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*In the name of Allah,
the Most Beneficent,
the Most Merciful*

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Title:

Scientific Hangman: A Framework to Gamify Scientific Evidence for the
General Public

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Abstract

Governmental and private funding for research in many fields has resulted in a significant body of scientific evidence. Scientific evidence is made available in the form of thousands of peer-reviewed articles in online digital libraries. This evidence is principally used by researchers, students and on occasions for eventual societal impact such as commercial exploitation and popular science communication. How can we engage the general public in understanding scientific evidence while assuring the provenance from a reliable source? Based on the principles of *gamification* this thesis addresses the question using a web and mobile framework called Scientific Hangman. Scientific Hangman creates a direct link between scientists and the general public. It contains a web administration tool for scientists to create puzzles and a mobile game based on the traditional game of hangman for general public, adolescents for example, to solve the puzzles in a fun manner. The puzzles in our game are created by researchers through the web administration tool based on their research and an active link to the publication is mandatorily made part of the clue. Players play the game in an attempt to guess a word given a clue that is simple and informative at the same time. We evaluated our first prototype on a focus group at the Cancer Registry of Norway by communicating information from invitation letters for cervical cancer screening. Based on the feedback from focus group we improved the game in design, user experience and interface and added gamification elements to make it fun for the player. We evaluated the improved version to test its perceived ease of use, enjoyment and usefulness by employing the Technology Acceptance Model (TAM). Our results from evaluation of gamified mobile app shows 79.9% and 59.9% agreement on usefulness and enjoyment respectively. However, it shows low agreement of only 42.8% on ease of use feature. On the other hand, evaluation of web administration tool on ease of use and usefulness shows agreement of 82.9% and 80% respectively. We discuss results and also provide a future direction for forthcoming research in gamification of scientific evidence.

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1. INTRODUCTION

In May, 2014 Google scholar articles were estimated to reach 160 million [1]. This has happened as a result of rise of the Internet which allowed scientists to collaborate on a global scale and publicize their research results rapidly [2]. European Research Council (ERC), via the Horizon 2020 program, is financing projects worth almost €80 billion over the next 7 years (2014 - 2020). The purpose of such a program is to create ground for scientific research, to tackle societal challenges and to help scientific ideas fly to market¹. As a result of this kind of funding in research and innovation a significant amount of scientific evidence is being produced in the form of scientific articles and publications. This production has also popularized scientific evidence as it is regularly reported on websites and magazines such as ScienceAlert² and frequently distributed through social media such as Facebook³. There exist similar (popular) science websites with social media presence having millions of likes and thousands of active users commenting, liking and sharing science posts. These science posts on social media is a way of increasing user base and generating traffic to the respective website where they present a summary of the actual scientific article. The summarized content often takes the form of a blog post sometimes with images or videos but could benefit from strategies to generate challenge and engagement for the reader. This form of science communication also lacks strategies to improve long-term retention such as repeated testing [3]. In this thesis, we plug-in puzzle based engagement on scientific evidence to challenge the readers, make it interactive and test the understanding of scientific content using the game of Scientific Hangman(SH). Scientific Hangman uses the well-known framework of the word guessing game Hangman to present scientific evidence as a game of solving a mystery one puzzle at a time where the clues lie in a scientific article itself.

The research in this thesis aims to develop and evaluate SH to address the following research questions:

¹ <http://ec.europa.eu/programmes/horizon2020/en>

² <http://www.sciencealert.com/>

³ <https://www.facebook.com/ScienceAlert/>

RQ 1: How can scientific evidence be simplified, gamified and communicated to general public?

RQ 2: Can a communication channel between researchers and general public be useful and fun?

We address **RQ 1** by developing a framework, **Scientific Hangman** (SH) that has 2 parts: *i*) a **gamified mobile application**, Figure 1, which maps scientific content to a puzzle by leveraging the concept of the traditional hangman and uses gamification elements for engagement. Figure 1a shows the game play screen with an active puzzle question which reader must guess or find the answer by reading the clue, Figure 1b,

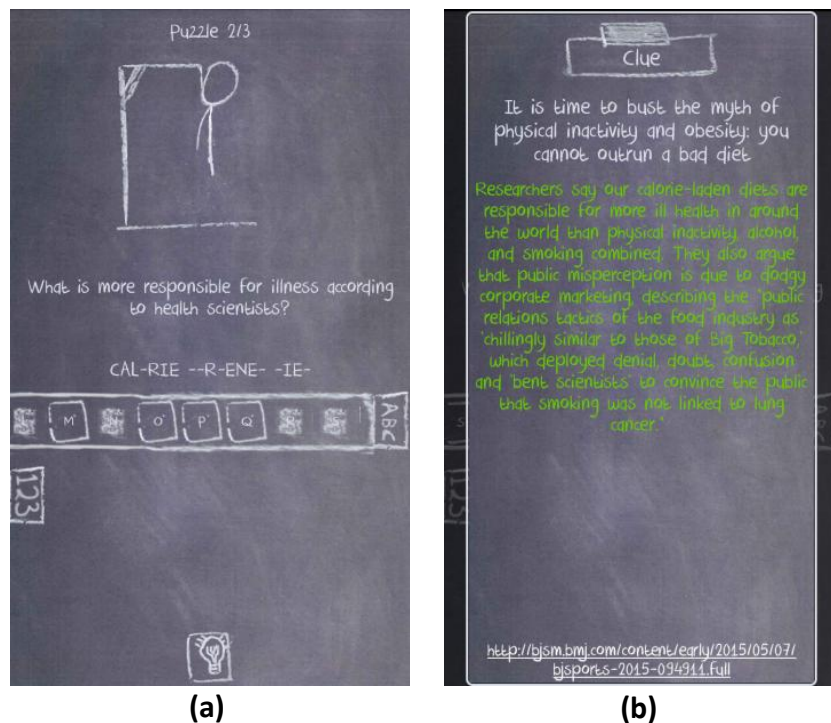


Figure 1. Puzzle with a question and clue

and *ii*) a **web administration tool**, Figure 2, for **researchers** to contribute game content to be used in the mobile app. The web administration tool allows researchers or teachers to create puzzle based on a scientific article (or summarized article from ScienceAlert, for example) by adding 1 - 3 questions and giving appropriate clues, Figure 2a. It also lets a researcher to group these puzzles into studies, Figure 2b, and evaluate a study on potential participants and view their response in the web administration tool.

Hangman Home **Create a Puzzle** Create a Study Logout Scientific Hangman by Waqas Moazzam

Create game content

Paper Name

Paper URL

Puzzle Pic/Video

Puzzle Insight
0/150

Puzzle Question

Puzzle Answer [Click to add more questions](#)

Puzzle Clue
0/500

Get suggestions from a summarization tool [Create](#)

(a)

Hangman Home **Create a Puzzle** **Create a Study** Logout Scientific Hangman by Waqas Moazzam

Create a study - A code will be generated which you can provide to your audience

Study Name

Study Description
0/300

[Create](#)

Puzzle Name	Action
<input type="checkbox"/> COMPUTERS AND HEALTH--INDIVIDUAL AND INSTITUTIONAL PROTECTIVE MEASURES	Detail
<input type="checkbox"/> Informasjon til kvinnen som legen skal gi ut	Detail
<input type="checkbox"/> Din celleprøve vil bli testet for HPV	Detail
<input type="checkbox"/> Science of Dogs	Detail
<input type="checkbox"/> Negativt svarbrev med reservasjon på baksiden - etter fokusgruppeintervju	Detail
<input type="checkbox"/> Carcinogenicity of consumption of red and processed meat	Detail

(b)

Figure 2. Web console to create puzzles and studies

We address **RQ 2** by evaluating the benefits of this framework using (a) A Focus Group Discussion on its effectiveness to communicate information about HPV-related cancers to women between 25-69, and (b) A Technology Acceptance Model (TAM) proposed in 1992 by Davis et al., in [4] to evaluate perceived ease of use, enjoyment and usefulness of the mobile game and an earlier version of TAM proposed in 1989 by Davis in [5] to evaluate perceived ease of use and usefulness of Scientific Hangman web console.

The results show that mobile application was received positively by participants in Focus Group Discussion at Cancer Registry of Norway. The responses on the constructs based on TAM showed the information consumption through the game to be enjoyable and useful with agreement of **59.9%** and **79.9%** respectively. However, it lacked good response on the ease of use of the mobile application due to some navigational flow issues resulting in agreement of only 42.8%. On the other hand, **82.9%** researchers in the web console study agreed on its ease of use and **80%** agreed on the usefulness of it. However, web console study population was small having researchers from few domains only. To have more fine grained results on TAM constructs large study is required.

The idea of using gamification to share scientific evidence will hopefully equip people with scientific knowledge and a thinking process that could help them make better and evidence-driven decisions. Addressing RQ 1 is challenging because communication of scientific evidence to general public faces a number of obstacles such as (a) high-specificity of research articles (b) articles consider a relatively small community of researchers as audience. This makes scientific research very hard to communicate, sometimes even among researchers⁴ in other disciplines. A contrasting example would be multimedia content such as music or videos that are consumed quite easily by people through user-friendly services such as Spotify and YouTube. Furthermore, scientific innovation is affecting almost every part of our lives very rapidly. However, the underlying scientific advances leading to the innovation is communicated relatively slowly. It is very easy for a youngster to use an iPad, for example, being unaware of the scientific achievements behind that led to its construction. Our knowledge is shielded from complexities by the black-box services that are part of our daily lives. More work is required on creating information systems that uses hedonic motivations to trigger interest for science in individuals. The Scientific Hangman framework is one such effort to communicate scientific evidence to keep people curious and up to date about the scientific content being produced at a high velocity which has been recognized as a vital need [1].

In the rest of this chapter we present how SH evolved in Section 1.1. We present challenges faced by SH in Section 1.2 and finally the outline of the thesis is described in Section 1.3.

⁴ http://ec.europa.eu/research/science-society/pdf/communicating-science_en.pdf

1.1. Evolution of Scientific Hangman: A gamified mobile application

Scientific hangman (SH) is a mobile game to introduce gamification, using game elements in non-game context [6], to first generate curiosity in users for evidence followed by directly linking a user to a scientists real contribution. The concept and the use of SH evolved from a very narrow scope, communication of invitation letters for cancer screening, towards a broader scope of presenting content on all kinds of scientific evidence such as health and climate. We worked on the mobile app to enhance its use by adapting changes based on improvements that were identified through Focus Group Discussion and feedback from different users. The following text will give an overview of the gamified mobile application development.

