GAMIFICATION OF DISCUSSOO: AN ONLINE AI-BASED FORUM FOR SERIOUS DISCUSSIONS

Elena Bakhanova
UTS Games Studio, Faculty of Engineering and Information Technology, University of Technology Sydney
81-113 Broadway, Ultimo NSW 2007 Australia

Madiha Anjum
School of Computer Science, Faculty of Engineering and Information Technology, University of Technology Sydney
81-113 Broadway, Ultimo NSW 2007 Australia

Jaime A. Garcia
UTS Games Studio, Faculty of Engineering and Information Technology, University of Technology Sydney
81-113 Broadway, Ultimo NSW 2007 Australia

William L. Raffe
UTS Games Studio, Faculty of Engineering and Information Technology, University of Technology Sydney
81-113 Broadway, Ultimo NSW 2007 Australia

Alexey Voinov
Faculty of Engineering Technology, University of Twente
Drienerlolaan 5, 7522 NB Enschede, Netherlands

ABSTRACT

Engagement in the discussion process is one of the common challenges of asynchronous online forums. It becomes especially crucial if the discussion is organized over a serious topic about a complex problem with a group of diverse stakeholders. Gamification gives much promise in addressing this challenge. In this paper, we propose possible game design solutions to the engagement challenge for an existing online AI-based platform Discussoo and reflect on the results from the expert interviews and an experiment with students.

KEYWORDS

Asynchronous discussion, game design, stakeholder engagement, participatory modeling

1. INTRODUCTION

Today effective science-based policy-making assumes transparency and trust from the stakeholders involved and affected. Stakeholder engagement usually means that there is an educational component in the exchange of knowledge between the parties. Participatory modeling (PM) is one of the methods that imply 'a purposeful learning process for action that engages the implicit and explicit knowledge of stakeholders to create formalized and shared representations of reality' (Jordan *et al.*, 2018, p. 3). PM organizes stakeholder engagement around the process of building models of the systems of interest. Models offer a unique opportunity to study human reasoning and elucidate the way in which one thinks and makes decisions regarding the system at stake (Voinov *et al.*, 2016). Building explicit and shared models using the PM approach can greatly increase the applicability and robustness of the results.

However, the PM method has several challenges associated with its implementation. Modeling workshops are usually restricted in time (between 2 and 5 hours) and these workshops can accommodate only a limited number of participants (normally up to 30 people) (Van den Belt, 2004). It would be challenging to conduct a constructive discussion by inviting many more stakeholders and it will be hard to get all of them to join a

workshop at a particular time in one place. One of the possible solutions to overcome these limitations is to use online discussion forums. Still, there are two difficulties associated with this solution in the PM context. Firstly, to our best knowledge, there is no discussion forum that holds modeling functionality or can mimic the modeling process. Secondly, it is challenging to sustain participants' engagement in such an asynchronous discussion setting.

In this paper, we focus on suggesting possible game design solutions to the engagement challenge for an existing online AI-based platform Discussoo that is designed to use in modeling context for the involvement of stakeholders in discussions on complex problems.

2. ONLINE DISCUSSIONS: ENGAGEMENT CHALLENGES AND EXISTING SOLUTIONS

Despite the anticipated value of using online forums for stakeholder involvement in problem analysis and decision-making, in the existing literature, such a format of asynchronous discussions appeared to be mostly used in formal and informal educational settings. In formal education discussion forums often serve as a complementary tool to promote peer-to-peer interaction and learning as well as critical thinking and stronger involvement in the topics of the subject (Huang *et al.*, 2019; Ding, Kim and Orey, 2020). This is due to the freedom of choosing the time and extent of interaction with other students and the ability to adjust the speed of learning and self-reflection (Hewitt, 2005; Huang *et al.*, 2019).

