Gamebrics: Integrating Analytical Rubrics into Serious Games to Teach Analytical Skills

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Abstract: Complex skills, such as analytical thinking, are essential in the rapidly changing society of the 21st century. An ongoing question is how to teach these complex skills in higher education. Serious games hold potential to stimulate the acquisition of analytical skills. Rubrics are proven feedback and evaluation instruments, but have never been directly integrated into the gameplay of serious games. This position paper discusses how the novel integration of analytical rubrics into serious games may fill this gap. We discuss our approach for this integration and illustrate it using an implementation of analytical rubrics into an existing scenario-based serious game. The discussed approach involves creating theory-informed rubrics, performing validated mappings of rubric elements to game activities and the formulation of appropriate reflective feedback. In addition, we outline the design and implementation of a player-facing dashboard to allow players to track their progress, in-game performance in terms of analytical skills and to receive reflective feedback. Finally, we provide a brief outlook to an ongoing evaluation study examining the effectiveness of the integration of rubrics into serious games.

1 INTRODUCTION

The acquisition of complex skills via active learning, especially in online settings, is a challenge for higher education – as evidenced during the COVID pandemic. A way to stimulate learning these skills is via well-designed serious games. These kinds of games for 'serious' purposes (Michael & Chen, 2006) provide the opportunity to offer students activating tasks in authentic settings. The use of serious games may have several advantages: increasing the motivation of students (Connolly et al., 2012), but also lowering the workload of the involved educational staff.

This position paper focuses on the use of serious games to teach vocational (professional) competences in context. Analytical skills are an important prerequisite for such professional learning. To this end, rubrics are directly integrated into the gameplay of serious games. Rubrics are proven feedback and evaluation instruments, which link criteria to proficiency levels (Van den Bos et al., 2017; Arter & Chappuis, 2010). In this paper, we focus on analytical rubrics, containing not just scores but also an analysis of a certain proficiency level, and on rubrics related to analytical skills. While rubrics focusing on complex skills exist, and can be used to assess the acquisition of these skills, they have never been integrated into the actual gameplay of serious games. The Gamebrics project[1] aims to fill this gap by looking at for-

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mative assessment of complex skills via the integration of analytical rubrics into the gameplay of three serious games.

Achieving this goal involves theory-informed design, development and evaluation of the integration of rubrics into existing serious games. For this, analytical rubrics have to be created, as well as validated mappings of game activities to these rubrics via a content validation method (Hummel et al., 2017). Furthermore, guidelines for in-game feedback have to be formulated. To allow players to track their progress and to receive feedback, the design of an in-game dashboard is required.

This paper first describes the backgrounds and previous literature on serious games, rubrics, thinking skills and feedback (Section 2). This is followed by an outline of the approach of the project, and the utilized serious games (Section 3). Next, we discuss the initial results of our work (Section 4), followed by the conclusions and future work (Section 5). We will provide an outlook to ongoing work: an evaluation study with students in which the effectiveness of the integration of analytical rubrics is being examined.

2 BACKGROUND

This section introduces the concepts related to serious games, formative assessment, analytical rubrics, analytical skills and reflective feedback, which are used in the design and development of the Gamebrics tools.

2.1 Serious Games and Formative Assessment

Serious games have been defined as games for which the prime purpose is not just entertainment, but the achievement of serious goals, ranging from learning to behavioral change (Michael & Chen, 2006; Gee, 2007). Previous meta-analyses (e.g. Connolly et al. (2012); Wouters et al. (2013)) have shown that these games can contribute to knowledge acquisition and content understanding. However, these analyses have also shown that complex skills such as problem solving and analytical thinking may be developed using serious games.

One important element of serious games is the assessment of learning by the players. This can take the shape of formative assessment, but potentially also of summative assessment resulting in a grade. An open issue of assessment in serious games how to carefully integrate this into the gameplay, to avoid interrupting the state of 'flow' a player may be in (Csikszentmihalyi, 2008; Shute et al., 2009). At the same time, the assessment should have a high reliability and validity. Hummel et al. (2017) have developed a way to integrate formative assessment in serious games in a way assuring content validity, involving the mapping of game activities on performance indicators and proficiency levels.

Serious games cover a wide diversity of game genres, for instance simulations, strategy games or adventure games (Connolly et al., 2012). The focal point of this paper is on scenario-based games, which can be created using platforms such as uAdventure (Pérez-Colado et al., 2019) and EMERGO (Nadolski et al., 2008). EMERGO has been described as "a methodology and generic toolkit for developing and delivering scenario-based serious games". Using EMERGO, more than 70 serious games have been developed. Often, these games have focused on complex (thinking) skills, such as analyzing information & problem solving in professional workplace learning settings.

