

# An Approach to Scoring Collaboration in Online Game Environments

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**Abstract:** With technological advances, it is now possible to use games to capture information-rich behaviours that reveal processes by which players interact and solve problems. Recent problem-based games have been designed to assess and record detailed interactions between the problem solver and the game environment, and thereby capture salient solution processes in an unobtrusive way (Zoanetti, 2010; Bennett et al., 2003; Shute & Wang, 2009). The Assessment and Teaching of 21st Century Skills project used an innovative approach to capture these processes through responses (activities and communication patterns) within collaborative games (Griffin & Care, 2015). Game player response patterns are identified as behaviours that are indicative of skills and are captured in real-time game play within time-structured log files. The analysis of these log files allows for inferences to be drawn in regard to the efficiency and quality of player performance. A concern with this approach is that game development for this purpose is complex, time consuming and expensive, with unique scoring applied to each game. This paper presents another approach that identifies, across games, common behaviours. A systematic scoring system for assessing player behaviours in games could provide access to useful data not only from new games but from existing games. This paper presents such an approach using collaborative games situated in a problem-solving context.

**Keywords:** Collaboration, problem solving, online assessment, log stream data, measurement, e-learning

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## 1. Introduction

It is unsurprising that references to 21st century skills have started many debates over what and how today's students should learn in order to become productive citizens (Kim & Shute, 2015). Lists of 21<sup>st</sup> century skills typically include problem solving, critical thinking, decision making and collaboration (Binkley et al., 2012). While these skills are not new, their relevance is greater than ever in this information age, where dissection of information, rather than just consumption of information, is critical. The increasingly rapid spread of sophisticated technologies into every facet of society is causing significant shifts, including how educational systems should be structured to prepare students effectively for life and work in the 21st century. Knowledge workers, now confronted by complex problems, need to be able to think systemically, creatively and critically, and at the same time be able to apply extensive problem solving and complex communication (McClarty et al., 2012) skills. Continuing to provide the same types of education to students as the world continues to change will not serve them well. The skills and knowledge exposed by traditional education are no longer seen as adequate preparation for success in life. Moreover, traditional assessments often fail to assess complex skills or measure what students can do with the knowledge and skills acquired through education (Shute & Kim, 2014).

## 2. Embedding assessments in games

How and what we learn is rapidly changing and researchers argue that games possess unique affordances to address complex problem-solving skill development that our current educational system is failing to provide (OECD, 2013). Assessment generally refers to the process of gathering information about competencies and attributes (Kim & Shute, 2015). Games can be powerful vehicles to assess competencies and dispositions, such as persistence, flexibility, creativity, self-efficacy, critical thinking, systems thinking, openness, problem-solving and teamwork, which can positively impact student academic achievement and other aspects of life (Delacruz, 2011; Zein & Diab, 2015; Care et al., 2015; Wang et al., 2015; Deniz et al., 2014; Kim & Shute, 2015)). Technologies, as well as educational and psychological measurement approaches, have advanced in recent times (Wang, Shute, & Moore, 2015). Technologies allow us to embed assessments into games by extracting multifaceted evidence from a learner to infer competency levels across a network of skills, addressing what the person knows and can demonstrate (Shute & Kim, 2014).

One area of promise is a movement toward the use of well-designed games to provide meaningful student assessment environments that require the application of various complex competencies. Traditional assessments, such as paper and pencil multiple choice tests, do not necessarily capture the dynamic and complex nature of 21<sup>st</sup> century skills. Many researchers are exploring the possibility that games are well suited to improve instruction and differentiate learning while also providing more effective and less intrusive measurement than traditional assessments can offer (McClarty et al., 2012). Gee (2007) argues that if games are designed appropriately, they will stimulate higher-order thinking and collaborative activities among participants. Games are likely to address 21<sup>st</sup> century skill development through active interactions, collaborative experiences and complex problem solving (Schifter, 2013). Thus, embedding an approach to scoring within games provides a way to monitor participants' level of competency and provide useful feedback (Shute & Kim, 2014). Assessment is a process of drawing reasonable inferences about what a person knows by evaluating what they do, say, make or write in a given situation (Griffin & Care, 2015). Games can be designed to increase in complexity and cognitive demand as play progresses, such that gameplay can be used for assessment purposes (Delacruz, 2011; Gee, 2007).