However, a range of researchers mentions that the positive outcomes of using online discussion forums largely depend on the level of engagement and motivation of the students (Tsai *et al.*, 2018; Ding, Kim and Orey, 2020). Hewitt (2005) explored the dynamics behind the growth and death of forum threads. Among the reasons for thread death were exhaustion of the discussion, a high degree of confrontation, loss of interest, lack of moderation, and use of 'clunkers' (phrases such as 'I agree' that prevent further elaboration on the topic).

There are multiple ways of how engagement challenges have been addressed in education literature. Following the principles of self-determination theory, Ding et al. (Ding, Kim and Orey, 2020) focus on the motivational drivers of the students such as the need for clear expectations and free expression along with the need for a sense of competence and relatedness. In an earlier study, Ding et al. (Ding, Er and Orey, 2018) explored the use of gamification in the context of online education and concluded that it worked efficiently in increasing the number of comments and performance but did not contribute to the sense of community. Overall, online education has been significantly exposed to game design use. Hansch et al. (Hansch, Newman and Schildhauer, 2015) reviewed gamification use at MOOC platforms and summarized the most commonly used game mechanics (badges & certificates, levels & goals, unlock content, progress bar and so forth) and social elements (peer-to-peer grading, profile, followers and so forth). As for non-gamified solutions, Rovai (Rovai, 2007) suggested a set of principles for the design and facilitation of online discussions such as grading that encourages participation, setting clear rules, promoting the feeling of social presence, creating space for informal communication for building the sense of community and others.

There are also a few examples of using online discussion forums for learning in informal settings, for example, helping a group of stakeholders to initiate a discussion about some problem (and improve their learning about the problem), collecting opinions of citizens, building joint actions of a community, or expanding citizen science. Bista et al. (2012) described the case of creating an online community to discuss and facilitate the acceptance of a legislative change on welfare payments among citizens. All the three challenges for organizing such an online interaction were associated with engagement: how to attract new members and motivate them to participate, how to monitor activities and how to sustain long-term engagement. In the context of citizen science, the engagement challenge is also a significant one for involving citizens' skills and time into research tasks that could be initially perceived as tiresome (Ponti, Hillman and Stankovic, 2015). In both examples, gamification has been used as a tool to increase engagement. Points and badges introduced to the online community appeared to be a useful tool to monitor engagement (S. K. Bista *et al.*, 2012). The outcome of using gamified features in citizen science projects is more controversial since playful experiences might be misinterpreted by the participants and make them perceive real scientific work as unserious (Ponti, Hillman and Stankovic, 2015).

The above-mentioned literature on using gamification to improve engagement in online discussions suggests that this approach can be useful. However, the suggested gamified interventions for formal education

are not fully compatible with the context of discussions on serious topics with a group of stakeholders. For example, Ding et al. (Ding, Kim and Orey, 2020) discussed higher effectiveness of skill-related badges (the more skills acquired, the quicker a person progresses with receiving badges) as opposed to participatory badges (the more tasks completed, the quicker a person progresses with receiving badges). In online discussions there is no explicit goal to teach the participants, it is rather an intention to build an environment where they can get to a shared understanding of the problem while learning the perspectives of each other. Therefore, skill-based points or badges will unlikely work. At the same time, using participatory badges is also tricky because they promote active posting of comments without any attention to their quality, and in case of serious discussions quality of ideas is an important factor of the overall effectiveness. Several other suggested solutions such as the higher presence of a moderator support (Rovai, 2007) and points (S. K. Bista *et al.*, 2012) should be considered with caution since they might prevent free expression of opinions (if a moderator guides a discussion more tightly) and create undesired group dynamics (for example, if the most active participants in the forum get even more opportunities to express their opinions through the benefits of having particular badges). Both of these risks are undesirable in the context of organizing deliberative discussions with stakeholders because of its overall focus on equality in participation and democratization of decision-making. Hence, in our research, we elaborate further on existing solutions for increasing engagement in online discussion forums such as Discussoo.

3. INTRODUCTION TO DISCUSSOO PLATFORM

We can rely on some of the existing experience from the educational and gaming domains mentioned earlier, if we are to move a part or even the whole PM workshop process to the Internet, offering stakeholders an easy and asynchronous way to learn from each other and express their opinions about the problem at stake.

