Implementing Technology Infused Gamification in Science Classroom: A Systematic Review and Suggestions for Future Research

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Abstract

It is rather a challenging task for educators nowadays to get their digital native students engaged and motivated throughout the learning in spite of the emerging intensive demand for personalized learning and new technologies. For this reason, it is crucial for educators to think of creative ways to attract their students' attention and enhance their learning especially for subjects like science that needs highly conceptual understanding. Gamification is becoming a popular trend in the education world as a teaching tool that uses elements of games in a non-gaming context. This paper aims to review on implementation of technology infused gamification in science classrooms. A systematic review was conducted to analyze previous studies on three types of technology-infused gamification which are currently implemented widely. Most of the studies agreed that technology infused gamification settings which were well planned and executed in classrooms successfully served their purpose by providing a fun, improving motivation in learning; hence, increasing students' engagement. There are some limitations to make gamified learning meaningful that was highlighted by a few studies, including poor wireless connection and elements of games like awards that pave the way for competition and demotivation. Few suggestions were proposed to be considered by educators when planning to implement gamification in classroom settings.

Keywords: Gamification; Technology; Science classroom; Systematic review

Introduction

Background and Rationale

Nature and the speed at which the world progresses as a result of technological development affected the way members in the society live, think, study and progress. By definition, technology cut across every facet of human endeavor which brought about changes in the way knowledge, and skills are imparted.

In line with this development, digital games are gradually incorporated into the teaching of students of today who are identified as digital natives because they interact with technology much better than anything. On the other side, it also means that they may have very short spans of attention to focus on something that does not involve technology. This makes traditional teaching methods without technology support become not suitable since they don't emphasize on what the students are familiar with or interested in. Hence, it is very common for these millennial (i.e. people reaching young adulthood in the early 21st century) students to lose their attention very quickly to learn the curriculum's topics. Sadly, they become disengaged in learning even before the cognitive processes to absorb the content knowledge begin. Therefore there is demand for the learning strategies to incorporate technology so as to capture the interest of these young learners.

Problem Statements and Objectives of the Study

Considering the growing students' demand for personalized learning options, and while technologies like mobile devices become pervasive, it is wise for educators to make use of the technological advancement to introduce innovative learning experiences to students (Pechenkina, Laurence, Oates, Eldridge, & Hunter, 2017). With an increasing call for creativity and technology application in teaching and learning, it is rather a challenging task for educators to find appropriate teaching tools to accommodate students' needs. In addition, educators need to consider motivational factors that contribute to achievement when choosing teaching tools to make learning effective (Tan, Ganapathy, & Kaur, 2018). In this struggle, digital game-based learning which is also known as gamification was introduced considering the fact that it involves technology and a game which are parts of students' life.

In view of the foregoing discussion, this study reviewed the existing literature on the implementation of technology infused gamification in science classrooms with an analysis of the type of technology-infused gamification currently utilized. The study was seen necessary as very little effort was made by previous researches to reveal the actual situation.

Methodology

A systematic review is the research method implemented in this study. The literature search was done using keywords; (1) "gamification AND technology"; (2) "gamification AND infused technology"; (3) "gamification AND implementation"; (4) "gamed based learning"; (5) "benefits AND technology infused gamification"; (6) "challenges AND technology infused gamification"; (7) "benefits AND technology infused gamification"; (8) "gamification AND science classroom"; (9) "gamification AND mobile app design"; (10) "audience response system platform" and (11) "gamified web-based learning". The search was carryout through various databases including Scopus, Google Scholar, Web of Science, Willey, Tylor and Francis Libraries and Research Gate. The relevant literature on gamification in mobile app design, audience response system platform and gamified web-based learning were analyzed. Based on the inclusion and exclusion criteria, articles with content that has empirical data or some very relevant conceptual discourse and literature on gamification, games of game-based learning were selected. The article must also be published in indexed publication within 10 ten years (2010-2019). After the screening, 36 articles were finally selected and used in this review.

Systematic Review in Gamification: Definition, Related Research and Examples

In the following sections, the discussion was firstly made on the definitions of gamification in comparison with games and games-based learning. Then its roles in technology-enhanced learning in general as well as with exemplars in science education more specifically.