The use of games and simulations in assessment and learning is expected to increase over the next few years (McClarty et al., 2012). Additionally, assessments in this format have the advantage of providing teachers with tools that help them tailor instruction to the needs of students at different achievement levels (Mayrath, Clarke-Midura, Robinson, & Schraw, 2012). Test takers' skills in these virtual environments can be automatically assessed by tracking their behaviours. Moreover, analysis of log files can highlight the strengths and weaknesses of game design (Ifenthaler et al., 2014; O'Neil, Chuang, & Chung, 2004).

The use of games in education so far reports mixed results, despite theoretical endorsement of its benefits. Design, development and implementation of games is expensive, time-consuming, resource-demanding and challenging (Awwal, Alom, & Care, 2015), and the goals of games do not necessarily align with learning or assessment goals: ostentatious game features can distract players from their task. A scientific attitude with regard to the design of educational games requires validated measures of learning outcomes and associated assessment methods in order to determine which design elements work best, when, and why (Ifenthaler et al., 2014). Scholars from various disciplines have found that well-designed games require problem solving skills, persistence, and creativity (Gee, 2007; Prensky, 2004; Shaffer, Squire, Halverson, & Gee, 2005); these are competencies critical to success in the 21st century, but to date are not explicitly supported by education systems. With appropriate design, student learning of skills through games can be promoted (Moreno-Ger, Burgos, Martínez-Ortiz, Sierra, & Fernández-Manjón, 2008).

### **3. Measuring collaboration**

Theorists have for decades emphasised the importance of social interaction during learning (e.g. Vygotsky, 1978; Dillenbourg, 1999). From a learning perspective, the benefits of working collaboratively lie in the process rather than the end goal. If an individual is faced with a problem, they may have ways and means to solve it alone. However, if a student collaborates to solve a problem they enter into an iterative process in which they engage with others, understand perspectives, and regulate social interaction. A collaborative approach provides different learning opportunities than working individually. However, it is reasonable to presume that it is in the individual's interests to learn how to work alone as well as to collaborate.

Game theory has been based in two long-standing categories of people working together: competitive and cooperative. Marschak and Radner (1972) recognised that a team is an organisation in which players can possess different information and skills, and individuals need to work together to maximise a joint outcome. Recent research places competition, cooperation and collaboration on a spectrum with competition and collaboration at opposite ends, determined by whether players have a shared goal (Zagal, Rick, & Hsi, 2006). In competitive games, participants typically work against one another, whereas in cooperative games they work together. The key difference in collaborative games is that there is a necessity for players to work together, with each player contributing uniquely to the game. Collaborative games can be designed to reduce any competitiveness players may initially possess. This can be addressed by providing shared goals and ensuring dependency between players through division of information and resources. Such strategies may constitute effective learning mechanisms. Cooperation, collaboration, and competition are combined in real life, where workers at times understand that they need to work together in order to achieve their goals, notwithstanding that they may also be competitors.

Critical to the integration of collaboration into current education systems is development of tools and strategies for assessing the skill. There is recognition that collaborative assessment requires human-human interactions, complex problems that cannot be solved by a single individual, and diverse sets of knowledge, skills and experience (Hesse et al., 2015). Assessing individuals' collaboration while also ensuring a reliable, valid, and fair assessment of their skills represents a major advance in educational measurement (von Davier & Halpin, 2013). Measuring less explored skills such as collaboration therefore requires methods of assessment design and psychometric analysis that may not be contained within traditional methods of assessment. In order to assess 21<sup>st</sup> century skills such as collaboration, inferences about student ability are required, and technology is providing ways to capture the relevant data from which these inferences may be drawn. Log stream data are a familiar feature of computer use, but have only recently been generated at scale to provide new insights and perspectives in education. Log stream data capture student activities and retain a time-stamped record as students work through an online game. Students can thus be scored in real time in an automated approach that reduces the time and effort required for teachers to observe student performance in the classroom.