2.2 Analytical Rubrics and Skills

A rubric is a feedback and evaluation instrument. It is usually structured as a matrix of two dimensions (Van den Bos et al., 2017). The first dimension, presented on the vertical axis, contains criteria for evaluation. The second dimension, presented on the horizontal axis, contains proficiency levels. Two types of rubrics are commonly distinguished: *holistic* rubrics, in which complex skills are assessed as a whole and *analytical* rubrics, in which individual, singular criteria are specified. Van den Bos et al. (2017) make a further distinction between *task-specific* rubrics (which can be only applied to one context) and *generic*, domain-independent rubrics, which can be utilized in a broader context, but at a less specific level of detail.

As Arter & Chappuis (2010) indicate, rubrics can be used for assessment in various settings. They can support assessment goals at the level of understanding and application of knowledge, performance skills (e.g. presenting), creation of products (e.g. reports) and higher-order cognitive skills such as analytical skills. The latter entail sub-skills like analysis, synthesis, critical thinking and problem solving.

The New Taxonomy of Educational Objectives by Marzano & Kendall (2007, 2008) also defines various 'operations' in relation to critical thinking skills, which include *Matching* ("identify important similarities and differences"), *Classifying* ("identify superordinate and subordinate categories"), *Analyzing Errors* ("identify errors"), *Generalizing* ("construct new generalizations or principles") and *Specifying* ("identify (...) logical consequences").

2.3 Reflective Feedback

Hattie & Timperley (2007) have defined feedback as all the information an educator provides about the progress of learners, with the goal to increase learning and achievement. Effective feedback decreases the gap between the current and the desired knowledge and understanding of a learner. Further, Hattie & Timperley (2007) distinguish three types of feedback: *feed-up* ("where am I going?"), *feedback* ("how am I doing?") and *feed-forward* ("what should I do next?").

In addition, it is possible to look at the ways to effectively give feedback in interactive tutoring systems. Narciss & Huth (2004) created a conceptual framework for the design of this kind of feedback. They distinguish between the feedback *content* (evaluative and informative components), *presentation* (e.g. timing) and *function* (cognitive, metacognitive and motivational). Reflective feedback provides information on both the progress achieved and on ways forward to further improve the mastery of skills.

3 GAMEBRICS APPROACH

Within our Gamebrics approach, formative assessment via analytical rubrics is designed, developed and evaluated, based on previously validated methods. We implemented this tooling in three serious games which are in different stages of development, but will focus our illustrations on one of them.

3.1 Development Steps

The project consists of four main phases. In the *first phase*, a domain-independent, analytical rubric for analytical skills is developed. This rubric is mapped to game activities of two existing serious games, via a validated method for content validation (Hummel et al., 2017). The *second phase* involves the creation and integration of existing and enhanced tooling into the EMERGO framework (Nadolski et al., 2008). This includes a student dashboard and an authoring environment for teachers. Within the *third phase*, an experimental comparison between gameplay with and without rubrics is conducted. Finally, the *fourth phase* involves the reporting of findings, the documentation of created tools and the depositing of underlying source code.

This position paper focuses on the first and second phase of the Gamebrics project, and describes findings and its achievements thus far.

3.2 Exemplary Game Implementation

The support for formative evaluation via rubrics is integrated into three serious games at different stages of development: *Kastanjehoeve* (already in exploitation over a year, domain management science), *Junior Scientist* (launched in Feb. 2023, domain psychological research) and *EduMythbusters* (under development, domain educational science). However, we limit our illustration of the implementation to the first game.

The Kastanjehoeve game (Figure 1) constitutes an introduction to the field of business administration (within the field of management sciences). Within the game, students perform a virtual internship in an elderly home (named Kastanjehoeve) and have to solve authentic management problems. The game already forms an integral part of Management & Organization, a first-year Bachelor course in Management Sciences at the Open Universiteit (OUNL).

These games already support online active learning in higher education, but are expanded to include rubrics on analytical thinking.

Figure 1: Screenshot Kastanjehoeve game: question from supervisor. Note: the original game is in the Dutch language. The screenshots in this paper have been translated to English.

4 INITIAL RESULTS

This section describes the initial results of the first two phases of the Gamebrics project. We focus on the created rubrics, the mapping of game activities, guidelines for in-game feedback, the design of a dashboard and the implementation so far.

4.1 Creation of Rubrics

Essential to the integration of formative assessment of complex skills into the gameplay of the selected serious games is the creation of the rubrics themselves. The aim was that these would cover various aspects of analytical thinking and would be domain-independent.

Table 1: Analytical thinking skills defined within the Gamebrics project, and corresponding skills in previous literature.