Mobile game to use Cervical Cancer screening reminder letters in a gaming context

Initially the concept was in the context of Cancer Registry of Norway (CRN) to test and improve understanding of reminder letters by using them as content for the mobile game of hangman. The Norwegian Coordinated Cervical Cancer Screening Program (NCCSP) has sent reminder letters to women with overdue screening tests, or lacking recommended follow-up procedures since 1995 [7]. The purpose has been to invite women of age 25 - 69 for the screening. The statistics shows that the screening coverage has been improved as 80% of the targeted women regularly participate in screening and 65-70% of women with high abnormal results return within one year [8].

According to CRN annual report 2012 the reminder letters has been effective but there is still room for improvements in some areas [9]. The same report says, there are challenges as participation rates are deteriorating especially in the younger age groups [9]. These statistics provoked a need for testing the use of technology in combination with the reminder letters. We developed a simple mobile game with only the mechanics of traditional hangman game. We were provided with 3 reminder letters and 3 questions per letter with answers by CRN. The app enlisted the letters and upon selection it loaded the question/answer screen where user could answer by guessing or reading the clue, the reminder letter itself. This app was tested on a

focus group of 10 women at CRN. Figure 3 (a-d) shows different screens from the first version of the mobile app.

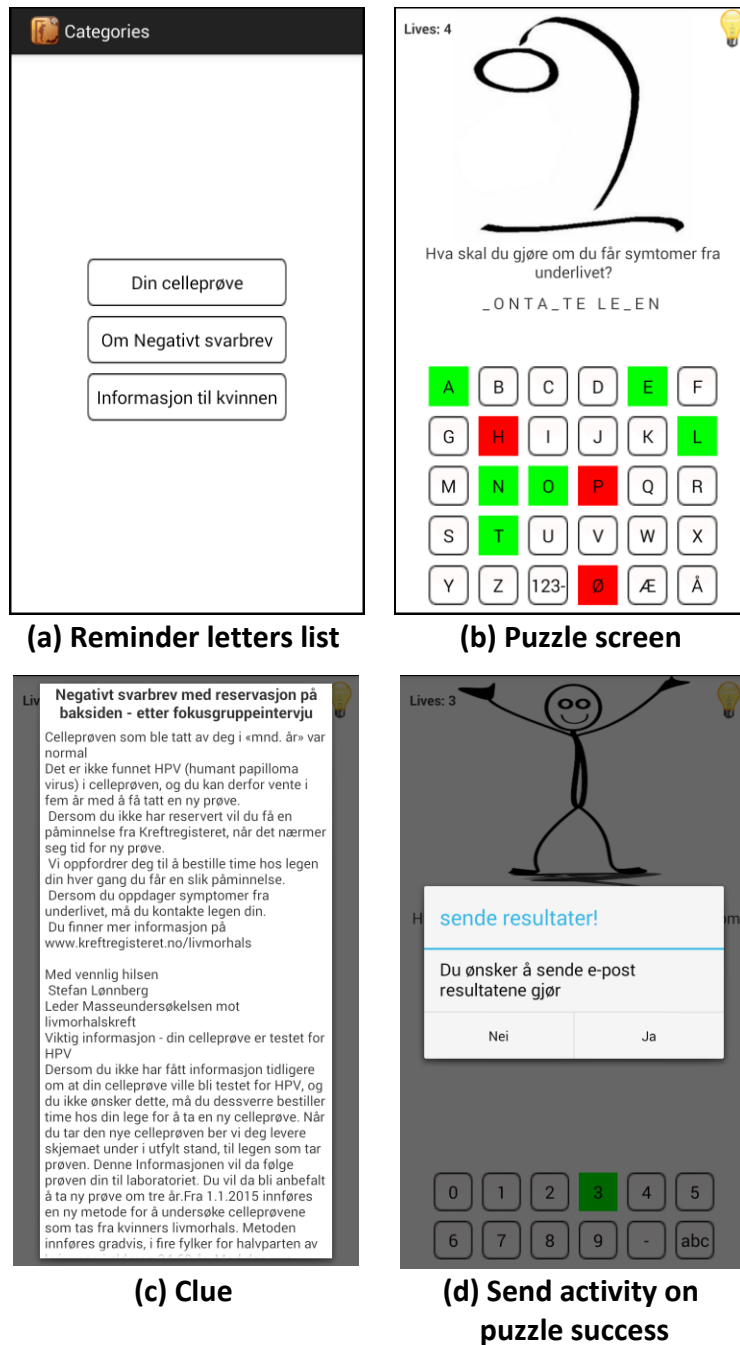


Figure 3. Prototype 1 tested at Cancer Registry of Norway

As Figure 3. show no game aesthetics other than just one stick man being drawn on the screen, many women were not attracted to the game due to the lack of natural gaming art work and it looked more like a simple rather lifeless app.

Hangman after incorporating the feedback from the focus group study

User interface is an important factor and plays a vital role in communicating with the end user [10]. Optimal user interface design and theme helps player to focus on the gaming tasks with greater attention. To improve it we worked on the design part to bring the gaming look of the app that would catch anyone's eye. As the concept of the framework is purely educational and to make user aware of scientific research in an educational context, we designed the art work with a traditional *blackboard chalk theme*. The new UI design resulted in a good feedback as it was very close to educational context and at the same time it was attractive for the players. In Figure 4 we show the next iteration over prototype 1 in terms of UI/UX.

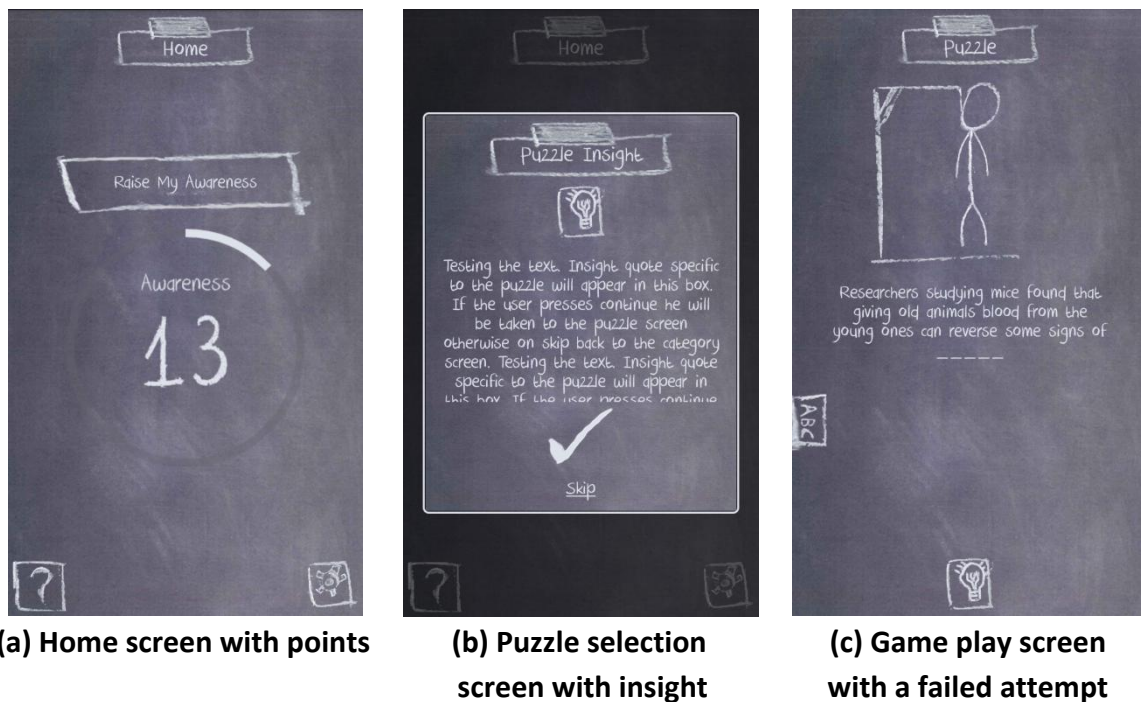


Figure 4. UI/UX iteration on prototype 1

Apart from changing the artwork a chalk themed typeface was used to give a natural handwriting look that is commonly seen on blackboards. Other than UI/UX changes we added some new game elements such as awareness points (Figure 4a) that user is rewarded upon successfully solving puzzles and an Insight quote text to motivate user to play a puzzle (Figure 4b) among several puzzles.

Scientific Hangman with content from a variety of scientific evidence

After working on improving the design for the end user we started to gather thoughts to enhance the game by including content from domains such as climate change and health. The choice of these domains is due to its relation to our daily lives. The important point here was to base all the content on peer-reviewed scientific publications. The sole purpose for this was to convey information that have peer-reviewed scientific evidence behind which can be read by the player if there is a curiosity. We refer to game content as 'puzzles'. The puzzles are comprised of a set of questions, their answers (hidden from the player in the game) and short clues to help the player guess or find the answer. Every puzzle can have at least 1 and at most 3 questions with answers and clues. In the first case we evaluated with CRN where the game content was hard coded in the application. To include more scientific domains and a variety of game content arose a need of having a web console, an administration tool. A medium where researchers or authors can create game content based on their own research and background scientific knowledge. Therefore, in the second version Scientific Hangman is divided into 2 parts, 1) mobile game for the end users to solve puzzles by reading information from the research, and 2) web app for researchers to contribute research based content for the game and extend their work to enhance awareness in society. SH also contains a scoring system and leaderboard to create a sense of competition between players. To create engagement we ask players for feedback about how much the game content is useful and informative. It gives them the sense of being an integral part and not merely a subject and creates their connection with content designers [11]. We will discuss the complete details of what Scientific Hangman is now and what features it holds both in the mobile game and the web console in Chapter 3 of this manuscript.

1.2. Challenges in Developing Scientific Hangman

When designing and developing a software system, to serve a research purpose, on a large scale and in favor of science education, we encountered several challenges. Out of all the challenges, we will mention the three most significant challenges that were crucial to the success of the application.

1.2.1. User's motivation

The scientific information based puzzles in Scientific Hangman can be beneficial if consumed by users over a long period with consistency. This would serve the purpose of pitching science education and user's interest through science based puzzles. It will also help in setting user in the direction of latest research publications, if user wills. However to make this happen, in schools, controlled studies spanning over a small time can be conducted on daily basis or 2-3 times a week. But to achieve greater results, user should be motivated to regularly come back on their own. It is quite easy to imagine that after solving a few puzzles of different difficulty levels from a wide range of scientific domains user would lose his way back to the game. It will stop the pitch that we want to initiate and see growth. This could be a result of poor engagement between user and the game. We want to increase the reading engagement through the game and it demands to set means of motivation [12].