Definition and Background of Gamification in Comparison to Game and Game-based Learning

In order to understand better how technology-infused gamification can be applied in the science classroom, this section reviews systematically the operational definitions of gamification in comparison with other commonly found terms such as games and game-based learning as summarised in Table 1.

Table 1
Features of Gamification in Comparison with Games and Games-based Learning

	Gamification	**Games**	**Games-based Learning**
Teaching and learning	using points and badges (Ceker & Ozdaml, 2017)	matching, sorting, and trivia (Stenros, 2017)	points and stars, badges, leader boards, and rewards (Plass, Homer, & Kinzer, 2015)
Concepts/content knowledge and skills	encourage discussions commonly on education (Arnold, 2014)	may be educational or for entertainment (Li, 2016)	increased responsibility and accountability (Coleman & Money, 2019)
Improve motivation and engagement	motivate and engage students to learn (Al-Azawi, Al-Faliti, & Al-Blushi, 2016; Buzko, Bonk, & Tron, 2018)	motivation to learn, increasing the likelihood achieve learning outcomes (Stenros, 2017)	enhances both intrinsic and extrinsic motivation (Erhel & Jamet, 2019)
Learning outcome	positive students' attitude and academic gain (Kiryakova, Angelova, & Yordanova, 2014)	mostly for pleasure (Kabita & Grace, 2016)	deep learning and understanding (Huizenga, Admiraal, Dam, & Voogt, 2019)
Lifelong learning and hands-on	create conditions for an effective learning process. Kiryakova, 2014)	skills and literacy (Li, 2016)	active learning and developing a student's sense of autonomy and team performance (Huizenga et al., 2019)

Entrenched within social and real-life contexts	enhances social interaction among learners (Hursen & Bas, 2019)	the cooperative game increased social interaction but competitive game sometime create violence (Creighton & Szymkowiak, 2014)	Enhance interaction (Plass etal., 2015)

A point of clarification here is that the terms games, game-based-learning and gamification are wrongly presumed to be the same by many educators and researchers. While games take the approach of using an activity within a well-defined game space as a game board or within a computer browser, gamification tends to take the use of a game outside of a defined space (John, 2012).

Game is an activity guided and described by some set of rules most especially for the purpose of entertainment or competition. When certain elements of games and its mechanics are used in non-gaming contexts such as the existing learning process, it is called gamification (Al-Azawi et al., 2016). Deterding, Sicart, Nacke, O'Hara, and Dixon (2011) defined gamification as an umbrella term for the use of video game elements to improve user experience and user engagement in non-game services and applications such as marketing and education. Also, while games are described as activities using full established game design, gamification applications, don't use all of the aspects in games (Çeker & Özdaml, 2017). The most relevant functions are emphasized in line with the purpose of incorporating the game such as business, marketing, or education.

Table 2 described some benefits and limitations associated with technology-infused gamification

Table 2
Benefits and Limitations of Technology-Infused Gamification

No.	Benefits	Limitations
1	Providing fun, improving students' motivation and motivation in learning (Al-Azawi et al., 2016; Buzko et al., 2018).	Poor wireless connection and elements of games like awards that pave the way for competition and demotivation (Antonaci, Klemke, & Specht, 2019)
2	Enhances social interaction among learners (Hursen & Bas, 2019).	Not effective for students who are not naturally competitive (Furdu, Tomozei, & Kose, 2017).
3	Create conditions for an effective learning process (Kiryakova et al., 2014)	Sometimes students' feel unmotivated or fearful (Furdu et al., 2017).
4	Encourage collaboration and discussions among learners (Arnold, 2014)	Difficulty of assessing suitable game resources within the school budgetary, logistical or technical constraints (Bolstad & Mcdowall, 2019).

5	Instant feedback and better learning experience (Furdu, Tomozei, & Kose, 2017)	Users perform behaviors only when rewarded (Hyrynsalmi, Smed, & Kimppa, 2017).

Gamification using Technological Tools for Technology-Enhanced Learning

Gamification was initially applied in the business and marketing world to boost customer engagement by introducing rewards and loyalty elements. For instance, coupon collection, redemption and discount vouchers provided by chain department stores like AEON, My-Starbucks Rewards by Starbucks and mobile app flash sales deals by e-commerce merchants like LAZADA are a few prominent examples of gamification in the marketing world. Realizing the fun and excitement gamification can offer, it was gradually in cooperated into teaching and learning.