#	Sub-skill	Marzano et al. (1993)	Marzano & Kendall (2008)
1	Comparing & selecting	Comparison	Matching
2	Identifying errors in reliability	Error Analysis	Analyzing Errors
3	Inducing	Induction	Generalizing
4	Deducing	Deduction	Specifying
5	Decomposing information	Classification	Classifying
6	Structuring information	Classification	Classifying
7	Making decisions	Constructing support	Decision making
8	Analyzing perspectives	Analyzing perspectives	Investigating

Based on an analysis of previous EMERGO games as well as previous literature (Marzano et al., 1993; Marzano & Kendall, 2007, 2008), eight sub-skills of analytical thinking were defined: *Comparing and selecting, Identifying errors, Inducing, Deducing, Decomposing, Structuring, Making decisions* and *Analyzing perspectives*. These sub-skills are further defined and related to previous literature in Table 1. For each defined skill, a rubric was created. The contents of these rubrics were adapted from operationalizations of skills by in terms of learning objectives by Marzano et al. (1993) and Marzano & Kendall (2008). The final rubrics contained four proficiency levels, expressed in stars. These levels were inspired by the first four levels of Krathwohl (2002)'s revision of Bloom et al. (1956)'s taxonomy, ranging from one star ("recognize"), to two stars ("understand"), three stars ("analyze") and four stars ("apply").

4.2 Mapping of Game Activities to Rubric

While the created rubrics provided a detailed overview of different sub-skills of analytical thinking, there was no direct connection to the game activities in the serious games used in our project. Therefore, we created a mapping of the different rubrics and their proficiency levels to the existing game activities.

The method for this mapping was inspired by a previously validated method for content validation by Hummel et al. (2017). Specifically, this method involves the mapping of *learning activities* (from the scenario of the serious game) to *performance indicators* (from the rubrics for each analytical thinking subskill created in the previous step). This process was done by the subject matter experts: the educators involved in creating the original serious games and using these in their courses.

A challenge occurring in this process was that Kastanjehoeve, the existing serious game used in the mapping, contained important elements of analytical thinking, but was not originally designed with a specific focus on the eight analytical sub-skills defined in the previous step. Therefore, each separate game activity (denoted as "micro-challenge" within Gamebrics), had to be classified in terms of the *analytical thinking skill* it captured, the *proficiency level* which applied to it, the *weight factor* for the total score in the game, and the *observables* which could be used to observe the performance of a player. For this process, a structured mapping table was constructed, by which the subject matter experts could systematically note down these elements.

Table 2: Number of measurement points of analytical thinking skills after mapping to game activities Kastanjehoeve.

#	Sub-skill	Measurement points
1	Comparing/selecting	3
2	Identifying errors	1
3	Inducing	1
4	Deducing	6
5	Decomposing	1
6	Structuring	4
7	Making decisions	6
8	Analyzing persp.	10
	Total	*32*

Table 2 summarizes the results of this process for the Kastanjehoeve serious game. In total 32 measurement points for the eight analytical skills were found. For some sub-skills, relatively few measurement points were identified (e.g. identifying errors), while for other sub-skills, many points were identified (e.g. analyzing perspectives). The observables ranged from relatively simple measurements, for example whether a game activity has been completed, to more complex ones, for instance how many management techniques a player could identify in video fragments and how many attempts she needed.

4.3 Guidelines for In-Game Feedback

An important element of in-game support for students to potentially improve their analytical thinking skills is the feedback they receive during the gameplay. Within Gamebrics, we distinguish two types of feedback. First of all, there is *natural feedback*, which is part of the game scenario itself. For instance, the player's supervisor in the Kastanjehoeve game may indicate why a provided answer to a multiple-choice

question is wrong. Here, we take this type of feedback "as is". A second type of feedback is *generic reflection feedback*. This type of reflective feedback, in our case pertaining to the analytical skills, is added after playing parts of the game, but should not disturb the game experience itself (in other words: should be unobtrusive).

To formulate the feedback and to decide when to display it, we took into account two of Narciss & Huth (2004)'s factors contributing to the informative value of feedback: *content* and *presentation*.

In terms of evaluative and informative *content*, in-game feedback was formulated based on Narciss & Huth (2004)'s guidelines and an inventarisation of the necessary conditions for game-independent feedback. The feedback consists of a generic part, the *base*, formulated on the basis of the proficiency level, and a *content remediating* part, which is also coupled to the proficiency level.[2] The games within Gamebrics vary considerably, as they originate from Management Sciences, Psychology and Educational Sciences. Therefore, similar to the rubrics, the feedback is formulated in a domain-independent way, so they can be applied to all games in question. A challenge in this process is that a balance has to be struck to avoid that the feedback is either too broad or too narrow. Therefore, the base of the feedback only gives an indication of the performance (the score compared to the maximum score). In the remediating part of the feedback, a textual description of the desired behavior is included to improve the mastery of the analytical thinking sub-skill.