Solution: Solving this issue requires elements of gamification. Gamification is a technique of including game elements in a non-game context for purposes other than just pure entertainment [13]. Every player get scores to solve puzzles. These scores are determined based on different actions such as reading the clue, visiting the research article to read further, successfully solving the puzzle and providing feedback. Two users on the same puzzle might perform differently hence getting different scores. To extend the use of scoring system, we used the concept of leaderboard to show a list of top users. This prompts user to perform better to not only become the top user but to also make efforts to maintain that position. This also ignites the sense of competition among users. There is also a social platform element which can be used to share user's high performance on Facebook, for example.

1.2.2. Making it easy for the users

Feeling the *ease of use* is an important challenge while playing the game. The ease of use can be evaluated in terms of overall time spent, selection of a puzzle and understanding. The time that user would spend in the game solving a puzzle should not be very high as this could drive the user away. The puzzles in Scientific Hangman are supposed to pass on interesting scientific

findings in an entertaining way and not to consume a lot of user's time on one puzzle. Also, there are chances of puzzles being ignored by the user during the puzzle selection process.

Solution: Consuming user's least time in order to view and select one puzzle out of many, the actions to go to the puzzle screen were kept only one tap away. A play button is given right on the home screen which shows user the list of puzzles to select from. As the goal is to pass on information, a notion of 'insight' was introduced, insight is a short piece of information from the underlying research publication that shows up to the user during the selection process. This was done to attract user's attention to the underlying puzzle and the research it is linked to. Furthermore, even if the user decides to ignore the puzzle, the insight should be designed in a way that it still passes at least some information. To make the selection process more exciting different statistics are displayed along with insight of a puzzle, such as, number of up/down votes and number of people who have solved this puzzle. These stats also motivate user to take on the challenge.

1.2.3. User Interface and Experience within the Game

The look and feel of the system should serve the underlying purpose of the system. It should contribute towards the goal of user engagement. Only employing gamification elements in an app and call it a game does not bring game aesthetics in it. The look and feel and artwork of the gamified application should comply to gaming standards to make it interesting for the user interacting with it.

Solution: We introduce a *natural look and feel* of the game to make it interesting for the users. As the idea revolves around educating the user, we brought in the sense of being in a classroom and the traditional blackboard and chalk theme. We designed elements of the artwork by drawing them with chalk on a black piece of paper, later scanning the black paper and slicing the elements through Photoshop. Using these kind of elements gave a very rough and natural look to the game hence contributing towards the learning goal of the game. The figures showing the user interface of Scientific Hangman can be seen in Chapter 3 of this manuscript.

1.3. Organization of the thesis

This thesis contains 5 chapters including introduction. The content of the next four Chapters is organized in the following way:

- **Chapter 2: Background and State of the Art**
In this chapter, we analyze the current state of research in the key concepts of the context of this thesis such as education and gamification.
- **Chapter 3: Scientific Hangman**
In this chapter, we describe Scientific Hangman as a science education framework. We list the requirements, explain the architecture and implementation showcasing the current state of Scientific Hangman both the mobile app and web administration console.
- **Chapter 4: Preliminary Evaluation of Scientific Hangman**
In this chapter, we present the results of the focus group study at Cancer Registry of Norway and the responses collected by employing Technology Acceptance Model.
- **Chapter 5: Future Work and Summary**
In this chapter, we discuss the potential enhancements for further development of Scientific Hangman and summarize the work done in the thesis.

2. Background and State of the Art

This chapter presents some background information on science communication in Section 2.1, talks about motivation behind this work in Section 2.2, explains gamification with examples in Section 2.3, analyses results of a systematic mapping on gamification applied to education [14] in Section 2.4 and mentions different technology acceptance models for evaluation in Section 2.5.

2.1. Background

Online science communication is gaining wide spread popularity. it is being done through science websites, magazines and through social media such as Facebook and Twitter. This approach allows the general public to easily read and spread the knowledge with others. The articles in magazines and social media are written in a form of an essay containing hundreds of words. These articles also do not come directly from the scientists who conducted the underlying research. When on social media, authors often use a video or an image as supportive material to explain the article. This kind of essay demands users to spend good amount of time and requires special interest to completely read it. These hidden demands are the reason of low number of likes, comments and shares on ScienceAlert Facebook posts despite having approximately 7.7 million users. Average of Few thousand likes and few hundred of comments and shares are considered low when compared to the number of page members i.e. more than 7 million. These activities (likes, comments, share) are of important value in the context of gamification as explained in Section 2.3.1. This activity also depends on the level of interest a person has in science. One culprit here is the approach of presenting information which lacks interaction and engagement to motivate the user irrespective of the user's background.

A report [15], "Public Attitude to Science", published in 2014 highlighted interesting facts gathered from the studies conducted on the UK population. Some of the statistics from the report are as follows [15]:

- 55% of the audience reported that they do not feel informed about science
- 51% said they see and hear too little about science
- 58% think scientists put too little effort into informing the public about their work
- 68% of the participants reported that they would like scientists to talk more about the social and ethical implications of their research
- 40% of scientists are poor at communication

Report also found that people would put greater trust in scientific information if it comes directly from scientists rather than from journalists.

Another report, *Special Eurobarometer 401* (European Commission, 2013) [16] found that majority of EU citizens do not feel informed about science. The scores gathered from the UK public are higher in the context of being informed as compared to France, Ireland and Germany [15]. The numbers from the report shows lack in science communication and an interaction gap between researchers and the public.

We aim to use gamification to bridge the gap between public and researchers and communicate scientific evidence to enable awareness driven choices by individuals. Awareness is defined as knowing and understanding a lot about what is happening in the world or in the surroundings. The idea of gamification is not very new but it gained popularity from the second half of 2010 [13]. It is about using game play elements and mechanics outside the scope of games [6]. We also aim to use mobile platforms for this as mobile technology is available in very remote areas. It has become ubiquitous. For instance, mobile health (mHealth) field has emerged largely in developing countries and has resulted in raising the quality and capacity of health systems [17].

2.2. Motivation: Why do we need to gamify communication of scientific evidence?

Science Education and communication is a hot topic in European Commission (EC). In 2014 EC brought together experts who published a report [18] on science education that offers a 21st century vision of Science for Society. We quote few objectives from the report,

"Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship."

"Science education should focus on competences with an emphasis on learning through science and shifting from STEM to STEAM by linking science with other subjects and disciplines."

"Collaboration between formal, non-formal and informal educational providers, enterprise and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers to improve employability and competitiveness."

"Greater attention should be given to promoting Responsible Research and Innovation (RRI) and enhancing public understanding of scientific findings and the capabilities to discuss their benefits and consequences. "

The need of bringing all societal stakeholders together and creating a collaboration between them by the use of formal or informal methods of science education is of crucial demand of current time. This can help in addressing the societal challenges, create awareness among public and enhance scientific thinking process. Altogether, it ignites smart growth in the society and the report deems this growth vital to solve the societal and technological challenges along with 2 other key drivers [18]. The report defines smart growth as:

- Fostering knowledge
- innovation
- education
- digital society

As the use of smart technology in education such as smart phones and various multimedia systems has sky rocketed, various ideas can be employed in education sector through the use of these technologies. Society is very much familiar with these technologies, for example the use of smart phones all over the world has doubled over these years. Number of applications and games on the smart phones have helped people understand and discover its use to a greater extent. We created Scientific Hangman, keeping in mind the use of mobile technology, to play a role that could simplify scientific research for non-scientists in our society. As described earlier one part of the framework runs on smart phones for the public and the other on the web intended for the researchers, authors, teachers, etc. to feed in the scientific content for science

education and communication. The sole purpose of this framework is to enhance public understanding of scientific findings from the domains that directly influence our lives, such as health, the environment, food, energy and consumption, etc and to employ strategies that could fire long-term retention. The time required to go through the content within Scientific Hangman is small and at the same time it pitches users towards scientific thinking by presenting findings in simple words as fed in the framework by researchers. The EU report mentioned in this section and two reports mentioned in previous sub-section concludes our motivation of building the scientific hangman framework.

2.2.1. Problems and Challenges in Science Education

Researchers have unveiled several challenges in science education, some of them are as follows:

- Asymmetry in basic science literacy across Europe [19],
- Imbalance in the attendance in science education [19],
- Declining interest in science studies and related careers [20]

The basic literacy is important and needed for accurate understanding of scientific knowledge and its use while decision-making. Also, the imbalance in the attendance exists across regions, cultures and genders which hinders sufficient participation of all citizens and society. The interest should be injected in youngsters of our community from an early age. This is where Scientific Hangman comes in to address the above challenges by using mobile technologies to pitch basic science knowledge and new findings in the society continuously and in a simplified manner. Having mobile and web based solutions also makes it easier to reach the potential audience across regions, cultures and genders as Internet is an integral part of everyday life.

2.3. Gamification

Gamification as described earlier is the idea of employing game techniques and aesthetics in a non-game context for the purpose of motivating actions, enhanced e-learning, improving user engagement to achieve desired results [21]. Gamification is not a very new concept and since

its emergence it has been widely used in different contexts but it gained widespread acceptance in late 2010 [13]. Researchers have studied gamification and its use in the education since the eighties [22-25]. The interest in using gamification techniques in the context of education has been growing and this growth, to some extent, is influenced by the use of gamification in other settings [26]. Gamification has been useful to accomplish tasks from domains such as human computer interaction (HCI) for example image ranking upon their relevance [27], e-learning [6] or education because it has the potential to be helpful in engaging and motivating users towards learning activities [14] but also for increasing the productivity [28]. There are different concepts in the context of "game" such as:

- **Playful design**, to use design aesthetics based on game elements in a non-game context with sole purpose of increasing user's attention. This concept has the power to create an emotional response in users [14].
- **Serious games**, have a good use in non-recreational environments and for educational purposes [21]. They are called serious games because of their possible use in simulating real world scenarios such as from health, military, economics, education and engineering. The main purpose for such a training tool is to bring the information to the user [29].
- **Digital games**, or often called video games are for pure entertainment and it engages users in solving challenges based on pre-defined set of rules [30]. Such games have the potential of creating emotional link between the system and the user. The approaches used in these games have elements that can motivate users, maintain his interest and continuously challenge them.
- **Classic gamification approach**, uses only some elements of game design, instead of entire games. **leaderboard** and **badges** are the 2 most common and widely used elements in classical approach [31].