Gamification in Mobile App Design. A smartphone is a priority gadget for people nowadays most especially the students. The smartphones are installed with varieties of mobile applications that keep the user engaged and addictive all the time. The use of the applications could be a very good way of attracting students to learn something easily as most of their time is spent operating their mobile phones. Hence, gamification using mobile applications can make students engage in their learning process (Buzko et al., 2018). Creating gamification in mobile app design is a wise approach for teachers or educators to attract their students' attention and keep them engaged throughout learning as relevant activities are gamified in their mobile app which may enhance students' general achievement in learning.

A study conducted by Pechenkina et al. (2017) on how a gamified mobile learning app used in science lessons could positively affect students' academic engagement and achievement.. They created a mobile app integrated with gaming features and the main focus was to assess students on what they have gained through lecturing process and how deep is their knowledge of the content. Those who chose to use the app received consistent notifications about lecture notes and invitation to take part in multiple-choice quizzes sent to their mobile app. Based on students' login activities, a leader scoreboard is displayed and the winner was awarded digital badges. The result of the study showed that students who used the app demonstrated higher performance in the quiz compared to those who did not use the app. By implication part of the time they spent using their mobile app was shared with their education career.

In another study, Buzko et al. (2018) demonstrated the importance of incorporating mobile apps and augmented reality elements in binary lessons; lessons that combine two different educational disciplines. In the context of science education, it is somewhat similar to the concept of STEM education which integrates four different disciplines. For instance, during the lesson 'Environmental Problems of Nuclear Energy', the elements of the augmented reality were applied with the aid of mobile apps. Before the lesson, the students were required to download the 'Augmented Nuclear plants' application. Then, the students were assigned to answer questions related to the topic based on their observation. Through this study, the researchers assert that gamification and augmented reality in education in secondary school allow the participants to get involved in an outside classroom setting learning process. Similarly, Su and Cheng (2015) investigated how Mobile Gamification Learning System (MGLS) applied in science learning. In their research, a sequence of gamified learning activities was developed and implemented using a mobile app called "Find Insect Mobile App". After login to the application, students were required to browse and select one of the learning games. The system then sends students a reminder with instructions on how to start the learning

task. The learning contents represented on the screen after students scan the QR code of a specific learning target. The mobile app proved effective on students' learning outcome.

Audience Response System (ARS) Platforms. Online quizzes portals like Kahoot and Quizizz (Figure 1) or Quizlet (Figure 2) are examples of audience response system (ARS) platforms that allow teachers to set questions in the form of online quizzes that can be administered to test students during the lesson.

Figure 1. Quizizz (Vincent, 2015).

Figure 2. Quizlet (Vincent, 2015).

Students are given options either to answer the questions individually or in teams as illustrated in Figure 3. They gather points based on the speed and accuracy of the answer provided that will be showcased in the digital leader board (Mader & Bry, 2019).

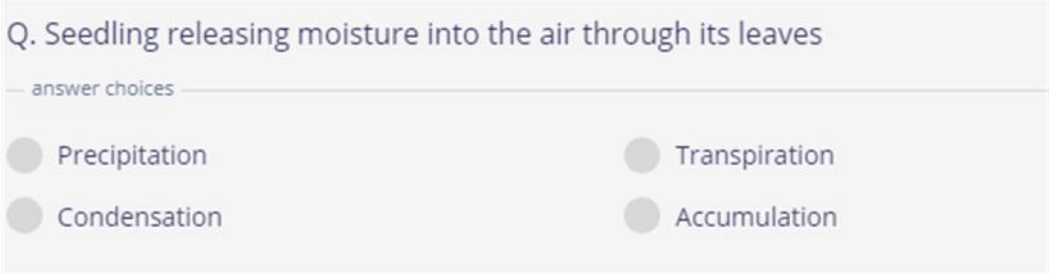

Figure 3. Sample quiz posted onto Quizlet with options to be chosen by students.

Implementation of this type of ARS platform is gaining popularity among lecturers in Malaysian Higher Education Institutions. Research towards the usage of these platforms among undergraduates found to be beneficial in terms of inducing motivation and engagements (Tan, Lin, & Kaur, 2018). However Boutaba, Salahuddin and Liman (2018) did point out the limitations of using ARS platforms particularly the dependency on a wireless connection. According to the researchers, the lack of a stable Internet connection had interrupted the quiz answering sessions.

