AN INVESTIGATION INTO USING A COLLABORATIVE GAMIFIED LEARNING ENVIRONMENT AS A TOOL TO ENHANCE THE LEARNING OF BASIC COMPUTER PROGRAMMING CONCEPTS

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Abstract

This paper outlines the importance of the synthesis of collaborative learning and gamification techniques to teach basic computer programming and identifies the need for a collaborative gamified learning environment (CGLE) in order to maximise student opportunities to learn programming within a supportive environment.

Over the past four years, the teaching of computing has undergone substantial changes within the UK National Curriculum, advancing from Information and Communications Technology (ICT) towards the more demanding Computer Science (CS). The Computing at School Working Group was set up to provide leadership, direction and resources for teaching basic computing and programming skills in order to address the clear need to provide support for teachers new to the CS curriculum. Another important factor is the need to find a balance between supporting struggling students, whilst also retaining the interest of those with prior experience. Studies including that by Carter and Hundhausen in 2016 found that it is not only the programming tasks themselves which affect learning success, social activity and peer engagement of students are also a predictor of outcomes due to the demonstrable benefits of collaborative working. Currently there is a gap in the literature with regard to the application of collaborative gamified techniques to support the teaching and learning of basic computing concepts.

This paper focuses on the use of gamification and collaborative learning to enhance the computer programming learning process. To this end a set of six basic computer operations that can be taught through learning to program have been identified and form the quantifiable aim of the research.

A review of the current literature in gamification and collaborative learning has been undertaken in order to form the foundation of a framework that can be used in an experiment with a cohort of novice undergraduate students.

Persuasive evidence has been found that suggests collaborative learning can leverage the benefits and motivational factors of social learning and interaction, however, the core challenges in this approach are team matching and dynamics, group decision-making and communication.

Analysis of the current rise of gamification as a motivational tool in both business and education is offered, with a detailed focus on its use in learning. Recent gamification frameworks are reviewed and common features and concepts identified in order to assess their suitability for use in a collaborative educational setting. These include, but are not limited to: epic meaning or setting purpose, marking accomplishment with rewards and visible status, providing feedback to aid engagement, giving a sense of ownership in the system, using social influence for motivation and providing the freedom to explore and make mistakes in a safe environment. \[1\],\[2\],\[3\],\[4\]

Having identified the core challenges and opportunities in gamification, collaboration and learning and their inter-relationships, this paper will propose an initial framework for a CGLE that can be used within the curricula to increase engagement and effective learning.

Keywords: Gamification, gamified, collaborative learning, computer programming, social learning, collaboration.

1 INTRODUCTION

1.1 Background

Computing teaching is currently undergoing a huge change within the UK National Curriculum for pupils aged 5-17 years old, with the move from ICT to Computer Science [5]. The Computing At
School Working Group [6] was set up to provide leadership, direction and resources for the teaching of computing in schools and they provide much information and have a vibrant online community of practitioners. The need to motivate struggling students, and yet keep the interest of those with some background in the subject adds another layer of complexity [7]. Carter and Hundhausen [8] discuss the idea that not only the programming tasks themselves affect learning success but that social activity and peer engagement of students has a bearing on outcomes too.

1.2 Gamification

Gamification, a term first coined by Nick Pelling in 2002 [9] is the concept of applying game mechanics and game design techniques to engage and motivate people to achieve their goals [10],[4]. Gamification taps into the basic desires and needs of the user’s impulses, which revolve around the idea of status and achievement. Huang and Soman [11] provide some clear distinctions between games and gamification. For example, games have defined rules, objectives and a possibility of losing, whereas gamification may offer a collection of tasks with some form of reward where losing is not an option, as the point is to motivate people. Deterding et al [12] further defined gamification as the use of game design elements in non-game contexts. In his book Actionable Gamification Yu-Kai Chou [2] prefers the term “Human-Focused design” to gamification, suggesting a move away from what he calls “function-focused design” i.e. putting the motivation of the user in front of the requirements of the system.

1.3 Collaborative learning

Collaborative learning is based on the idea that learning is a naturally social act in which the participants talk among themselves and it is through this interaction that learning subsequently occurs. There is persuasive evidence that cooperative teams display a greater understanding and retain information longer than learners who work quietly as individuals [13].