## **4. Method**

### **4.1 Design**

The online games described harness log stream technology transforming them into assessments of collaboration. Behaviours such as action and chat communication are captured in real-time in a time-series log file, allowing for reasonable interpretations of such behaviours to be made in relation to a player's collaborative ability. The games presented act as a neat illustration of the similarity of the skills applied across collaborative games and therefore of the opportunity to capture similar behaviours. The method outlined was designed for a pilot study to test an approach to scoring involving common behaviours across games. The analysis presented in this paper involved three collaborative games developed by the ATC21S project: Laughing Clowns, Balance Beam, and Game of 20.

### **4.2 Participants**

Each game was administered to 410 students (186 males and 224 females) across six schools in Victoria, Australia. The principal in each school was responsible for selecting which classes and, therefore, which students were involved in the trial. The principal selected classes primarily on the basis of availability for timetabled visits. The students were 12 to 15 years old ( $X = 14$  years).

### **4.3 Materials**

The games presented in this study were designed for two players to work together in an online environment. The players are provided a login and required to work through the assessment together. Their communication is facilitated by an embedded chat box. Players can collaborate on the game irrespective of physical location, provided they login simultaneously. Players cannot progress through the assessment independent of one another, and often cannot solve the problem without input from their partner. From the players' perspective, these assessments present as games. The log stream data generated allows for identification and scoring of player behaviours during game play.

In the Laughing Clowns game, illustrated in Figure 1, the players are presented with a clown machine each and 12 balls to be shared between them. The goal for the players is to determine whether the two clown machines work in the same way. In order to do this, the two players need to share information that is available to each of them and discuss the rules, as well as negotiate how many balls they should each use for problem resolution. This game requires players to find patterns, share resources, form rules and reach conclusions (Care et al., 2015).

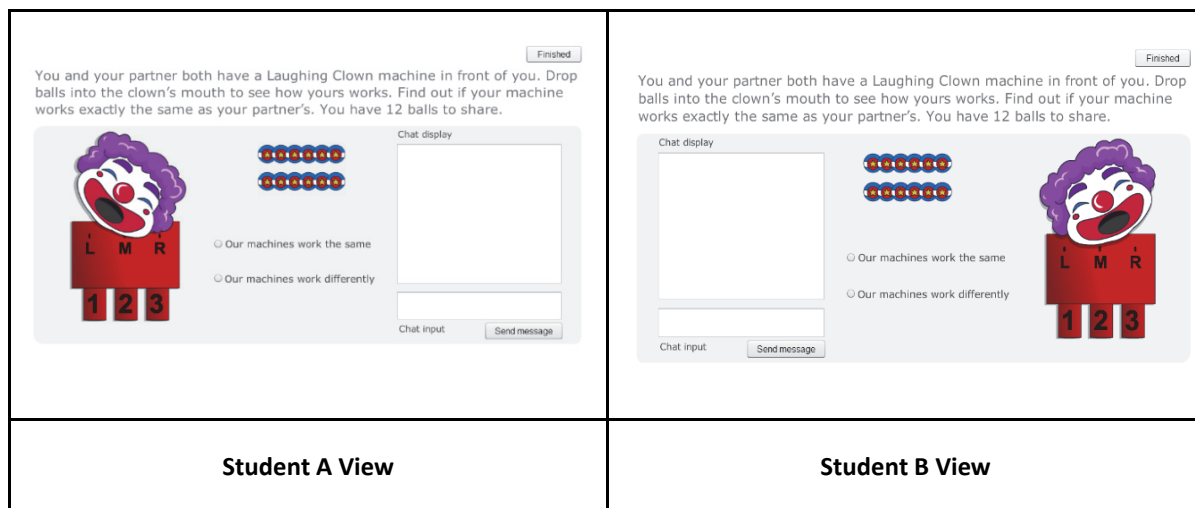


Figure 1: Screenshots of the Laughing Clowns game.