Mader and Bry (2019) introduced team-based social gamification in their research which allowed students to answer quiz as a team. Each student is assigned to a team and the students' answers to questions posted on quizizz cumulate points to their respective team. The results of the quiz were immediately displayed on the screen which enhances students' motivation to active participation. The finding of the study indicates that, while the approach was effective in a small class, it failed to improve involvement and commitment in a large class. The researchers proposed a few approaches in their study to make learning fun and engaging even when involves a larger group of students such as allowing students to choose their own team members. By implication, this type of game is more appropriate in a small size class. As such overcrowded classrooms are not suitable.

In addition, Çeker and Özdaml (2017) discovered that quizizz posted on ARS platforms enable each student to work at his/her own pace, take own initiative and have the freedom to make decisions. The teacher needs to reflect and plan formative assessments through quizzes based on the student's individual ability. This gives a measure of individual learner ability and achievement. In another interesting study, Aşıksoy and Sorakin (2018) reported the implementation of clicker-aided flipped classrooms coupled with ARS in a Physics class. In this study, the physics course was taught using the flipped classroom model (Figure 4).

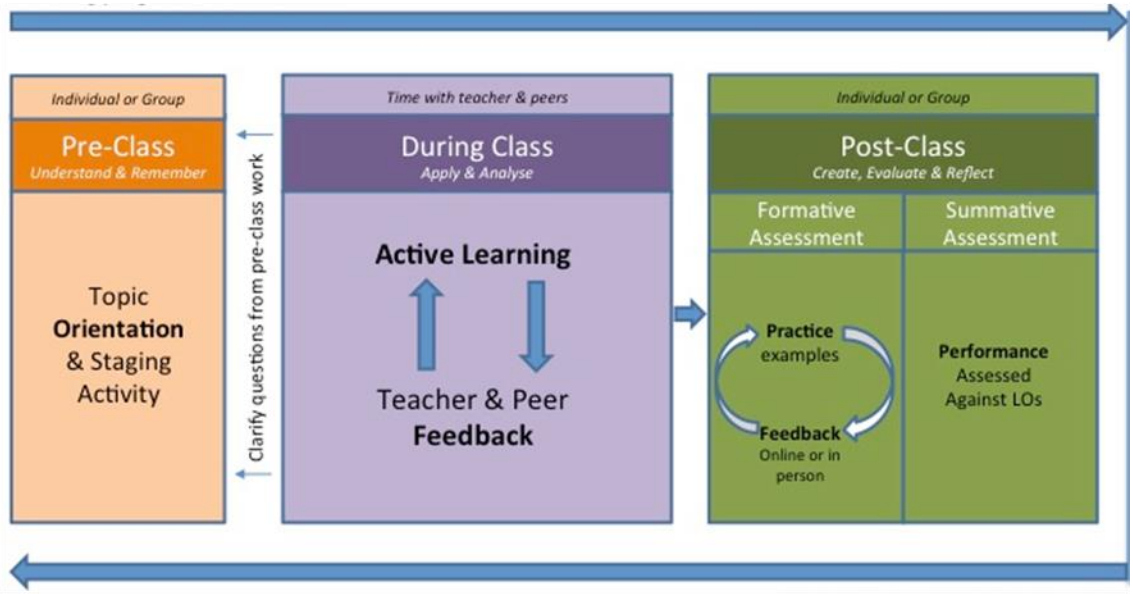

Figure 4. Sample flipped classroom model (Karanicolas, Snelling, & Winning, 2018).

The content-related notes and videos uploaded by lecturers prior to the lesson for students to prepare themselves. During class activity time, they were asked to answer quizzes to test their knowledge on the materials that were uploaded by lecturers initially. For individual quiz activities, a time limit is set for students to answer Multiple Choice Questions (MCQ). The results of the research indicated the positive effects of the clicker-aided flipped classroom model on students' learning achievements in physics. What could be gathered here is that the audience response system plays a significant role in enhancing students' motivation and attitude toward better learning outcomes in science.