One could also refer to the existing online platforms (like Facebook or Twitter) to mimic some parts of the discussions that are normally occurring during the PM workshops. However, there are several limitations associated with such social media platforms: (1) limited access to the information collected in the comments, which makes it hard to process the comments and extract any knowledge from them; (2) absence of a facilitator who could guide the discussion; (3) absence of the functionality of translating discussions into more formal models (qualitative or quantitative). These considerations and challenges convinced us that instead of relying on existing platforms, we should develop a designated online tool, Discussoo, that can be deployed in the PM process (*Figure 1 (1)*) (Anjum *et al.*, 2021). This tool provides a platform for stakeholders where they can share their opinions by submitting comments. The recorded comments are immediately processed, and with help of artificial intelligence (AI) algorithms, information is extracted from available texts to generate on the fly the conceptual model (mind map), which can be instantly fed back into the discussion for stakeholder checking and validation. As with all AI methods, they require training and learning to improve their performance. It might take some time for us to make sure that the methods that are being used always produce meaningful and useful conceptual models automatically or in real-time. At this stage we also allow the moderator to play a role in validating and improving the conceptual model.

While involving multiple stakeholders in a discussion provides an opportunity for groups and organizations to improve the quality of their decisions, they inevitably face a new set of challenges about engaging people and managing conversations. Overall, people are time-poor and overloaded with information and it's difficult to sustain a high level of participation, especially if the topic of discussion is not a top priority for a particular group of stakeholders. The anticipated challenges can be the following:

(1) *Retention of stakeholders at the platform.* A better understanding of the problem is happening where the opinions are shared and discussed. Additionally, the output of AI algorithms (the conceptual model) will be more accurate if there is enough data to analyze. Therefore, there is a need to create mechanisms that motivate participants to come back to the platform and keep on participating in the discussion.

(2) *Too many comments that need to be read by the participants.* Since Discussoo is targeting serious discussions on complex problems, it's likely that comments of the participants will be long explaining the reasoning behind opinions. In addition to that, considering that there is no limitation on the number of participants, the quantity of comments can also be significant. Hence, there is a need to avoid single-pass practices when a participant scans all the new comments (Hewitt, 2005). On the contrary, the process should provoke the participants to read, understand and respond to the comments of others

(either elaborating on the opinions that they agree with or arguing about the opinions that are opposite to their own).

(3) *No feeling of community or social presence*. Asynchronous discussions and the anonymity of users provide very different experiences in terms of human-like connections as compared to face-to-face traditional workshops with stakeholders. However, most complex problems require joint actions to be solved, all these require trust and a sense of community. Although it's hard to claim that such online discussion tools can substitute actual participation in decision-making, still a certain level of community support would be desired and can be a motivational driver for extended conversations and debates on the platform. A range of researchers suggests that a feeling of community helps to sustain engagement in online discussions (Hansch, Newman and Schildhauer, 2015; Ding, Kim and Orey, 2020).

(4) *Validating the concepts extracted by AI algorithms for improving the conceptual model (mind map).* As mentioned earlier, at the initial stage of using algorithms there is a need for additional validation of the extracted concepts by the participants. If this task of sorting concepts into valid or invalid is suggested in a straightforward way, it could be perceived as a tiresome and uninteresting activity for the participants. Therefore, there is a need to make this process of concepts validation more entertaining but still meaningful.

4. GAMIFICATION OF DISCUSSOO PLATFORM

Considering the existing research about the positive effects of gamification on engagement, motivation, and enjoyment of a process (e.g., Sailer *et al.*, 2017; Sailer and Homner, 2019; Bakhanova *et al.*, 2020), we suggest incorporating gamified features into Discussoo platform with aim of solving the above-mentioned engagement challenges.