Gamification can have elements from the approaches used in digital games but the system does not revolve around these elements but they are used as the source of motivation for

continuous use by its users [6]. Next we will mention some examples from serious games and classical gamification.

2.3.1. Examples of gamification in its classical approach

As mentioned earlier, in this kind of gamification setting only some elements of games are used instead of entire games, leaderboard and badges, for example. A leaderboard is a list of players ranked in descending order on the number of points scored in the activities within the game. Therefore most **active players** are shown on leaderboard and it allows players to compare their progress with other active players [31]. Badges are **virtual goods** that are gifted to (or unlocked by) players on some achievement within the game [32], for example reach some points threshold. Badges have several advantages: they *set goals* (e.g. "reach 500 points"), build *reputation* of a user and allows user to *identify* with groups of people who have the same badges [32].

To some extent social networks use gamification to collect data. In networks like Facebook, Instagram, StackOverflow or YouTube people post and share texts, photos, videos etc. and are rewarded with "likes", "votes", "no. of shares", "no. of views", comments or any other kind of badges [32]. Many event organizers announce competition for the best photo from the event and by using minimal cost and introducing the challenge to the participants, they obtain huge number of photos [33]. This kind of method is usually seen on Facebook pages that want people to visit their page and be active. They use some kind of give away to motivate users to take part. Gamification also has an interesting application in car industry. Nissan Leaf, an electric vehicle, is equipped with the Eco Mode software that tracks some parameters of eco-driving and uses them in a gamification context [34]. It rewards drivers with immediate feedback and creates a sort of social network with a leaderboard where drivers can compare themselves to others.

Gamification has applications outside of software systems as well. For example in [35] the author explains how gamification is used to motivate employees to do some tasks or improve collaboration in a company. In such cases, gamification is obviously a secondary factor for

motivation and it does not seem to ever replace financial incentives at work. There are many more motivation factors other than just *money* and *entertainment* as mentioned by the author in [36]. Other motivational elements, for example, are *education* (people perform an activity because it allows them to learn something), *socializing* (a group activity or something that enables interaction with other participants), *vanity* (any activity to prove oneself how good one is) and *charity* (when the task has a purpose of helping others).

2.3.2. Examples of Serious Games

In classical approach only some elements of games are used, however there are multiple examples that use complete games for research purpose and are called **Serious Games**. They can be defined as games, “*played with a computer in accordance with specific rules, that use entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.*” [37]. One of an interesting example is Foldit [38], a multiplayer online biochemistry game designed for players to reasons about the 3D structures to determine protein shapes. The game presented computationally difficult protein folding problems in the form of puzzles, allowing ordinary players to gain expertise and help solve these problems. There were 57,000 users working on a set of 600 protein structures in the first two years. Another successful example is Galaxy Zoo [39], where galaxy photos were given to users to classify them. More than 200,000 users contributed in the game with more than 100 million galaxy classifications. These games were related to science but the contribution was more associated to the research topic by collecting data for further research on motivation of the players in Galaxy Zoo, for example. Two other developed at Simula research Laboratory: Picture Sort [27] and Picture Guess [40]. These games ask players to perform some sorting and guessing operations on the images being displayed which as a result generates data for further research in the domain of human computation. It is a technique to leverage human brainpower to solve complex computational problems that yet computers cannot [41].

Other than the use in human computation such games are also used in raising awareness on social issues. Multiple examples of such games can be found in [42], which also describes three categories of serious games and mentions examples of interesting games that won the contest

at the *Games for Change Festival in 2007*⁵. Example of the first category, *awareness-raising games*, is *Ayiti: The Cost of Life* [43], where players have to manage the budget of a virtual rural Haitian family and in the process they learn about the effects of poverty. Second category is the *transformation games* which targets social issues and transform players' view on them. The game that won the award in this category is *Peacemaker* [44], which challenges players to find a peaceful solution to the Israeli-Palestinian conflict. The last category, *Social Commentary/Art games*, has *The Arcade Wire: Oil God* [45] as an example where the player, as an Oil God, is given a deadly goal to double the oil prices by using a combination of eight godly wraths. These games are high budget professional products supported by big organizations. However, there are other examples from research background. An example of those is Scientific Hangman: Gamifying Scientific Evidence for General Public [46], first paper on this topic that we published at the Workshop for Gamification on Information Retrieval (GamifIR'15). The reason to mention SH in this section is due to the goal we want to achieve, i.e. communicating scientific evidence to the potential audience either through controlled environment or by putting the game out in the wild. This goal puts SH under the umbrella of serious games with added use of classical gamification elements. We will explain the details of how scientific content is added in the game and how it is consumed by players in chapter 3.

2.3.3. A hangman game similar to Scientific Hangman in structure

We came across a web based game that we find interesting to mention as it serves the purpose of education and it is close to SH in structure. Science Vocabulary Hangman [47] developed by Jefferson Lab is available on web for free. It does not have any gamification elements other than presenting the content through a game of hangman. This game presents knowledge based puzzles in question, answer, clue format. These puzzles are subject specific such as Mathematics, Chemistry, Computer Science, Geology, Physics, etc. and also further breaks down the subjects into concepts such as force, motion, heat, sound, light, etc. The structure of the game content is similar but lacks proper gamification elements and it does not link game content to scientific research. Based on different references and literature review and to our

⁵ <http://gamesforchange.org/conference/2007/program.php>

best knowledge there has been no study that connects scientists or teachers to students or society for science communication by using gamification to increase interest and engagement.

2.4. Gamification review in context of education

Scientific Hangman, the gamified mobile app contains some classical gamification elements such as leaderboard with game aesthetics and focuses on domains such as health, education, and climate. The nature of Scientific Hangman in the context of desirable domains we want to cover makes it close to "Serious games" which is why we have mentioned some notable examples from serious games in the previous section. We studied an **existing systematic mapping of gamification** applied to education [14] to review gamification use in context of education. The keyword used by the authors to search for primary studies was "*Gamification*" to keep the search broader and to not miss out any relevant study.

The literature review authors devised the following inclusion and exclusion criteria and we quote [14],

Inclusion criteria:

- *If several papers reported the same study, only the most recent paper was selected;*
- *If the paper describes more than one study, each study was assessed individually.*

And the following exclusion criteria:

- *Papers that do not present studies relating to education;*
- *Papers in languages other than English;*
- *Technical reports and documents that are available in the form of summaries or presentations (gray literature) and secondary studies (i.e., systematic literature reviews and mapping studies).*

1 out of 3 research questions answered in the mapping are in interest of this manuscript:

RQ: In what educational contexts and levels has gamification been most investigated? [14]

After filtering out search results based on keywords, inclusion and exclusion criteria, the authors use 26 studies have been used in [14] as primary studies.

2.4.1. Analysis

In this section, we will give a brief analysis of the results presented in the systematic mapping under study in favor of this framework. The list of papers as primary studies for this mapping can be found here [48].

Authors of the systematic mapping of gamification applied to education categorized primary studies according to the target audience. Most of the primary studies linked the use of gamification to higher education students i.e. 46%, which means that gamification techniques have been tailored mostly to use in the context of higher education. Gamification when applied in higher education in universities, for example, is subject oriented having a very narrow scope. It does not contribute towards general science education. For example, a tool called GLABS [49] is used to assist in the gamification of the classroom in the context of higher education in universities. Results, on the other hand shows elementary education has received less attention among the primary studies: total of 2, which accounts to only 8% of the selected studies. These studies discuss gamification techniques for teaching elementary students. For example, a social gaming framework presented in [29] applies to an existing K-6 social learning environment called schooooools⁶. This learning environment is intended to be applied in any education institution for kids from 4 up to 12, which means it has a very wide scope and caters the early education of children. It is not focused on science communication for domains such as health and climate, for example. Table 1, taken from the systematic mapping under study, shows how all primary studies were categorized according to target audience.

Table 1. Primary studies categorized according to target [14]

Target Audience	Number	Frequency (%)
Higher Education	12	46.15%
Non-specific Context/level	6	23.08%
Training and Tutorials	3	11.54%
Languages	2	7.69%
Elementary Education	2	7.69%
Lifelong education	1	3.85%

⁶ <http://www.schooooools.com>

2.4.2. Conclusion

The results of the background study show an increasing use of gamification in context of education but does not show the use of gamification for science communication and general science education outside the boundaries of schools and universities. The results from the systematic mapping, key findings from the report, "Public Attitude to Science, 2014", and *Special Eurobarometer 401* (European Commission, 2013) mentioned in Section 2.1 of this chapter concludes our purpose of building this framework. It is to enable our society, individuals with access to a mobile phone and (at the moment) knowledge of English, to engage in learning about simplified scientific information in a fun manner while ensuring the provenance of the scientific evidence. The question, answer, clue formation of scientific information is a useful strategy to employ as it has the potential to help individuals remember the information for a longer time. This strategy has been studied on undergraduate students [3]. The results from the study has demonstrated that learning by repeated retrieval enhances retention.

2.5. Technology Acceptance Model as Evaluation method

Technology adaptation has been a major area of research within Information Systems and user acceptance is a critical success factor in it [50]. Davis, Fred D. in 1989 [5] proposed a Technology Acceptance Model (TAM) as a means of predicting technology usage. It has been studied a lot since then. Google scholar shows huge citation count i.e 26,565 citations for the work done by Davis, Fred D.. TAM focuses on 3 features of user acceptance: Perceived Ease of Use (PEOU) Perceived Usefulness (PU) and Intention to Use (IU). TAM has been used in many empirical studies with utilitarian systems focusing on extrinsic motivations. However, intrinsic motivations were also studied by Davis and the co-authors in 1992 which added a new feature of user acceptance called Perceived Enjoyment (PE) [4]. There has also been different studies claiming which feature is a stronger determinant of intentions to use a system. Van der Heijden in 2004 studied the technology acceptance model with PE for intrinsic motivations and showed PE and PEOU to be stronger determinants of intentions to use as compared to PU [51].

However, another study examined dual context of use i.e. both productivity-oriented and pleasure-oriented reported PU to be more important in determining intentions to use as compared to PE [52]. It depends on the nature of the system and the purpose of the users. For example, this distinction can be seen in the use of world wide web as it serves both productive and fun use. The nature of the websites determines which feature takes precedence [51]. This was reported in a study which explored students use of World Wide Web [53], PE strongly determined the intention of web use for entertainment purposes and PU strongly determined the intention of web use for course-related purposes.