A challenge with regards to the *presentation* of the feedback is the timing. It should be shown at moments which should not interrupt the 'flow' of the gameplay. Therefore, we implemented the display upon completing parts of the game. For instance, in the Kastanjehoeve game, the dashboard containing feedback is shown for the first time when completing the introductory part of the game.

4.4 Dashboard Design

Via the Gamebrics dashboard, the player can inspect her progress in terms of the gathered points in the game, the performance with regards to the analytical skills and receive reflective feedback. During the design process, design elements and learned lessons were incorporated from the Pe(e)rfectly Skilled project[3], such as the skills wheel, a circular visual representation of a player's performance. A design challenge during the creation of the dashboard was to make it generic enough to be usable in existing serious games.

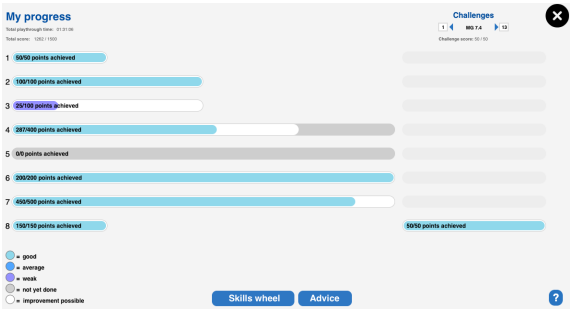

Figure 2: Gamebrics Dashboard: Progress screen (a), Kastanjehoeve game.

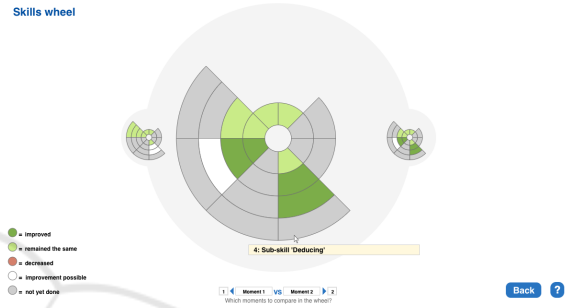

Figure 3: Gamebrics Dashboard: Skills Wheel (b), Kastanjehoeve game.

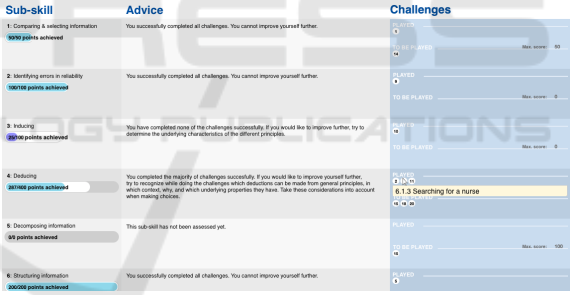

Figure 4: Gamebrics Dashboard: Advice screen (c), Kastanjehoeve game.

The dashboard shows a player's progress (a), the proficiency level for analytical skills via the 'skills wheel' (b), and feedback for improving the analytical skills (c).

Figure 2 depicts the progress screen within the dashboard (a). It includes the scores and maximum scores on the eight sub-skills, based on the currently completed challenges. Via two buttons, a player can switch to a screen with the skills wheel, or the advice screen. Figure 3 contains the skills wheel (b). It displays via different colors and tooltips whether a player has improved, stayed at the same level, or has wors-

[2] Since our eight rubrics each contained four proficiency levels, we had to create 24 feedback texts for each serious game.

[3] https://www.surf.nl/peerfect-vaardig

ened on each sub-skill in the last part of the game. Via additional functionality it is possible to compare different moments in time in the game. Figure 4 shows the feedback screen (c). All eight sub-skills are displayed, with for each skill an advice how the player could improve herself. This advice is structured based on the description in Section 4.3. Finally, there is an indication which game challenges have been completed and which will still follow.

5 CONCLUSIONS & FUTURE WORK

With the continuous advent of online learning, serious games hold potential to enhance the acquisition of complex skills, such as analytical thinking skills. Rubrics are proven feedback and evaluation instruments, but these have never been directly integrated into the gameplay of serious games. This position paper has shown how the novel combination of analytical rubrics into the gameplay of serious games (hence 'gamebrics') may fill this gap. We have highlighted our approach, involving the creation of theory-informed rubrics, the validated mapping of rubric elements to game activities and the formulation of reflective feedback based on existing guidelines. Moreover, we have outlined the player-facing implemented dashboards in Gamebrics, where players can track their progress without interrupting the 'flow' of the game.

At the moment of writing this paper, the effectiveness of integrating rubrics is being examined in a large-scale evaluation with students, for the Kastanjehoeve and Junior Scientist serious games. In both evaluations, an experimental group is given the game without formative evaluation through the rubric, and another group *with* the formative evaluation of the rubric. This will be combined with validated questionnaires. The analysis of the experimental data will shed more light on the effectiveness of directly integrating rubrics within the gameplay of serious games for formative assessment.

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