Raija Hamalainen [14] is clear about the need for students to experience collaborative work, especially in the realm of vocational study. He also sees a clear distinction between co-operative and collaborative learning. The former divides tasks into subtasks, which are then assigned to participants to complete as part of a whole, whereas collaborative work involves constructing a shared solution to achieve a shared aim. According to Vuopala et al [15], collaborative learning can be placed in social constructivist learning theory in that it involves mutual engagement to construct knowledge and solutions. The challenge is to present a common goal that an individual cannot complete alone.

In 2014 Govender [18] undertook a study on the effectiveness of “Pair Programming” to determine how a collaborative learning technique can be used as a pedagogic intervention for effective teaching and learning of a programming course. This study produced positive results with students demonstrating improved problem solving and independent learning skills.

In conclusion these studies demonstrate positive outcomes for students undertaking collaborative work, while gamification offers techniques designed to increase engagement and motivation. The combination of these ideas within the context of the teaching of computer programming is therefore considered a potentially effective way of promoting learning.

2 RESEARCH AIM

The specific aim of this paper is to outline an approach to test the hypotheses that the application of gamification and collaboration applied to learning programming is more successful than traditional methods of learning programming. By investigating these two approaches and identifying the key elements it will be possible to produce a framework for the use of collaborative gamification within the computer programming discipline.

Students find learning how to program difficult and studies show that their motivation is often low which impacts on their ability to succeed in this area [24]. In their paper “Designing Prototype Model of an Online Collaborative Learning System for Introductory Computer Programming Course” Othman et al [25] concluded that collaboration in an online/virtual environment increased engagement and self-esteem.

Gamification is already becoming a well-established method of engaging and motivating learners [19],[20]. This is supported by the recent work of Sung and Hwang [21], Santos et al [22] and Lytras et al [23] where students take ownership of their learning. Thus a framework that combines the attributes of
gamification and collaboration should support academics in developing a learning environment that will enable novice programmers to reach their full potential.

3 COMPONENTS OF THE PROPOSED ENVIRONMENT

3.1 The 6 Basic Computer Operations:

The following list forms the core set of concepts to be taught to the students [26] which are commonly accepted basic operations in computing. These concepts are currently being taught in a BCS accredited level 3 undergraduate introductory programming course at the University of Greenwich. The course content already exists and has been delivered using JavaScript for the past 4 years. This presents an ideal opportunity to devise and run an experiment and gather data on the results. The learning outcomes will remain in place, but the delivery will be adjusted to include collaborative gamification.

1. A computer can receive information
2. A computer can output information
3. A computer can perform arithmetic
4. A computer can assign a value to a variable or memory location
5. A computer can compare two variables and select one of two alternate actions
6. A computer can repeat a group of actions

As the experiment will involve collaboration on the acquisition of programming skills the use of an off the shelf project hosting service such as GitHub is being proposed. Students can code, edit, and collaborate in one place that has excellent version control and allows for an assessor to track individual student contribution to the project.

3.2 Collaborative problem solving.

Care et all [16] identified, from the literature, a teamwork model and a problem-solving model. The teamwork model consists of six skills: [27]

1. Decision making
2. Coordination
3. Adaptability
4. Interpersonal
5. Leadership
6. Communication

The problem-solving model, [28] has three identified elements.

1. Content understanding,
2. Problem-solving strategies,
3. Self-regulation

Whilst the objective is not to make a game per se, but to employ gamification techniques, referencing the work carried out by Daylamani-Zad et al [29], the following list is synthesized from their collaborative decision-making games research and the teamwork model above to produce a set of criteria. These will then be aligned with gamification techniques and programming tasks as the framework develops.