Hedonic-Motivation System Adoption Model (HMSAM) [54] was proposed in November, 2013 as an extension of TAM to study pleasure-oriented systems such as digital games. This model proposed Cognitive Absorption (CA) as a second-order construct which was made up of 5 sub-constructs namely Joy (for perceived enjoyment), Control, Curiosity, focused immersion and temporal dissociation. It conducted 2 experiments on 4 digital games to show significance of the sub-constructs as compared to PE as second-order construct in previous models.

We decided not to employ HMSAM for evaluating SH as it experimented only on digital games and it is more inclined towards fun use. We used technology acceptance model proposed by Davis et al., [4] to determine SH gamified mobile app acceptance among general public. However, we used the model without PE proposed by Davis in [5] to determine web console acceptance among researchers. We discuss relevant details in chapter 5.

3. Scientific Hangman

In this chapter, we present Scientific Hangman (SH) as a framework/tool. We will describe the architecture of the Scientific Hangman to give you an overview of the system (Section 3.1) and its requirements specification (Section 3.2). Next sub-sections will contain more information on the components that are part of the system along with screenshots representing the current state and different functions and features. In the last sub-section we will describe the process of how Scientific Hangman was designed, implemented and tested.

3.1. Overview of the framework: Scientific Hangman

Scientific Hangman consists of three main components that together make it a tool to gamify science communication and education. The components and their relation can be seen in Figure 5.

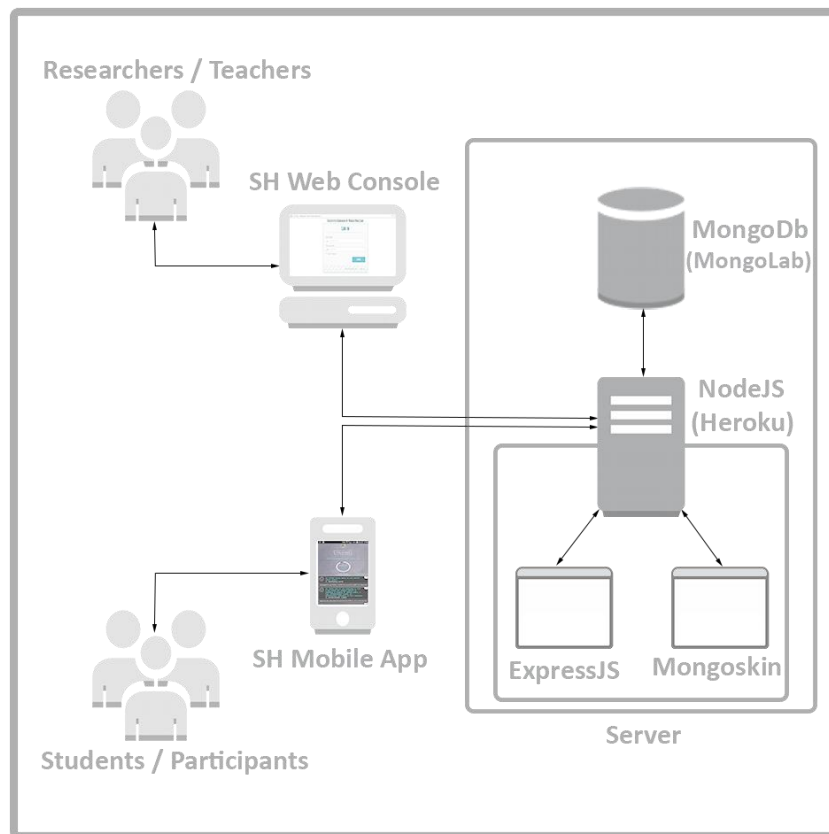


Figure 5. Flow of Scientific Hangman

There are two front end components: the web console and the mobile application. On the backend we have a server which hosts the web application containing the web services used by the mobile application and web console itself and the database. Following is a brief description of the components and the details of each component are given in the next sections.

Scientific Hangman web console⁷

The web console is part of the framework which lets researchers, teachers, or any actor involved in science education to create science puzzles and studies. It is also used by administrators to control the game content when required. The web console is implemented using the famous light-weight web application framework called ExpressJS built over NodeJS [55, 56], the web pages are written using pure HTML5, CSS and JavaScript and hosted/organized through express application. This web console application is hosted on Heroku⁸.

Scientific Hangman mobile application⁹

The mobile application can be used by students or any actor interested in science education linked to scientific evidence. The application obtains puzzles and studies through web service built as part of the web application. The users of the application can see all the puzzles and choose to solve them based on their interest while enjoying gamification elements. The application can also be used in a controlled environment where users are given a subscription code to access particular studies that include many puzzles preloaded by the creator of the study. The gamification elements are not present in the studies as these are conducted under controlled environment and are more intended to test users' knowledge in the controlled group. The mobile application is only developed on native Android platform [57] to conduct proof of concept for this research project.

Scientific Hangman database

⁷ <https://hangman-thesis.herokuapp.com/>

⁸ <https://www.heroku.com/>

⁹ <https://play.google.com/store/apps/details?id=com.thesis.hangman>

We have used MongoDB [58] as a database on backend. MongoDB is a document-oriented database. Instead of storing data in the form of tables and rows, it stores data in JSON-like documents with dynamic schemas. Such databases are also favorable to use with Node.js backend implementations [55]. The database currently lives on MongoLab¹⁰.

3.2. Requirements

The requirements in this research project have been specified during several project meetings involving my supervisor and sometimes his fellow colleague for active feedback and thoughts. In this setting, my supervisor served the customer role to specify desired abilities, based on his experience as a researcher, the tool must bring to end users. He also participated as an active web console user (researcher) to highlight the functionalities he would want to see in the end result. Whereas, I worked as a business analyst to convert the ideas into requirements and eventually the Developer to realize the entire system. In the next subsections, we use minimalistic lean form of user stories [59] to specify functional requirements. User stories are used to explain requirements in a very concise way. They represent small pieces of requirements implementable in relatively short time. They are expressed in the following short template:

As a [role], I want [goal/desire] so that [benefit].

The role represents the Actor in the system. The goal/desire is the actual functionality that the system should realize. The benefit is optional, but is often used to emphasize on the motivation behind the goal/desire.

3.2.1. Actors

There are three actors in Scientific Hangman. Researcher (or teacher) and Administrator use the web console and players (participants/students in a study or individual players) uses the mobile app.

¹⁰ <https://mongolab.com/>

Researcher

The researcher is the person who creates game content through the web console. The person creating the game content does not have to necessarily be an academic researcher. They can as well be a teacher as long as they are associated with an institution. The game content can be puzzles or studies (grouping three or more puzzles together). Researchers are not allowed to edit or delete the puzzles however they can email the administrator to delete a particular puzzle or study.

Administrator

The administrator has full control of the system. Administrator can perform similar actions as of researchers but they can also moderate the content. At the moment administrator can delete puzzles and studies.

Players

These are the mobile app users who are, willing to learn about scientific findings backed by authentic scientific evidence or participating in a study conducted by a researcher or a teacher in a controlled environment. The data is collected by the researcher or teacher during the study.

3.2.2. User Stories

Following are the user stories grouped by Actors.

Researcher

Following user stories for researcher are related to the Scientific Hangman web console.

1. As a Researcher, I want to create an account for Scientific Hangman web console
2. As a Researcher, I want to login with username and password
3. As a Researcher, I want to create a puzzle
4. As a Researcher, I want to see details of a puzzle
5. As a Researcher, I want to see number of up/down votes for a particular puzzle
6. As a Researcher, I want to create a study

7. As a Researcher, I want to see total number of participants who have subscribed the study
8. As a Researcher, I want to see all the answers submitted by the participants
9. As a Researcher, I want to send a subscription code of a study through an email
10. As a Researcher, I want to see the list of puzzles and studies created by me

Administrator

Following user stories for administrator are related to the Scientific Hangman web console.

1. As an Administrator, I want to login with username and password
2. As an Administrator, I want to see all the puzzles and studies
3. As an Administrator, I want to delete a puzzle
4. As an Administrator, I want to delete a study

Players

Following user stories for players are associated to the Scientific Hangman mobile app.

1. As a player, I want to register to start using the mobile app
2. As a player, I want to login into Facebook
3. As a player, I want to see available puzzles
4. As a player, I want to select a puzzle to play
5. As a player, I want to read clue of the active puzzle
6. As a player, I want to give feedback after solving a puzzle
7. As a player, I want to see the list of solved puzzles
8. As a player, I want to subscribe to a study
9. As a player, I want to answer questions in a study
10. As a player, I want to see the list of subscribed study
11. As a player, I want to contact the creator of the puzzle
12. As a player, I want to contact the creator of the study
13. As a player, I want to see the list of players with high scores

3.2.3. Non-functional requirements

User stories can be used to express non-functional requirements. Few examples are listed below.

1. As a Researcher, I want web console to be available at all times
2. As a Researcher, I want web console to not loose content created by me
3. As a Researcher, I want web console pages to load faster, within 1 second
4. As a Player, I want mobile app to have high usability by minimizing the number of steps used to start a puzzle or a study.

3.3. Scientific Hangman web console

The web console allows researchers to create game content such as puzzles or studies based on authentic scientific evidence. It is available online and accessible at all times.

3.3.1. Key functions

In this sub-section, we will explain the key functions and the pages of the web console. we will lay down the details from the perspective of a **Researcher** and afterwards we will mention some actions that an **Administrator** can perform.

Sign up page

Anyone who wants to submit content through Scientific Hangman web console must register an account using their institute email address. Any email address coming from Gmail, AOL, Yahoo, Hotmail and similar social domains are denied. This is only to ensure contribution from people associated to some institution so that random game content is not submitted. Administrator of the system can give administrator privileges to any user by modifying the database through a 3rd party console.

SCIENTIFIC HANGMAN BY WAQAS MOAZZAM

SIGN UP

Your full name

Your email

Your password

Please confirm your password

Your age

[SIGN UP](#)

Already a member ? [Go and log in](#)

Figure 6. Signup page

Log in page

Every web console user is shown the same log in page. The system recognizes the logged in user as researcher or administrator and presents relevant user interface.

SCIENTIFIC HANGMAN BY WAQAS MOAZZAM

LOG IN

Your email

Your password

Keep me logged in

LOGIN

Not a member yet? [Join us](#)

Figure 7. Log in page

After the system has recognized the credentials, user is redirected to the home page.