Gamification in Educational Settings

When using gamification in education, teaching and learning activities are refined using points and badges, which have been transformed into a classroom setting (Çeker & Özdaml, 2017). By implication when game activity is employed in the learning of a concept it triggers learners' creativity and makes the learning environment a fun-filled which may encourages discussion about learning concepts amongst students. Studies have proved that learning outcomes of gamification are mostly positive, especially in improving motivation and engagement in learning (Al-Azawi et al., 2016). Some of the examples of gamification include ChemCaper, Metal Blast, Universe Sandbox, Electric Shocktopus. Although these games could provide learners with entertainment, it also describes scientific concepts and phenomenon which enhance learners' understanding of science.

Realizing the role of games in fostering efficiency and creativity among learners, gamification of education is gaining popularity among educational researchers. When applied in educational settings, gamification tremendously improves opportunities for lifelong and hands-on learning. Despite providing fun while learning, gamification enables students to gain sufficient content knowledge and skills (Arnold, 2014). It is a student-centered approach where students' learning is self-regulated as the teacher acts as a facilitator (Ismail et al., 2018). Gamification, therefore, supports varieties of active learning strategies such as problem-based learning, discovery learning, some aspects of inquiry-based learning.

Gamification as a Science Education Teaching Tool

In choosing a type of teaching tool for science education, Morris, Croker, Zimmerman, Gill, and Romig (2013) opines that learning of scientific practices should consider the knowledge on how these practices are entrenched within social and real-life contexts. Students should be aware that concepts and scientific investigations must be based on social needs. Gamification, therefore, should help students make more connections between the topics of scientific study and the global, sustainability concerns they observe in daily life (Mellor et al., 2018). Games are only incorporated in teaching scientific concepts if the activities in the game could support these concepts and scientific investigations in line with social needs. In this context, Morris et al. (2013) analyzed the idea of gamification in science education by providing a framework to apply existing games and design new games to cultivate scientific thinking skills. As a finding of their research, they suggested that science education can be improved by incorporating main elements of games that will affect motivation, cognitive and metacognitive achievements. This argument is supported by a finding of the research conducted by Rouse (2013), which proved that when science lessons among community college students were gamified, their motivational level would be improved, paving way for improvement in their test scores.

Furthermore, technology-aided gamification of science lessons seems to increase student enjoyment and motivation. Arnold (2014) advocates that digital gamification is now widely used by a vast number of people as the thriving development of tablets and smartphones makes it portable and convenient to be used in any setting or location. For example, in a research conducted by Vaibhav and Gupta (2014), it was discovered that when gamifying massive open online course (MOOC) providers such as edX, Couresera, and Udacity, users' enrolment, achievement and retention ability of the students enrolled in the said learning tools had increased. While there are various different studies that advocate gamification of science lessons to be effective, this study reviewed the literature on how technology-aided gamification is implemented in the classroom setting to promote students' motivation and achievement.

Gamified Web-Based Learning Tool

The online and video game-based learning environment is an educational approach to motivate and engage students to learn scientific content using games. The environment is reported to have a positive impact on students' learning outcomes in science. For example, Fleischmann and Ariel (2016) described the development of a web-based learning tool in microbiology aimed to assist the students to observe microscopic specimens with a touch of gamification to enhance their understanding of the microscopic processes. The website was designed using some features of gamification (Figure 5) such as interactive interface, options to choose different level challenges, immediate feedback, reward and integration of sound and animation. students who used the web-based tool gave positive feedback on the role of this tool in enhancing their learning by enabling them to clearly visualize microbiological processes.

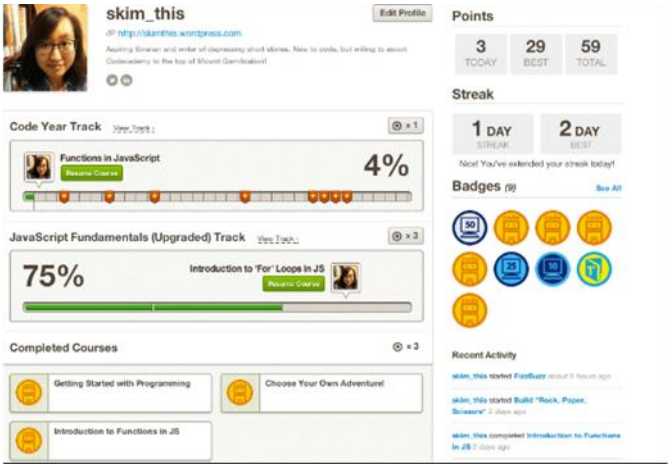

Figure 5. Sample website with some features of gamification (Brown, 2019).