Retention of stakeholders at the platform. Often the challenge with user retention in online discussions is solved by using email notifications. In the case of Discussoo, there are four types of notifications that consider the context of several possible scenarios:

1. If you reply to a user comment, you get an email notification with a suggestion for action (e.g., 'Hey, others are commenting on your opinion. Have a look and let us know what you think!').
2. If several other participants rate your comment at 7 scores or above, then you get an email notification with a suggestion for action ('Hey, your comment is trending! Look at what those people who liked your comment think!').
3. If no one replies/rates your comment, you get an email notification pointing to someone else's idea ('Hey! There are some like-minded people in the discussion. Check out what their arguments are!').
4. If you do not come back to the platform for 5 days in a row, you get an email notification with a reference to someone else's comment and a suggestion to give feedback (e.g., 'Peter XX said 'Citation of comment'. Do you agree?')

Some of the notifications build on "satisfaction of the need for relatedness", others on the "need for competence" as per definitions from self-determination theory (Ryan and Deci, 2000).

Too many comments that need to be read by the participants. With the passage of time, the number of comments about particular topics will become larger. Since the participants are usually time-poor, they will hardly be willing to go through all the available comments. But one of the main purposes of using such a platform is to provide the stakeholders with an environment where they can learn about the opinions of others and debate in a constructive way, which could be hardly achieved if many of the comments are neglected. A chatbot is introduced into the platform functionality to solve this challenge (*Figure 1(2)*). The chatbot suggests the participants to read a relevant comment from any other participant. Then it encourages the participant to rate or respond to the suggested comment. Additionally, when the comment of a user is too short, the chatbot asks to elaborate more on the idea. The rationale behind it is to keep the conversation going and to get more detailed responses that could be better processed by AI algorithms. With the introduction of this chatbot into the discussion, we aim at satisfying the need for competence through giving the participants a chance to take the challenge of responding to a comment that is contradicting their opinion about the discussed topic.

No feeling of community or social presence. A system of points and badges is introduced in the platform (*Figure 1 (3)*). The higher and more a participant's comments are scored by others in the community, the more points s/he gets and, hence, progresses through three levels of 'Influencer' badges (beginner - mid-level - pro).

Here we target the need for relatedness (Ryan and Deci, 2000) and direct encouragement from the peers that motivates users to keep on participating in the discussion.

Validating the concepts extracted by AI algorithms for improving the mind map. This challenge is about converting the tiresome task of sorting the concepts into a more entertaining one. This task can be implemented in a form of a mini-game similar to the classical 'bubble shooter' game (*Figure 1(4)*). In the game concepts extracted earlier from the comments are suggested one-by-one to the users. To keep a concept, they need to throw a blue bubble at it; to discard a concept they throw a red bubble. The game continues till all the irrelevant concepts are removed. Following the principles of self-determination theory, this game targets the satisfaction of the need for autonomy. On the one hand, the user can independently decide whether to keep or discard a bubble with a concept. On the other hand, the task is still challenging since one gets most of the points if hits a larger number of bubbles (similar to the standard 'bubble shooter' game).