Home page

Home page of every user displays the profile details such as name, email, age, no of puzzles and studies created. Researcher can also see all the puzzles and studies owned by him along with some useful stats. Researchers are not allowed to edit or delete the puzzles and studies they have created to avoid some complex implementation scenarios in this basic version of the web console.

User Profile

Full name: Waqas Moazzam
 Email: waqasmb@ift.uio.no
 Age: 27
 Total Puzzles: 7
 Total Studies: 3

Paper Name	Puzzle Question	👍👎	Action
COMPUTERS AND HEALTH--INDIVIDUAL AND INSTITUTIONAL PROTECTIVE MEASURES	What is the reason of eyestrain, headaches, and impaired vision?	5 / 1	Detail
Informasjon til kvinnen som legen skal gi ut	Vil en HPV-infeksjon alltid gi symptomer av noen slag?	1 / 0	Detail
Din celleprøve vil bli testet for HPV	Hvilken aldersgruppe får tilbud om HPV-test i primærskanning?	1 / 0	Detail
Science of Dogs	Are dogs colorblind?	0 / 0	Detail

Study Name	Study Description	👤	Code	Action
Cervical Cancer Screen	This study contains puzzle questions from the reminder letters that are sent by CRN to women of age 34 - 69 in order to remind	2	4776019406	Detail

Figure 8. Researcher's home page

In the first table researcher is shown puzzles where they can see useful information such as number of votes received by the puzzle. They can also see complete details of the puzzle such as all questions, answers and respective clues.

User Profile

It is time to bust the myth of physical inactivity and obesity: you cannot outrun a bad diet
<http://bjsm.bmj.com/content/early/2015/05/07/bjsports-2015-094911.full>

Questions and Answers

Q: what does physical inactivity does not promote?
 A: weight loss
 Clue: Regular physical activity reduces the risk of developing cardiovascular disease, type 2 diabetes, dementia and some cancers by at least 30 percent. However, physical activity does not promote weight loss.

Q: What is more responsible for illness according to health scientists?
 A: calorie burdened diet
 Clue: Researchers say our calorie-laden diets are responsible for more ill health in around the world than physical inactivity, alcohol, and smoking combined. They also argue that public misperception is due to dodgy corporate marketing, describing the "public relations tactics of the food industry as 'chillingly similar to those of Big Tobacco,' which deployed denial, doubt, confusion and 'bent scientists' to convince the public that smoking was not linked to lung cancer."

Q: Which factor contributes more towards getting diabetes?

Study Description

This study contains puzzle questions from the reminder letters that are sent by CRN to women of age 34 - 69 in order to remind

Figure 9. Puzzle detail dialog

Second table on the home screen contains all studies created by the current researcher with stats such as the number of subscribed participants. With the available action of detail, researcher can see the answers submitted by the participants and the no of participants who actually answered the questions.

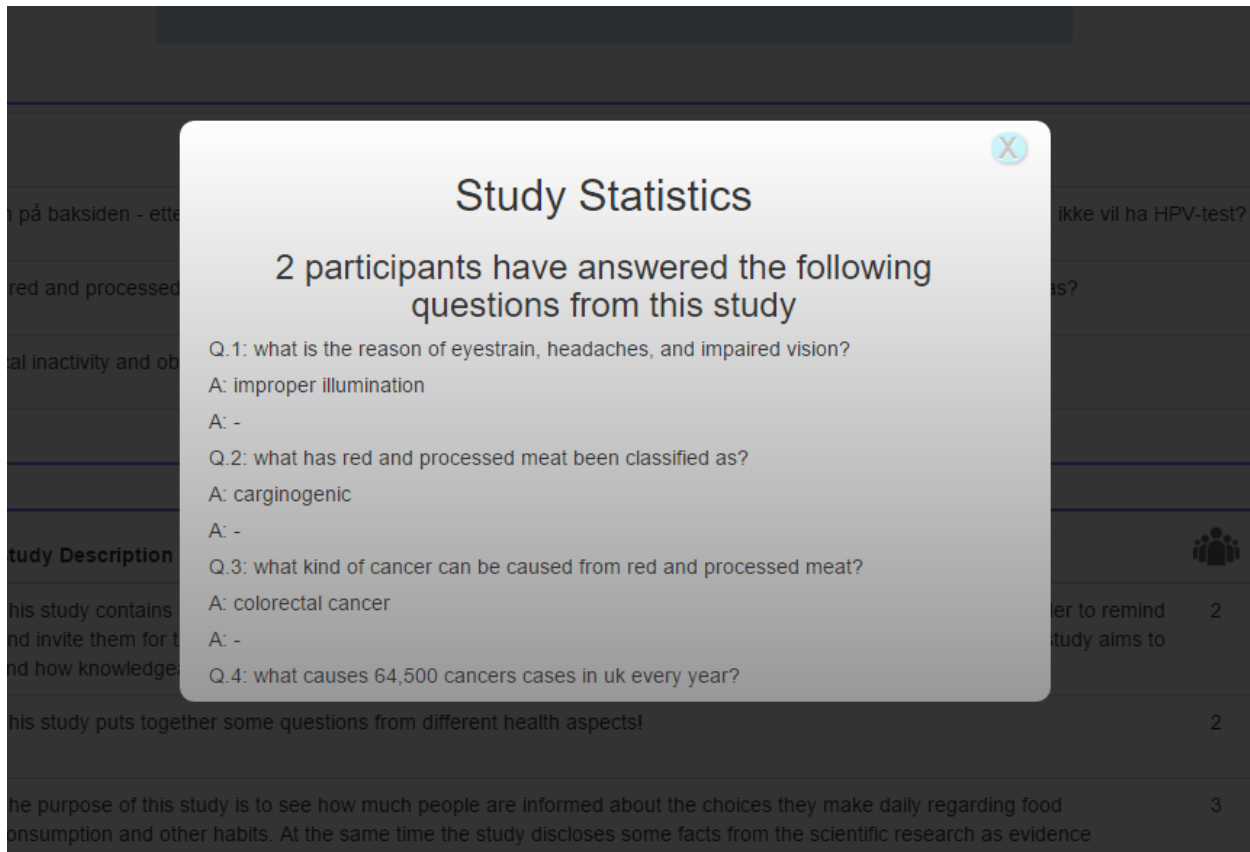


Figure 10. Study stats dialog

Researchers can create new puzzles and studies on the respective pages.

Create a puzzle

In order to create a puzzle researcher must provide some details. Create a puzzle web page allows a researcher to provide content based on scientific publication or article whose link goes in the **Paper URL** field. All fields, except for **puzzle pic/video**, are mandatory. There cannot be more than 3 questions in a puzzle. Every **question** must have an **answer** with at least length **4** and a **clue** with maximum **500** characters. Every puzzle should have an **insight** text with length

not greater than **150** characters. The purpose of insight text is to give the game player a teaser of the puzzle to gain some attention.

The screenshot shows the 'Create a Puzzle' form in the Scientific Hangman application. The form is titled 'Create game content' and includes the following fields and buttons:

- Paper Name:** A text input field with the placeholder text 'Name of the reasearch paper'.
- Paper URL:** A text input field with the placeholder text 'URL to the PDF version of the research paper'.
- Puzzle Pic/Video:** A text input field with the placeholder text 'Optional URL to any image or a youtube video related to the research'.
- Puzzle Insight:** A text area with the placeholder text 'Some interesting text related to the research article which can attract or motivate the user to play' and a character count of '0/150'.
- Puzzle Question:** A text input field with the placeholder text 'A question you want to present as a puzzle'.
- Puzzle Answer:** A text input field with the placeholder text 'Answer to the puzzle'. To its right is a blue button labeled 'Click to add more questions'.
- Puzzle Clue:** A text area with the placeholder text 'Clue for the puzzle' and a character count of '0/500'.
- Get suggestions from a summarization tool:** A section with a green 'Create' button and a text input field containing 'Tools4noobs'.

Figure 11. Create a puzzle

Once the researcher presses **create** button the page asks to confirm the action and upon confirmation adds the content in the database. An email message is sent to the to the associated email address of the researcher.

Create a study

To create a study researcher must provider a **study name** and a **study description**. The description can be maximum **300** characters.

[Hangman](#)
[Home](#)
[Create a Puzzle](#)
[Create a Study](#)
[Logout](#)
Scientific Hangman by Waqas Moazzam

Create a study - A code will be generated which you can provide to your audience

Study Name

Study Description

0/300

[Create](#)

Puzzle Name	Action
<input type="checkbox"/> COMPUTERS AND HEALTH--INDIVIDUAL AND INSTITUTIONAL PROTECTIVE MEASURES	Detail
<input type="checkbox"/> Informasjon til kvinnen som legen skal gi ut	Detail
<input type="checkbox"/> Din celleprøve vil bli testet for HPV	Detail
<input type="checkbox"/> Science of Dogs	Detail
<input type="checkbox"/> Negativt svarbrev med reservasjon på baksiden - etter fokusgruppeintervju	Detail
<input type="checkbox"/> Carcinogenicity of consumption of red and processed meat	Detail

Figure 12. Create a study

Studies can be made up of different puzzles. Researchers is shown all the puzzles created by him as a list. The current researcher must select at least **three** puzzles and **seven** puzzles at max. We put these limits so that a researcher does not end up creating a very small study making no sense and/or very large study being too time consuming for participant. Depending on how the selected puzzles were designed, the study will have minimum **three** questions and **twenty one** questions at max. Once researcher submits a study, system generates a **subscription code** which is unique 10-digit code. Along with the confirmation dialog an email message is sent to the associated email address of the researcher.

