used in the final evaluation study.

The final evaluation study emphasized user acceptance and learning effects, centered around the concept of a quality label for serious games (Caserman et al, 2020). Fundamental quality criteria encompass aspects related to the game itself (usability, user/game experience), learning outcomes, and the alignment between these aspects within integrated gameplay, utilizing suitable technology that is appropriate for the specific learning environment. Special attention was directed towards AI-supported algorithms for personalization and adaptation: Do these approaches function effectively, and are they perceived positively by users?

For the evaluation, a separate course was created within the productive learning management system of the training provider, where the evaluation tools and access to the game were integrated via the SG4BB middleware. Participation was possible in both German and English and was voluntary, with agreement from supervisors during working hours. Interested service technicians of the value partner were enrolled in the LMS course and

received all instructions and guidance for the testing process there. We offered two test conditions: a) moderated in-person at a scheduled time using test devices, and b) online self-directed at any time using one's own mobile device during the testing phase, whereby the last setting reflects the realistic depiction of digital training offered and conducted within the company. Each test session was designed for 90 minutes, including instructions and clarification regarding study participation, anonymity and data protection, completion of pre- and post-game problem-solving tasks, a 60 minutes gameplay, and completion of an online questionnaire. The collected data was assigned using a personal code. In addition, audio and screen recording were conducted in the moderated test session to aid in data evaluation.

In order to investigate learning effects, we created six single-choice problem-solving tasks corresponding to the tasks, difficulty levels and objectives in the game. Four of them were anchor tasks, which were included in both the pre- and post-game test. To evaluate participant's experience with the game and the perception of learning, we developed and used an 18-item questionnaire oriented on the serious game evaluation scale by Fokides et al (2019), a validated instrument to assess the players' experience and perceptions towards serious games. Participants responded on a five-point Likert scale, from strongly disagree (1) to strongly agree (5).

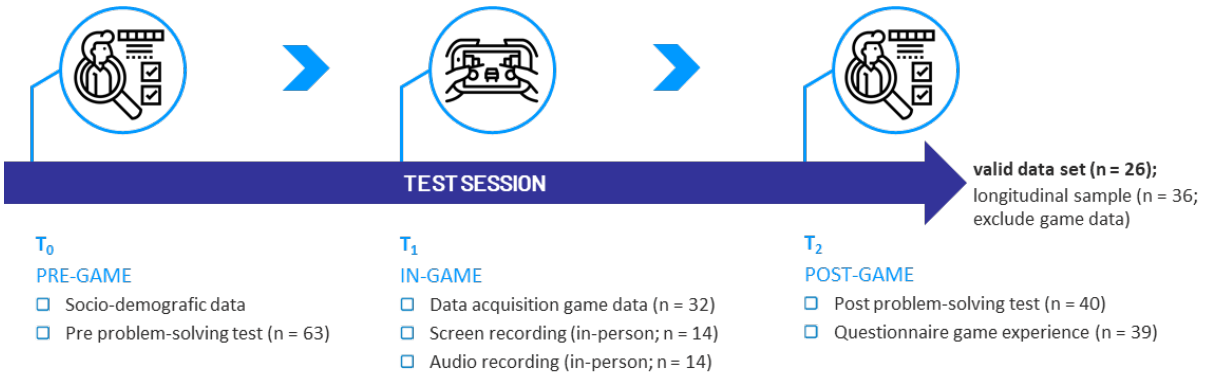

Figure 2: Data acquisition workflow and response statistics

Figure 2 depicts the workflow of the data acquisition and response statistics. We collected data from a longitudinal sample of 36 participants, predominantly male (n = 35), who played the game and completed both a pre- and post-game problem-solving tests along with an online questionnaire. The majority of participants (n = 22) engaged in the self-directed digital session, while the remaining 14 attended in-person. Over 50% of the participants were under 30 years old (n = 19), and 45% (n = 16) reported having no or less than one year experience with a corrugator plant, representing very well the target audience. However, 10 cases could not be included in the game analysis because these participants were not connected to the LMS during the gameplay despite receiving an alert message, resulting in no interaction data being transmitted to the LRS. For analyzing the game interactions, the longitudinal sample size shrinks to 26 participants.

The data analysis provides insights into specific in-game performances. We examined data related to the following: total number of missions (successfully) solved, total number of skill (facets) scores, playtimes and duration. These data form the basis for further investigations and calculations. Initial evaluation results support the assessment that the characterizing goal provides an enjoyable player experience for inexperienced professionals, with the game's progression positively impacting learners by offering varied learning paths across difficulty levels. This assumption could be supported by the results from the game experience questionnaire. In average, the computed mean scores for all questionnaire items were high ($M = 3.6, SD = 1.02, n = 36$), indicating that participants generally enjoyed the game. Additionally, we observed that many participants who engaged in online self-directed testing continued playing the game independently after the testing session. The comprehensive findings will be elaborated in a subsequent publication.

Figure 3 shows a dashboard with a learning analytics module enables user-friendly visualization of learning activities and outcomes. This allows displaying key metrics and information directly within the LMS.