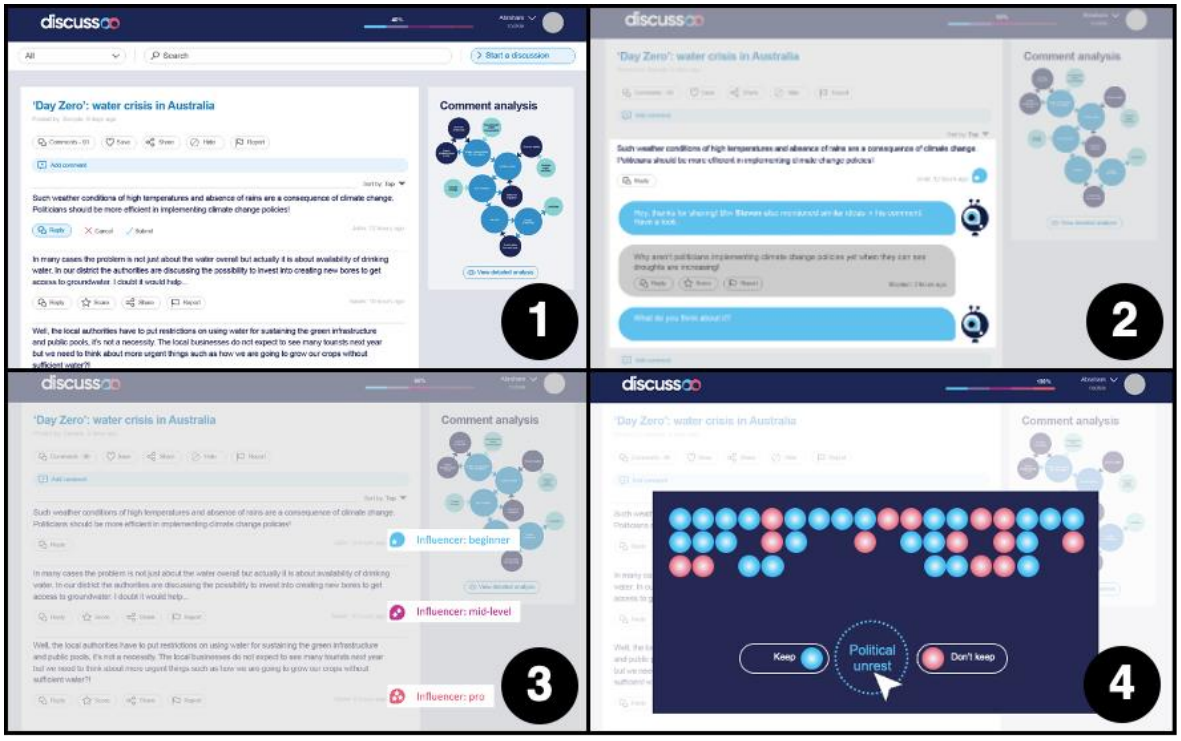

Figure 1. Discussoo platform: (1) standard discussion view, (2) chatbot for keeping conversations going, (3) 'Influencer' badges, (4) 'Concept shooter' game for validating the concepts for the model.

5. METHOD

The proposed gamified features were incorporated into the Discussoo platform (Discussoo, 2020). The 'concept shooter' game and the chatbot are optional features that can be switched on once the discussion organizer sets up the topic. Notifications and 'influencer' badges are by default operating for every discussion on the platform. Once the newly registered user enters Discussoo, they are suggested to go through brief introductory slides explaining the functionality of the platform including gamified features.

We conducted a pilot study to collect feedback on the usability of the platform and the overall idea of using Discussoo in the context of stakeholder engagement. There were two target audiences: those who organize such serious discussions with stakeholders (i.e., PM practitioners) and those who directly interact with the platform (i.e., stakeholders).

As for the first group, we conducted interviews with four experts in the field of PM, social sciences, and environmental engineering who actively involve stakeholders in their research. Experts represent not only

different scientific fields but also diverse geographies (Australia, India, Finland, and the USA). During the interview, we demonstrated the main features of the Discussoo platform as per descriptions in Sections 3 and 4 of this paper. The aim of the interviews was to understand what could be perceived as *successful* stakeholder engagement and to collect initial feedback on the idea of Discussoo and its implementation.

As for the second group, we conducted an experiment with 57 university students who were suggested to contribute to a discussion on learning in COVID time. They were given one week to participate in the discussion, after that they were asked to fill in a post-test questionnaire. It included questions associated with usability and level of engagement when interacting on the platform. There were eight statements to be assessed on the Likert scale; some statements referred to overall engagement during the online discussion (e.g., 'I felt like time went by quickly while I was active at the platform'), other questions were associated with specific gamified features (e.g., 'Interaction with the chatbot was interesting'). The questionnaire also included open-ended questions where the respondents could share what they liked and disliked in the Discussoo platform.