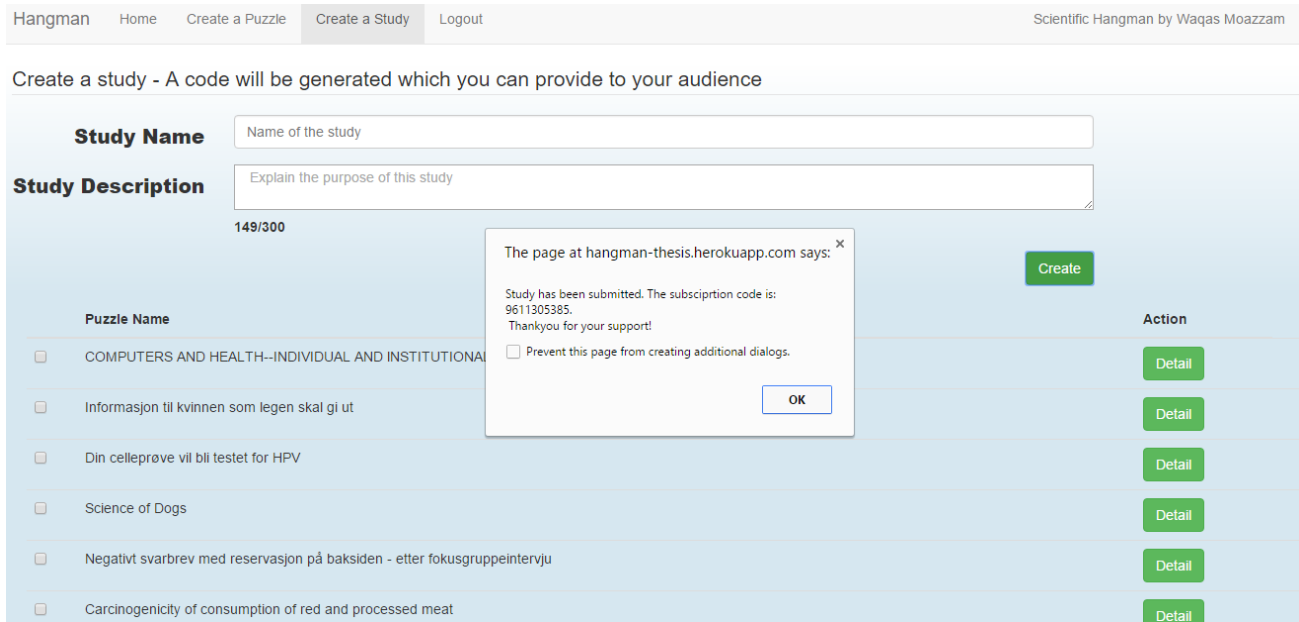


Figure 13. Study subscription code

This is an important parameter of the study. To invite any individual to participate in the study the researcher only needs to pass this code to the participant. The participants can then use the code in the Scientific Hangman mobile app to get the list of questions from the puzzles that were made part of this study. The researcher can actively see all the answers submitted by anyone for this study in the study detail dialog as shown in Figure 7. The same stats dialog is used to see all the questions that were made part of the study. Instead of displaying puzzles from that specific study, we show the list of questions to keep the flow simple for the researcher.

3.3.2. Extended Administrative Actions

Administrators can perform all the operations that any other user can perform on the web console. However, an administrator can perform delete operations on the puzzles and studies if required. Administrator can also make direct changes in the database by using 3rd party database console. This version of the web console only lets the administrator to perform delete operation on puzzles and studies.

User Profile

Full name: Admin
Email: scientific.hangman@gmail.com
Age: 27
Total Puzzles: 1
Total Studies: 0

Paper Name	Puzzle Question	Action
COMPUTERS AND HEALTH--INDIVIDUAL AND INSTITUTIONAL PROTECTIVE MEASURES	What is the reason of eyestrain, headaches, and impaired vision?	5 / 1 Detail Delete
Human papillomavirus genotype attribution in invasive cervical cancer: a retrospective cross-sectional worldwide study	What are the three most common high-risk (oncogene) HPV types in cervical cancer?	1 / 0 Detail Delete
Cervical cancer	Which one of the following is NOT a risk factor for cervical cancer?: a) smoking, b) history of genital warts, c) high socioeconomic status, d) micronutrient deficiency, e)	1 / 0 Detail Delete

Study Name	Study Description	Code	Action
Cervical Cancer Screen	This study contains puzzle questions from the reminder letters that are sent by CRN to women of age 34 - 69 in order	2 4776019406	Detail Delete

Figure 14. Home page for administrator

It does not provide a user interface for editing users, puzzles and studies but these actions can easily be performed by the administrator outside of the web console.

3.4. Scientific Hangman mobile app

The mobile app is the front end for game players to solve puzzles and for participants of a study. The app has been developed only on native Android due to limited access to Apple devices such as iPhone and iPads. This app has only been used on Android during my work on thesis.

The primary goal of the app is to present accurate scientific information from latest findings and/or areas of public interest in a gamified manner. The app needs to be simple and quick to use. The player can use it multiple times a day or as long as he wants to and because of it, we wanted the flow of the app to be simple and fast. For that purpose, player can start solving the puzzle in **two taps**. The standard workflow for solving the puzzles in the app should be following:

1. Start the app (no login required as registration for the first time is saved on the device)
2. Load puzzles

3. Select a puzzle
4. Read the clue and answer the questions to solve the puzzle
5. Give Feedback

The participant of a study, however, has to enter a subscription code which makes it only **one tap** from participating in the study. The workflow for participating in the studies should be as following:

1. Start the app (no login required as registration for the first time is saved on the device)
2. Enter a study subscription code
3. Start answering the questions in the study
4. Check the leaderboard for social progress

We have tried to make the design of the app as aesthetic as possible to match the learning concept of the app yet it is possible to make it more creative.

3.4.1. Key functions

In this section, we describe the core functionality of Scientific Hangman mobile app. As stated before, the app is simple and easy to use, there are only few screens that serve the functionality required to evaluate it as part of this framework.

Registration screen

After installing the application on any Android device, user must register to use the app. This registration saves the registered email address and device id locally and on server as well. Everything on server for this particular user will be stored and retrieved against the registered email address.

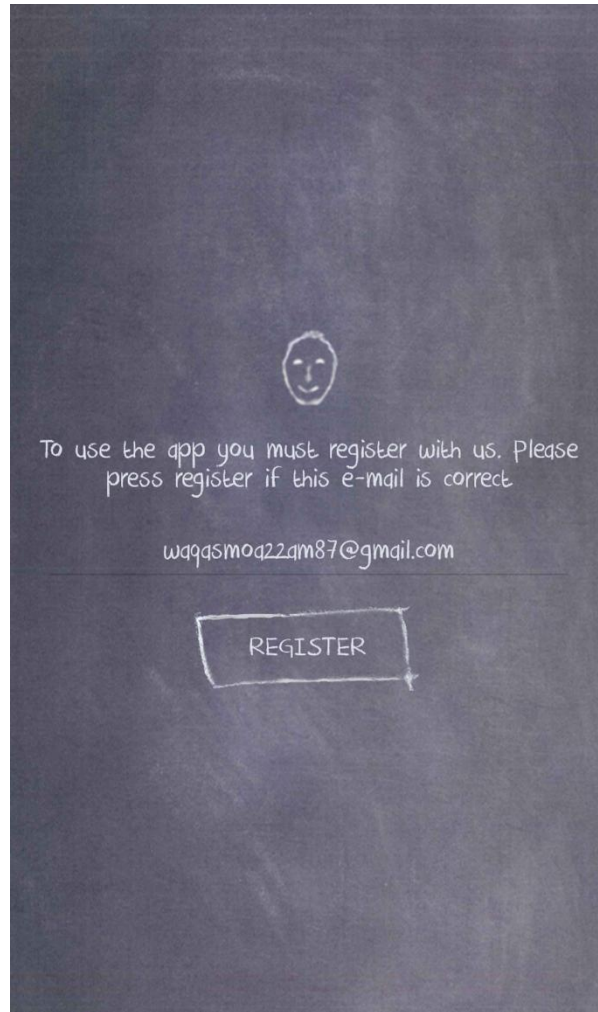


Figure 15. Registration

Home screen for new user

After registration user does not have to login again as mobile devices are personal gadgets. Every time user starts the app, home screen is displayed without any authentication. Also there is no such data that would be considered as critical to user's privacy. The home screen contains the list of solved puzzles, list of subscribed studies, level and score details, and options to get a list of new puzzles or to subscribe to a new study. The user can also link his Facebook account but it does not provide any functionality other than logging in to the Facebook account in this version.

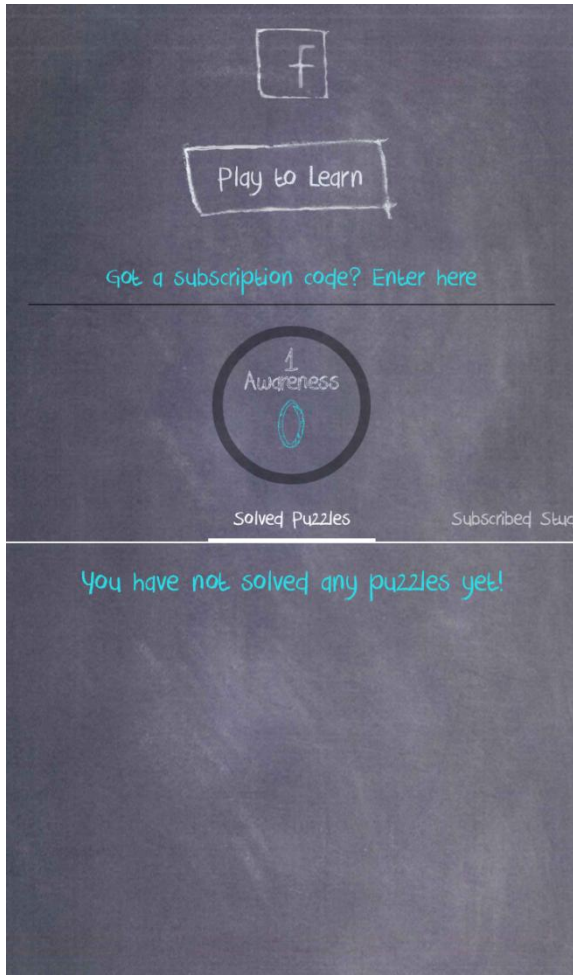


Figure 16. New user home screen, no solved puzzles on level 1 with 0 points

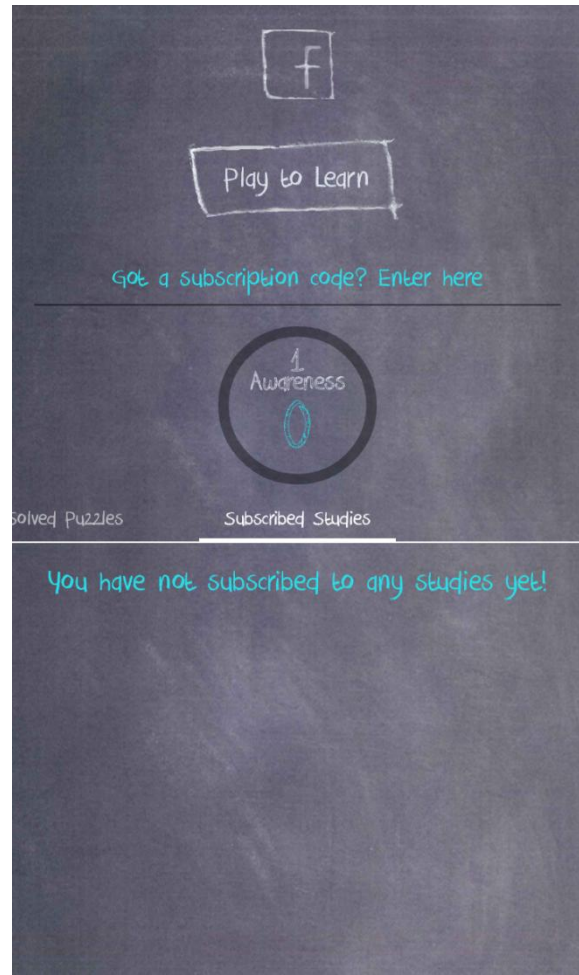


Figure 17. New user home screen with no subscribed studies

Selecting a puzzle to play

Once user clicks, **Play to Learn** user is shown a popup with a horizontal list of puzzle insights. Puzzle **insights** are a small but interesting piece of information from the research article. The insights serves as a teaser to gain user attention.