The Balance Beam game, illustrated in Figure 2, is presented so that each player can interact with only one side of the beam and is unable to see their partner's side. Both players are then provided with a limited number of weights. To make the process more collaborative, one player begins with all the weights, hence requiring sharing across players to progress through the task. Initially, weights must be passed from one player to the other; then each must place their weights in the correct position on the balance beam in order to achieve balance. Players need to apply and test rules in order to balance the beam, possibly leading to multiple correct solutions.

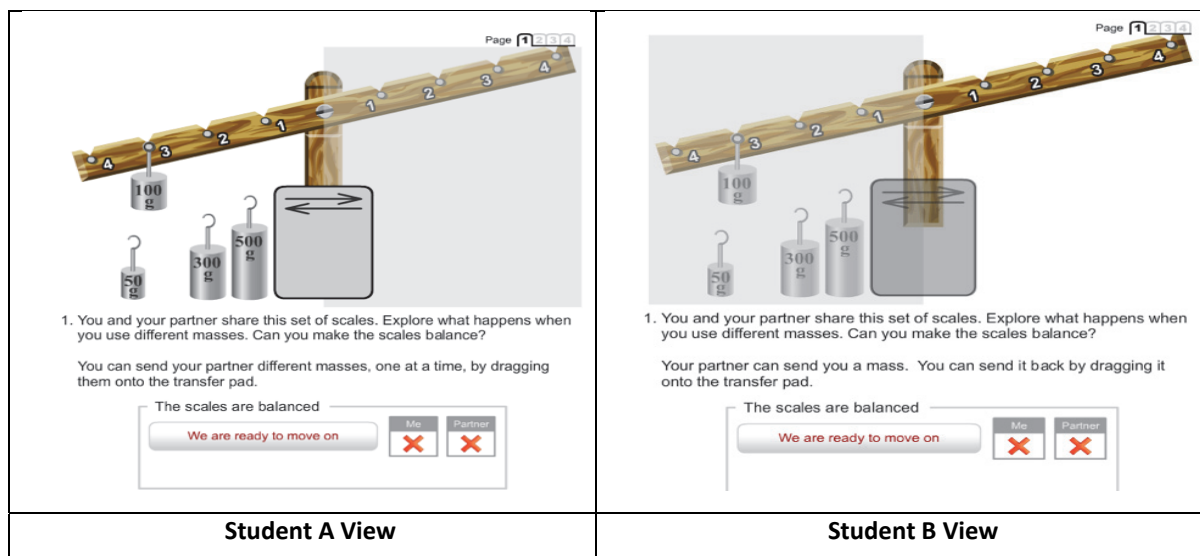


Figure 2: Screenshots of the Balance Beam game

The Game of 20, illustrated in Figure 3, presents a mathematics based problem, in which the object is to work out the ideal numbers to reach a sum of 20 before the competitor, which in this game is the computer agent, reaches that sum. The two players must collaborate in order to win against the computer. Players need to take turns at selecting a number, with their aggregated number the one ultimately played. Instructions provided to the players include "Where will your team place the counter to be sure of winning the game?" and "Remember that the number of counter advances will be a combination of your number and your partner's number". These instructions make clear both the competitive and collaborative nature of the game – that together the players need to win against a third party – the computer.