6. RESULTS

The interviews with the PM practitioners have shown two main positions related to the criteria of success in stakeholder engagement. One is focusing on the process of involvement itself and the fact that it should be intensive as well as flexible. Another position is associated with results that such engagement brings; the results could be concrete such as collaborative learning and acknowledgment of the perspectives of others or more generic such as whether the process served the initial stakeholders' needs whatever they were. As for the feedback on the functionality of Discussoo platform, there were two categories of questions: first is about the benefits and applicability of this tool; second is about drawbacks and potential challenges of its use. The experts mentioned several ways of applications of this tool: (1) for collecting perspectives/opinions of stakeholders at the early stages of the project, (2) for avoiding the bias of a facilitator (which is one of the possible risks of face-to-face workshops with stakeholders) and collecting direct responses from the participants. A few experts mentioned that the use of Discussoo should have a clear goal as well as it could be combined with other approaches and tools. As for the benefits, all the respondents agree that the current functionality of Discussoo platform can serve well the purpose of involving a large number of participants in a discussion about some problem as well as facilitate the process of knowledge elicitation. The attractive and user-friendly interface of the platform was mentioned as one of the plus points. The experts also mentioned several drawbacks or challenges associated with the use of such a tool for stakeholder engagement. Among them could be mentioned the following: (1) conceptual models that Discussoo generates with help of AI algorithms can capture only those ideas that are on the surface while for a deeper understanding of the problem other, qualitative methods, could be of more use, (2) the use of AI-algorithms could be misinterpreted by the participants of discussion as if there is lack of control over the content that is visualized in the final outcome, mind map, (3) typing comments is a slow process that is a limitation, (4) emotions associated with opinions are not captured while it could be useful if the topic is of high importance or sensitive, (5) there is an 'ambiguity related to the language' which is about the fact that the same word/concept might have a different meaning for different people while AI-algorithms so far are not able to differentiate or clear out this issue.

The results of the experiment appeared to be overall positive: all of the statements from the post-test questionnaire were scored above three on a Likert scale where one is 'Strongly Disagree' and five is 'Strongly Agree' (*Figure 2*). The interaction with the platform got an average score of 3.88 (S1). The participants enjoyed scoring the comments of others (S7) and interacting with the chatbot (S5 and S6) more as compared to other features of the platform. Interestingly, female participants on average were less satisfied with the features of the platform; this could be observed from the responses on the statements S3, S4, S5, and S8 which correspond with such features as notifications, chatbot, and badges. The participants seem to be enjoying the possibility to score the comments of others (S7), but they enjoy much less when someone scored their comments (S8). This tendency can be also seen in the responses to the question 'What did you like the most about Discussoo?'. There were multiple responses appreciating the possibility to rate the comments. However, there were also several responses where the respondents did not appreciate the rating system and badges (i.e., rating someone's *personal* view did not seem exciting for some participants).

Among other positive aspects could be mentioned the possibility of getting the views of others, new perspectives, and seeing alike ideas; while the negative comments from the respondents included repetition of

ideas and the need to scroll through long threads. Although these comments were not common, still, it tells us that most likely the participants could not take advantage of the mind map developed by AI. One of the initial ideas was that a user can get a general idea about the discussion just by looking at the mind map and with no need to read all the comments. This could become one of the aspects for further improvement in terms of visibility and interaction with the mind map, so that the participants could take the most out of it.

Another aspect for further improvement is retention of users at the platform. As we can see from *Figure 5* (S4), statement S4 'I returned to the platform several times' received the lowest average score among all the other statements.