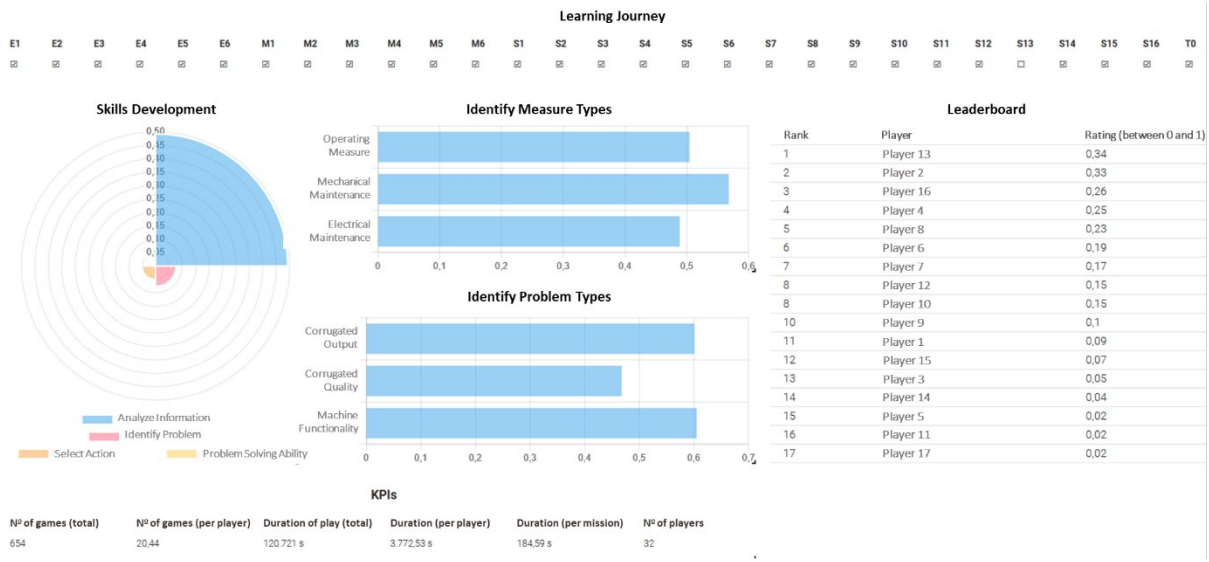

Figure 3: Dashboard with key metrics (i.e. gameplay results, learning progress).

The study also identified areas for improvement within the game, providing valuable insights for future development efforts. However, it was observed that the game's appeal may diminish over time and with increased experience if missions are repeated excessively.

Corrugated was acknowledged by the RAL Serious Games Quality Community as an exemplar of best practice in the field of a gamified learning offering for service technicians in the corrugated cardboard industry.

As a result, the game was described and classified in the SG-IC using the subject-specific application profile 'vocational education and training' of the SG-MDF. As the classification system enables a categorization between the dimensions 'occupational fields' and game-based learning opportunities, Corrugated can be located and found by potential users/educational providers according to its respective occupational field, main activity and industry focus.

3. Conclusion and Critical Reflection

The development and implementation of the Serious Games-Information Center (SG-IC) and associated Serious Games Metadata Format (SG-MDF) within the SG4BB project have successfully enabled the creation of a comprehensive search engine tailored specifically for vocational education and training. This novel platform facilitates the identification and integration of suitable game-based learning opportunities into VET settings, benefiting educational stakeholders by providing targeted, occupation-specific educational games. The platform's robust technical interfaces and middleware, tested through practical collaboration using the 'Corrugated' serious game, demonstrate its readiness for integration into existing learning management systems. The comprehensive analysis of the evaluation results appears to provide promising findings, suggesting valuable insights and implications for further research and practical applications in the field. Such advancements signify significant progress towards enhancing continuous vocational education and training through engaging and effective game-based learning solutions.

In reflecting on the outcomes of the game evaluation and development process within the scope of the project, several key lessons have emerged. Most relevant, these lessons underline the importance of methodological rigor, interdisciplinary collaboration and effective project management among learning providers, subject matter experts and game developers. Second, due to the small sample size, for sure the results of the game evaluation do not have statistically relevance and need to be cautiously examined and interpreted. With respect to the development of new educational games, two major lessons learned should be mentioned: First, it is crucial that the intended learning effects and evaluation/testing methods are clearly specified at the very beginning of a project. This enormously helps the game developers to design a game, and subsequently facilitates game and learning analytics at the end for testing and evaluation purposes. Second, more technically oriented, game developers (especially game developers which are typically focused on the development of entertainment games) need to be supported with practical information (technical specification, manual, 'cookbook') how to build the educational games. This considers both content-related aspects (e.g. knowledge spaces and logical

orders/sequences in the presentation of individual learning tasks and modules respectively educational game situations and game levels based on existing curricula etc.) and technical and conceptual aspects referring to the implementation of the game middleware and, practically speaking about the definition and frequency of interactions between a game and the backend of the system (LMS, Learning Record Store): when and how often should be passed 'which' information from the game to a LMS/LRS? Again, this underlines a strong collaboration among all involved parties in the collaborative, interdisciplinary educational game development process.

Overall, the project has established a comprehensive process pipeline and individual components for the development, provision, and utilization of gamified learning offerings in vocational education and training. The involved partners have gathered valuable experiences, particularly in the realm of gamified content delivery and integration with learning management systems, based on the xAPI standard.

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