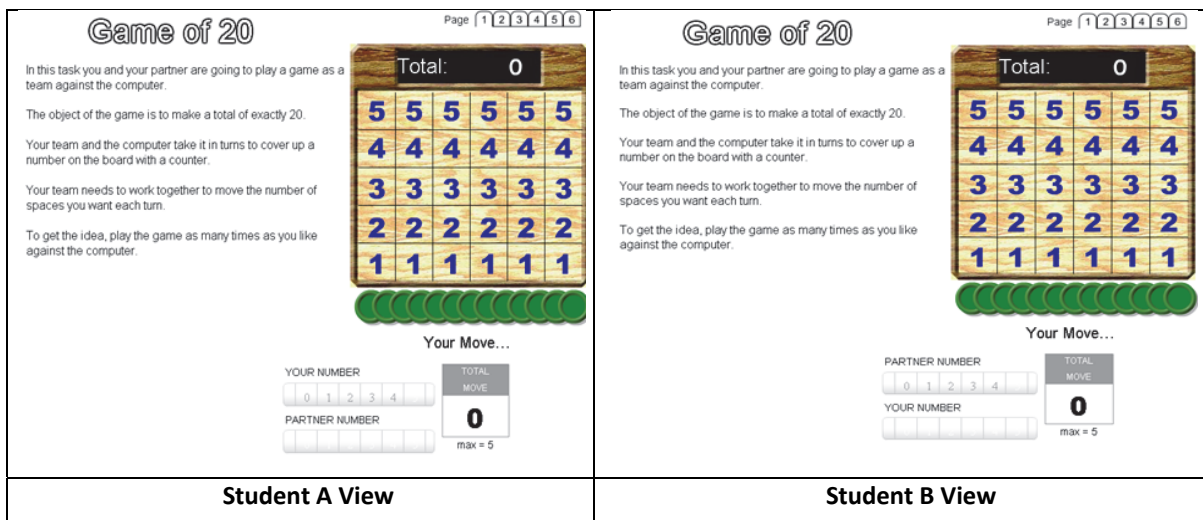


Figure 3: Screenshots of the Game of 20.

#### 4.4 Procedure

This paper outlines four behaviours identified as common across players and across each of the games. Each player completed all three games with the same partner within a classroom environment, taking approximately one hour. Log stream data was used to identify actions and communications undertaken and interactions between players. These observable behaviours are identified from the log stream data by employing search algorithms. The algorithms search the stream for the behaviours and score each behaviour as either present or absent for each player in each game. All activities and interactions that are possible within a game environment, if recorded systematically (records of player–game interactions), can measure salient solution processes in an unobtrusive way (Bennett et al., 2003; Zoanetti, 2010). These recorded detailed interactions between the problem solver and the game environment can be linked to each player's level of proficiency and used to evaluate the process and efficiency with which problem solvers complete games (Pellegrino, Chudowsky, & Glaser, 2001; Williamson, Mislevy, & Bejar, 2006).

#### 5. Results

The pilot study identified four common behaviours across the three games (Table 1). The percentages in the columns on the right refer to the frequency of each behaviour in each game, measured across all participating players.

Table 1: Common behaviours

Number	Behaviours	Scoring	Clowns (%)	Balance (%)	Game of 20 (%)
1	Sends partner resource	0 (absent); 1 (present)	54	44	57
2	Presence of chat immediately before selecting final answer	0 (absent); 1 (present)	34	23	32
3	Trials all resources	0 (absent); 1 (present)	34	55	62
4	Asks partner a question	0 (absent); 1 (present)	75	71	74

Behaviour number one identifies the percentage of players sending their partner a resource. This is an important component of collaboration, since to work together players need to identify and share each other's resources. Further, the asymmetrical nature of the games makes this sharing critical for solving the problem. Figure 4 provides an example of the log stream data from a pair of players in the Balance Beam game. This excerpt shows the data used to identify behaviour number one. The identification of the 'pass resource' data event, as indicated by the green arrow, represents the passing of a resource from one player to another. In this example, it is the passing of the 300g mass from player A to player B. To record the presence of this behaviour, the search algorithm for behaviour number one searched the log stream data for the presence of a 'pass resource' data event. If present, a value of 1 was recorded for that player against that behaviour. If absent, a 0 value was recorded. Instances of sending resources were identified in all three games.

team_id	student_id	task_id	role	page	event	arg1	arg2	arg3	outcome	timestamp
usapri0021	usapri0021b	BALANCE	B	3	chat	same again I have no weights				1/10/2015 11:42
usapri0021	usapri0021a	BALANCE	A	3	chat	yeh I have 4 again				1/10/2015 11:42
usapri0021	usapri0021b	BALANCE	B	3	chat	can you give me 300g?				1/10/2015 11:42
usapri0021	usapri0021b	BALANCE	B	3	chat	ill try it on 1 like last time				1/10/2015 11:42
usapri0021	usapri0021a	BALANCE	A	3	pass-resource	300g	B			1/10/2015 11:43
usapri0021	usapri0021a	BALANCE	A	3	chat	k done				1/10/2015 11:43
usapri0021	usapri0021b	BALANCE	B	3	move-resource	300g	1			1/10/2015 11:43
usapri0021	usapri0021a	BALANCE	A	3	chat	k ill put 100g on 3				1/10/2015 11:44
usapri0021	usapri0021a	BALANCE	A	3	move-resource	100g	3			1/10/2015 11:44

Figure 4: Example of log stream data from the Balance Beam game showing the ‘pass resource’ data event.