3.2.1 Personalisation

Kim et al [30] noted that personalisation is linked with game enjoyment and feelings of autonomy and control. González et al [31] in their paper ‘Enhancing the Engagement of Intelligent Tutorial Systems through Personalization of Gamification’ explain how personalisation techniques help to tailor the experience to the interests of the user, increasing loyalty and satisfaction.
3.2.2 Team matching

Team or group dynamics have a big impact on the decision making process and also on sense of enjoyment. Ku et al [32] identified 2 factors as having a direct effect on the sense of satisfaction in collaborative work. These are: Team dynamics, which focuses on patterns of communication within the group and Team acquaintance, which relates to familiarity with each others learning styles, personal beliefs and backgrounds. Awareness of the perspective of others in the group is another consideration. [16]

3.2.3 Decision making

Turban et al [33] have distilled various collaborative decision making models from Tuckman's [34] forming, storming, norming, performing and adjourning to Tubbs [35] orientation, conflict, consensus and closure. Their proposed process model is:

- Information gathering,
- Problem identification,
- Finding alternative solutions,
- Selecting an affective course of action
- Implementing the solution.

3.2.4 Leading

Scardamalia [36] suggests that in a truly collaborative endeavor the responsibility for success should be distributed amongst the group. In addition, Care et al [16] identified that there also needed to be strong negotiating skills and self-confidence in place within the group for it to be successful. Momo Kenfack et al [37] contend that even should a leader emerge, either naturally or by consensus, the other members could potentially overrule their decisions.

3.2.5 Proficiency index for problem solving strategies

In the decision making game environment suggest by Daylamani-Zad et al [29], the concept of a decisiveness index is described, whereby a positive or negative weight can be given to the competence of the decisions of each player or group member. This then feeds into the process of future collective decision making. In the context of the proposed environment decision making is analogous with proficiency in solving coding problems. The decisions the group makes and the proficiency of individual members can be used to identify and support weaknesses in solving programming problems.

3.2.6 Scoring

Scoring is a categorical part of any gamified experience. In the context of collaboration an individual can accrue points/credits for themselves and these can form part of the team score. Whitaker et al [38] suggest that scoring can help identify strengths and weaknesses as a participant progresses and can also encourage collaboration to improve both individual and team scores.

3.2.7 Communication

Ku [32] notes that the quality and frequency of communication encourages information exchange and can promote team cohesiveness. Selvaraj and Fields [39] also identify strong, clear channels of effective communication as essential for collaborative decision making.

3.2.8 Coordination and adaptability

The ability to adapt is core to team working and problem solving according to Care et al [16]. As a social skill the ability to adapt to the view and perspective of others is crucial and the ability to adapt to new information and ways of working are required for problem solving. Coordination of effort forms a building block of collaborative work whether face to face or in an online environment.

3.2.9 Levelling

Daylamani-Zad et al [29] have identified the benefits of breaking tasks or problems into discrete levels to both increase enjoyment and allow for better decision making as tasks become more manageable.
Levelling is also identified as a powerful motivational tool for encouraging users to pursue rewards and measure accomplishments.

### 3.3 Gamification

There are many gamification frameworks including Andrzej Marczewski’s gamification framework [42], Yu-Kai Chou’s Octalysis framework [2], Werbach and Hunters DMC (Dynamics, Mechanics, Components) Pyramid [3] The MDA (Mechanics-Dynamics-Aesthetics) games design framework by Hunicke, LeBlanc and Zubek [43], The MDE (Mechanics-Dynamics-Emotions) framework by Robson et al [44], An Coppens offers various solutions at Gamification Nation [46] and finally Karl Kapp and his book The Gamification of Learning and Instruction [4].

An evaluation of these options will be carried out to derive a set of features and requirements that both appear across all the frameworks and are most suitable to an educational environment with the best match to learning theory and motivational theory [4]. An initial overview of gamification techniques is outlined below.

#### 3.3.1 Epic Meaning / Goals and objectives - purpose

Generating motivation by setting a challenge. Applying meaning, instilling sense of purpose or group pride. Examples are when a user devotes time to maintaining a forum (Wikipedia) or when a user contributes to an entire community (Open Source projects) without expecting any form of payment. Sense of belonging, like houses or teams at school/university. T-shirts, wristbands, caps. [40],[2],[3].

#### 3.3.2 Accomplishment, Rewards, visible status

Making progress, developing skills, overcoming challenges. This is where most of the points, badges and leaderboards (PBLs) exist. These should be about the motivation to achieve PBLs not the PBLs themselves.