Additionally, Kim, Rothrock, and Freivalds (2016), in a study explored the effects of gamification on lab activities among undergraduate students, launched two types of websites; one was gamified and the other with conventional settings. In these websites, students could set their own questions as well as answer questions set by their peers. Students' points were determined by calculating the number of questions they created, the number of questions they have answered and also by taking into account peer feedback. The accumulated points were then used to determine their rank in the competition. The outcome of the students' learning revealed the positive influence of gamified web-based learning.

Although the gamified web-based learning revealed interesting and positive results, it was however pointed out that a drawback was discovered. Some of the gamification aspects found to be instilling negative impacts on student learning include badges, leader boards, and rewards (Figure 6) (Fleischmann & Ariel, 2016).

Figure 6. Sample gamification aspects with badges, leader boards and rewards.

This finding seems to align with outcomes from an analysis review by Sanmugam et al. (2015) in their research where they disclosed that it is crucial to identify levels of motivation as introducing a reward system in an optimized environment has a potential to disrupt the flow; resulting in dependency on the rewards, and demotivation if the reward system is removed. They proposed that to boost motivation among students, rewards must be attainable and realistic. Various types of rewards systems should be introduced according to students' cognitive ability and motivation level. The gamified environment needs to be paid attention, such that the effects of increased competition and evaluation would not bring disunity among students in the class as collaboration play a significant role in learning. Despite the significance of technologically aided gamification tools in boosting students' interest and active learning, there are some external factors that need to be taken into consideration while planning to implement these tools in classrooms. For instance, the stability of wireless internet connection as highlighted by Tan et al. (2018), during the application of online quizzes using ARS platforms. Especially when applied in schools, aspects like internet access and the strength of the wireless connection should be considered if teachers decide to use these platforms.

Conclusion

Summary and Implications

After thoroughly reviewing and discussing all the researches in this study, it can be asserted that gamification gives a positive impact on the engagement and motivation of students when implemented in classrooms as an educational tool. When mindfully integrated into an intervention's design, gamification worked in accordance with other aspects of the intervention to positively impact student learning. Technology infused gamification settings which are well planned and executed in classrooms successfully served their purpose by providing fun, improving motivation in learning; hence, increasing student engagement. An increase in motivation and engagement level correlates with achievement level where students score higher marks in the tests or quizzes.

Most of the researchers applaud the injection of game elements into the game designs such as badges, leader boards, and rewards; as factors contributing to the elevation of motivation and engagement among students. However, some studies showed opposite results where elements like leader boards and awards indirectly pave way for competition and demotivation when they were not rewarded or don't lead the leader boards.

Significance and Suggestions

Gamification learning using mobile phone apps might be ideal to be implemented in higher education institutions as almost all undergraduates' own mobile phones and are allowed to use them during lecture sessions. Unlike in schools, as underaged students, many of them might not own mobile phones, and even if they do, those devices are not allowed into school compounds. Therefore, the role of teachers or educators of all levels is crucial in carefully planning the type of gamified teaching tools, depending on the accessibility, users' need and educational goals.

Further research on the implementation and efficiency of gamification in science education is vital in ensuring the ultimate goal to provide meaningful learning to students is achieved. Perhaps more systematic review could be conducted to examine the operational definition of game-based learning (GBL) or gamification as compared to problem-based learning (PBL) supported by ICT and how its implementation in science classroom affect student's attitudes,

interest, motivation and thinking skills with research or evidence-based findings. In fact literature revealed that PBL supported by ICT tools was able to enhance students' motivation as evidenced from the pre-/post-tests before and after PBL using the motivation scale developed (Ng, Soon & Fong, 2010). The analysis of data collected from the study on the effect of PBL using scaffolded instruction (or abbreviated as PBL-SI) also revealed that the 'Fluid Intelligence Test' (FIT) as reported by Ng, Fong and Soon (2010) was effective to discriminate students with various aptitude levels. Hence more research should be conducted to explore if well-planned technology infused gamification incorportating project-based activities and scenario-based or PBL could enhance students' motivation and thinking skills.

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