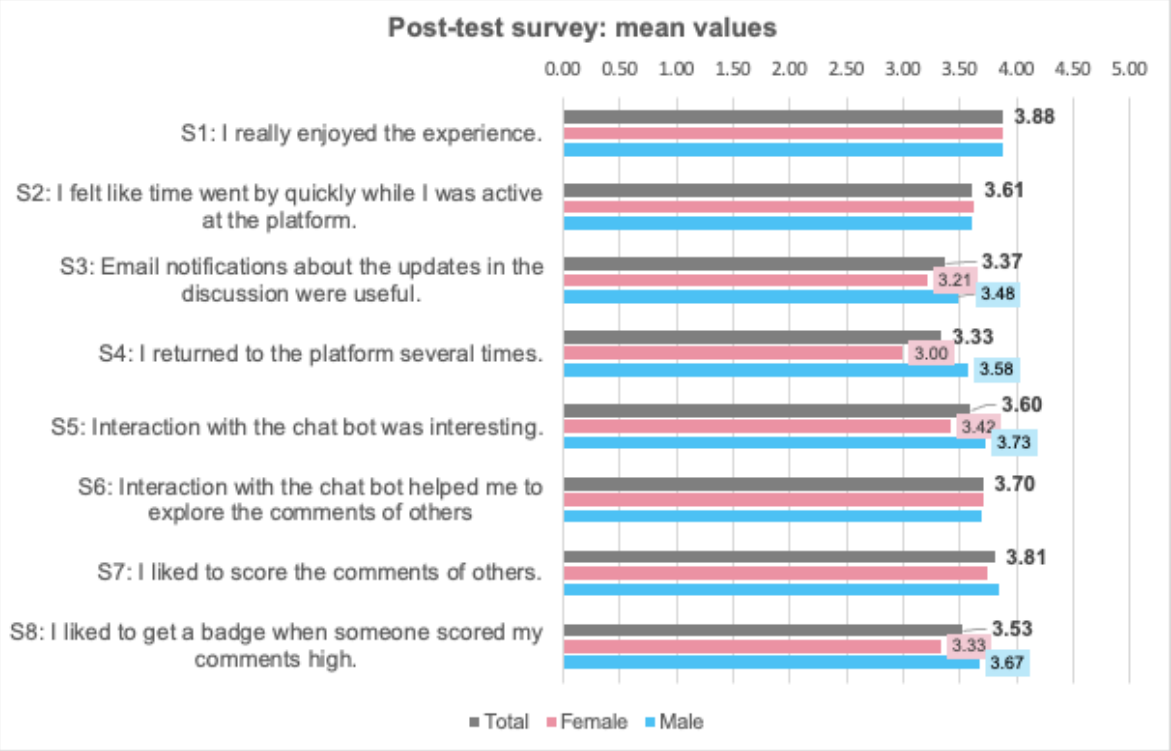

Figure 2. Results of the brief post-test survey: mean values for engagement-related statements

7. CONCLUSION

Game design offers a variety of possible applications for addressing the engagement challenges of asynchronous online discussions. The proposed gamified features for the Discussoo platform cover the most urgent challenges that are anticipated in the process of stakeholder involvement in serious discussions. In our pilot study, the respondents positively assessed the usability and gamified features of the Discussoo platform. Still, we could not achieve high scores for the retention to the platform and, therefore, there is a window of opportunities to improve the design of Discussoo. In general, with help of this experiment, we could assess the implementation of suggested game concepts. However, one could think of other ways to design the visuals of the badges or chatbot, which, in turn, can influence the overall user experience. From the methodological perspective, we managed to collect insights on the usability and usefulness of the platform from multiple angles (from PM practitioners as organizers and stakeholders as direct users). The survey gave us a general understanding; however, we still lack detailed information about what exactly the users liked about each gamified feature and why. The next step could be more in-depth usability studies with help of post-test interviews. It could be also useful to explore the perception of different gamified features from cultural perspective. For example, scoring someone else's opinion in some cultures can be perceived as a norm, in others, it could be taken personally and lead to unnecessary tensions in the group discussion.

Overall, there are many other potential directions for gamifying the process of online discussions. One could think of creating a user experience that is similar to reality (for example, an online forum as a fully developed virtual world where participants can choose avatars, enter the 'virtual' meeting rooms on diverse topics, see and interact with more visually appealing mind maps of the discussed issues). Based on the feedback from interviews with experts, one could also consider adding features of audio commenting and transcribing or introducing emoji panels to better represent emotions and make the process of discussions more human-like.