Points: Give players a feedback system to also keep track of their progress, can be gained, lost or perhaps and traded

Badges: Achievement symbols merely reflect achievement, but are not achievements by themselves.

Leaderboards: Designed to motivate people and bring in status but if implemented incorrectly can do the exact opposite. Group Leaderboards can show the combined effort of a team.[2],[40].

#### 3.3.3 Feedback/progress

Provide real time information of progression and goal attainment. An example would include wearable activity trackers such as the Fitbit. Monitoring progress and improvement is fundamental to engaging users. [3]

#### 3.3.4 Ownership & Possession

Users are motivated because they feel like they own something. When a player feels ownership, they inherently want to make improvements. For example if a person spends a lot of time customising their profile or avatar, they automatically feel more ownership towards it. [3], [2]

#### 3.3.5 Social Influence, cooperation and competition

This is part of what Kapp [42] calls game thinking and is a strong motivator where people can compete against each other or cooperate to achieve a mutual goal. It can be simultaneously encouraging for teams to try and better each other while strengthening a team bond.

#### 3.3.6 Scarcity & Impatience

According to Chou [2] this is wanting something because you can’t have it. The fact that people can’t get something right now motivates them to think about it all day long. This can feed the desire to progress and find out what is next, leading into leveling up and increased proficiency.
3.3.7 **Unpredictability, surprise**

This encompasses the desire to see what happens next or the inclusion of the unexpected to keep players interested and motivated and could include content unlocking of unknown features, easter eggs, special events, novelty. [40],[3]

3.3.8 **Freedom to make mistakes**

Taking risks without the impact of permanent consequences can encourage free thinking and creativity in groups. [2],[40] Examples include multiple lives and restore points within games.

3.3.9 **Player Types - Personalisation based on profiling**

Not all players play a game the same way or have the same motivations [42]. Marczewski [1] classified the following user types specifically for gamification:

1. Socialisers - interact with others and create social connections.
2. Free Spirits - create and explore.
3. Achievers - want challenges to overcome.
4. Philanthropists - want to enrich the lives of others with no expectation of reward.
5. Players - are motivated by rewards. They are in it for themselves.
6. Disruptors - are motivated by change and want to disrupt a system to force positive or negative change.

4 **CONCLUSIONS**

It has been shown that there is a pressing requirement in the UK educational system for innovative ways of engaging students in computational thinking and programming. This is due to the recent change from an ICT to a CS based curriculum. The literature recognises the significant challenges facing educators to engage and motivate students to achieve their full potential in computer science. Collaborative learning is becoming a more established practice as the evidence shows that it is highly beneficial to students. It fosters a supportive and shared learning environment and experience, which has been shown to produce better outcomes for learners. Gamification, while certainly not new, is still relatively novel in an educational setting. Whilst many gamification techniques are currently targeted at business situations, there are clearly aspects which also apply to learning. These should be assessed in order to determine which will effect the most positive levels of attainment.

4.1 **Preliminary mapping of the components**

Fig. 1 below provides an initial mapping of the various gamification and collaborative problem solving components that have been identified. The diagram shows a broad overview of the mappings at the bottom where gamification feeds into collaborative problem solving and then into the learning material itself, in this case the 6 basic computer operations. It can be noted at this point that the learning material content itself is mutable.

Although this diagram depicts a preliminary representation of the connections between elements, it can already be clearly seen where areas share common attributes. For example the gamification technique of providing feedback and giving a sense of progress map well to the collaborative processes of decision making, scoring, leveling and gaining proficiency. On the left of the diagram the gamification technique of leveraging social influence maps well to team matching, leading, communication and coordination of efforts.

It is clear that this model will evolve over several iterations as a result of further investigation and practical implementation. Nonetheless there is clearly potential for synthesizing these techniques into a coherent learning environment.
Figure 1. Preliminary mapping of components.

This figure depicts the interaction between the components as discussed above in 4.1. Gamification elements are pictured in red while green represents collaborative problem solving techniques.

4.2 Future work

Moving forward, an experiment in the form of a pilot study will be designed to gather preliminary data on the effectiveness of using the proposed collaborative gamified learning environment as a tool to enhance the learning of basic computer programming concepts.

REFERENCES