Table 1 presents the percentage of players for whom the presence of each behaviour was recorded in each game. Recording a present behaviour, resulting in a ‘1’ being recorded for that player in that game on that specific behaviour, is much like being scored correctly on a traditional test: for the purpose of assessment, behaviours are like test items. The frequencies of percentages correct (or, in this case, presence of a behaviour) can be taken as a proxy measure of the perceived difficulty of that behaviour (Adams et al., 2015). If a large proportion of players demonstrate a particular behaviour, this suggests that behaviour was easier to complete than those behaviours demonstrated by only a small proportion of the players. In the case of behaviour number one, the frequency appears reasonably consistently across the three games, at a mid-range (between 44-57%).

Behaviour number two identifies the presence or absence of chat immediately before the final answer in the game is selected. Discussion of suggestions or answers to the problem before entering them suggests good collaboration. From a game design perspective, there needs to be an opportunity to select a final answer to make this behaviour viable. As can be seen in Table 1, there is a relatively low frequency of players demonstrating this behaviour and this is consistent across games (between 23-34%).

Behaviour number three identifies whether players engage with every feature of the game. In problem solving, a systematic approach requires trialling, and in the collaborative context, this is made more complex by virtue of different resources being available to each player. In games of this kind, players benefit from pooling and trialling all joint resources. In the games demonstrated, some resources are redundant or of little use to the current activity, and players need to trial resources to assist in identifying the useful ones. Behaviour number three increases in frequency across the games suggesting that more players engaged with all of the features in the last game, Game of 20 (62%), than they did in the earlier game, Laughing Clowns (32%). It is possible players become more familiar with the interactive elements of the design in later games, or they become more confident in engaging with the game features.

Behaviour number four identifies whether a player asks their partner a question, indicated by the presence of key question words such as ‘what’, ‘why’ or ‘how’ in the chat box. Seeking more information from others is critical to building a shared understanding of the problem and will provide a foundation from which further collaboration can be built. The frequencies for this behaviour were consistently high across the three games (between 71-75%) suggesting that most players recognised the benefits of potential contributions from their partner.

## 6. Discussion

The approach taken in this paper highlights the ability to measure collaboration through games. In addition, it demonstrates that common behaviours can be identified across games to make inferences about player collaborative ability. Although the three games presented in this study demonstrated different problems and different requirements for collaboration, behaviours common to all three could still be identified. The identification of common behaviours makes scoring much more efficient, eliminating the laboriousness of scoring each game separately. Not only does the log stream data provide insight into what players are learning within the games, it provides an approach for assessing that learning.

Advances in technology have expanded the availability and opportunities for assessment game design. Computer-based performance assessment allows information to be captured, in relation to the processes and responses of the player (Bennett, Persky, Weiss, & Jenkins, 2007), that paper-based assessments cannot provide. This development also clearly possesses administrative advantages, such as automated scoring,

greater reach, instant feedback and a reduction in subjective scoring. The approach presented here allows for games to be transformed into assessments without the player experience or interface changing. This presents an engaging situation for students in the classroom and an opportunity to generate data for teachers to evaluate their students' collaboration skills. Future work will focus on identifying additional common behaviours in games from which the same inferences might reasonably be drawn.

## 7. Conclusion

The approach outlined represents an innovation in assessment, moving from a model in which abilities are identified by direct responses to questions with correct and incorrect answers to a behavioural inference model. In this model, inferences about capabilities are made on the basis of individuals' actions and communications in a game environment. The challenge for educators who want to employ games to support learning is to make valid inferences about what the students know and can do without disrupting their engagement with the game (Shute & Kim, 2014; Wang et al., 2015). The use of capture of actions through log streams provides this facility without students needing to consciously respond to assessment prompts.

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