ACKNOWLEDGEMENTS

The development of the prototype for the gamified version of the Discussoo platform has been done with the mentoring and financial support of the Techcelerator program of the Faculty of Engineering and IT at the University of Technology Sydney. The authors would like to thank the UTS Techcelerator team and experts who participated in the interviews for the evaluation of the Discussoo platform.

REFERENCES

Anjum, M. (2020) *Discussoo*. Available at: https://discussoo.com/ (Accessed: 2 May 2022).

Anjum, M. *et al.* (2021) 'Discussoo: Towards an intelligent tool for multi-scale participatory modeling', *Environmental Modelling & Software*, 140, p. 105044. doi:10.1016/j.envsoft.2021.105044.

Bakhanova, E. *et al.* (2020) 'Targeting social learning and engagement: What serious games and gamification can offer to participatory modeling', *Environmental Modelling & Software*, 134, p. 104846. doi:10.1016/j.envsoft.2020.104846.

Ding, L., Er, E. and Orey, M. (2018) 'An exploratory study of student engagement in gamified online discussions', *Computers & Education*, 120, pp. 213–226. doi:10.1016/j.compedu.2018.02.007.

Ding, L., Kim, C. and Orey, M. (2020) 'Design of gamified asynchronous online discussions', *Technology, Pedagogy and Education*, pp. 1–17. doi:10.1080/1475939X.2020.1801495.

Hansch, A., Newman, C. and Schildhauer, T. (2015) 'Fostering Engagement with Gamification: Review of Current Practices on Online Learning Platforms', *SSRN Electronic Journal* [Preprint]. doi:10.2139/ssrn.2694736.

Hewitt, J. (2005) 'Toward an Understanding of How Threads Die in Asynchronous Computer Conferences', *Journal of the Learning Sciences*, 14(4), pp. 567–589. doi:10.1207/s15327809jls1404_4.

Huang, B. *et al.* (2019) 'Effects of gamification on students' online interactive patterns and peer-feedback', *Distance Education*, 40(3), pp. 350–379. doi:10.1080/01587919.2019.1632168.

Jordan, R. *et al.* (2018) 'Twelve Questions for the Participatory Modeling Community', *Earth's Future* [Preprint]. doi:10.1029/2018EF000841.

Ponti, M., Hillman, T. and Stankovic, I. (2015) 'Science and Gamification: The Odd Couple?', in *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play - CHI PLAY '15. the 2015 Annual Symposium*, London, United Kingdom: ACM Press, pp. 679–684. doi:10.1145/2793107.2810293.

Rovai, A.P. (2007) 'Facilitating online discussions effectively', *The Internet and Higher Education*, 10(1), pp. 77–88. doi:10.1016/j.iheduc.2006.10.001.

Ryan, R.M. and Deci, E.L. (2000) 'Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.', *American Psychologist*, 55(1), pp. 68–78. doi:10.1037/0003-066X.55.1.68.

S. K. Bista *et al.* (2012) 'Using gamification in an online community', in *8th International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom). 8th International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom)*, pp. 611–618.

Sailer, M. *et al.* (2017) 'How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction', *Computers in Human Behavior* [Preprint]. doi:10.1016/j.chb.2016.12.033.

Sailer, M. and Homner, L. (2019) 'The Gamification of Learning: a Meta-analysis', *Educational Psychology Review* [Preprint]. doi:10.1007/s10648-019-09498-w.

Tsai, Y. *et al.* (2018) 'The effects of metacognition on online learning interest and continuance to learn with MOOCs', *Computers & Education*, 121, pp. 18–29. doi:10.1016/j.compedu.2018.02.011.

Van den Belt, M. (2004) *Mediated modeling: a system dynamics approach to environmental consensus building*. Washington, DC: Island press.

Voinov, A. *et al.* (2016) 'Modelling with stakeholders - Next generation', *Environmental Modelling and Software* [Preprint]. doi:10.1016/j.envsoft.2015.11.016.