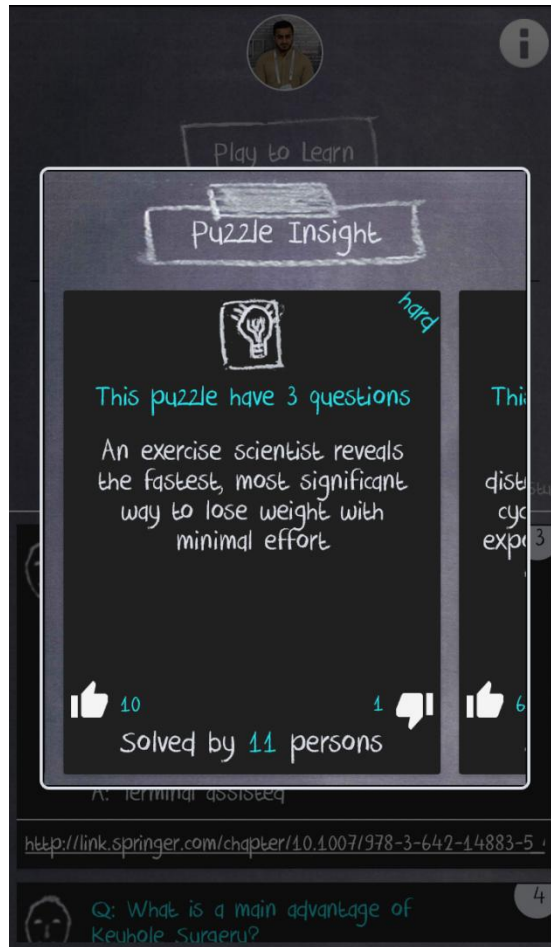


Figure 18. Puzzle insight and other statistics to gain user's attention

The insight also shows some statistics such as the difficulty level (easy, medium or hard) of the puzzle in the top right corner, number of up/down votes and the total number of people who have solved the puzzle so far. All this information on how other users have interacted with this puzzle is to motivate users to play this puzzle. This kind of information is presented with every puzzle insight to increase user interaction. User can also view **clue** of the puzzle without selecting the puzzle.

Puzzle screen

After user selects the puzzle from the insight popup, user is redirected to a new screen where a question from the puzzle is displayed along with the option to read the clue. A puzzle can have a maximum of three questions, a count on the screen shows the total number of questions in the current puzzle.

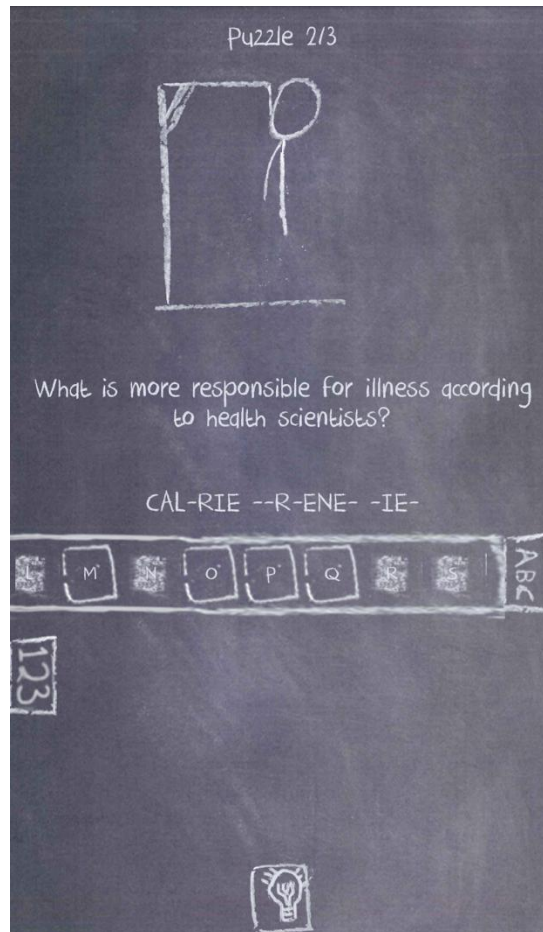


Figure 19. Puzzle screen

The puzzle in **Figure 19** is showing 2nd question from the total of three questions it contains. User can read the clue as many times as he wants. If user inputs 'E' all of its occurrences are made visible. The user has maximum **seven tries** to solve the puzzle by answering all three questions.

Clue screen

The clue screen for the current puzzle can be seen in the following figure. It displays small piece of text which contains the answer to the question and at the same time it passes important information to the user.

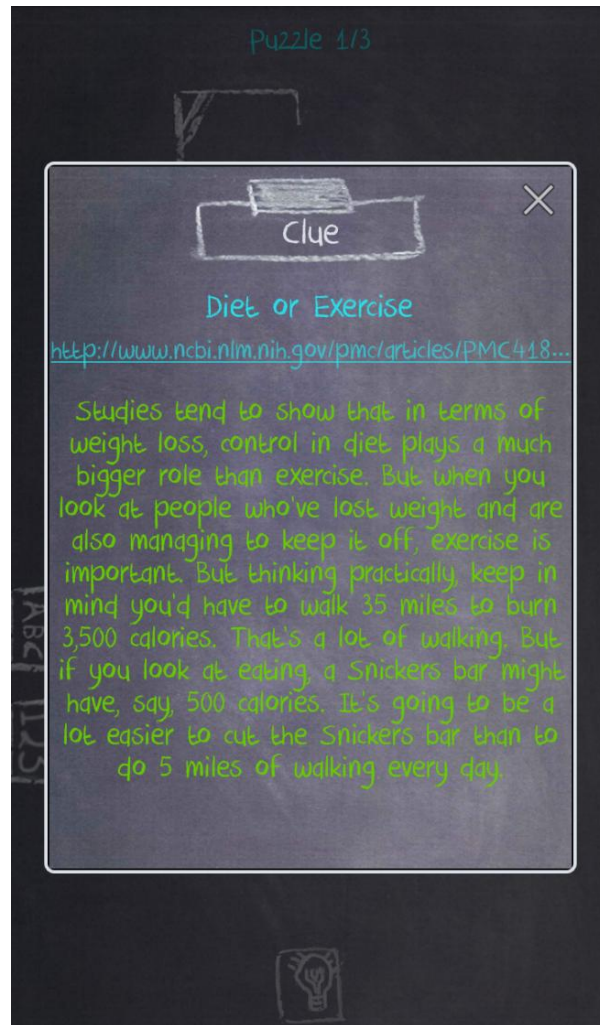


Figure 20. Clue screen for the active puzzle

It shows the **title** of the research article, relevant information as the actual **clue** for the current puzzle question and a **URL** to the full research article. The actual clue can be different for all questions within a puzzle whereas title and the URL remains the same. Also multimedia content (video or image) is shown if available.



Figure 21. Clue screen with a YouTube video as actual clue information

The purpose of adding multimedia content is to increase user's interest as multimedia content such as video or image is received better as compared to reading textual information. To avoid boredom textual information is kept short and to the point but still video or image is considered more interactive and fun to go through. It depends on the author of the puzzle to either add just text or both as clue.

Puzzle success and feedback

Once an user completes a puzzle by answering all the questions in it, a feedback popup is displayed asking user to vote up or down. User can skip the feedback but to keep this from

happening only 1 click feedback has been implemented i.e. either vote up or down which only takes a second.

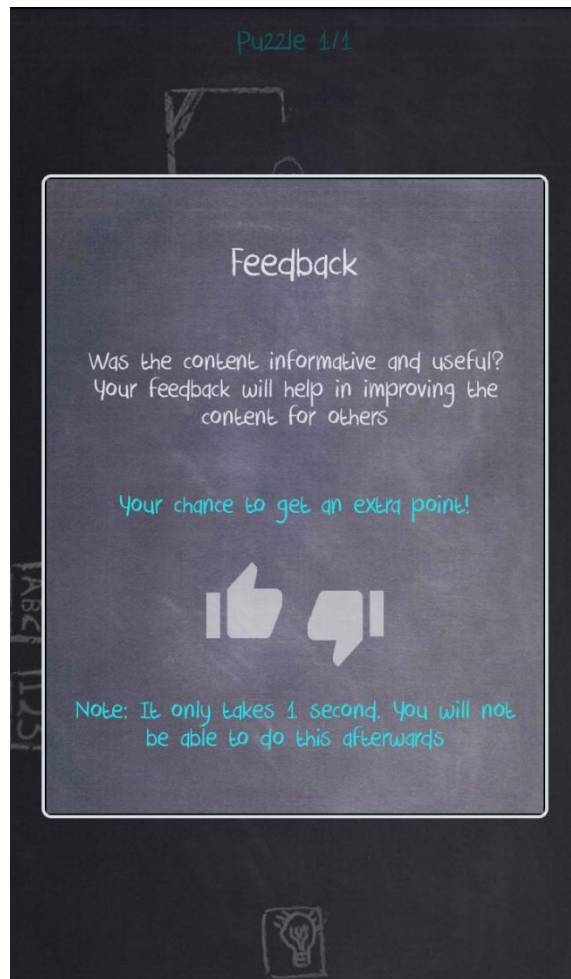


Figure 22. Feedback popup

After user gives or skips the feedback user is shown the puzzle success screen where user can see a success popup with score he earned on this puzzles.

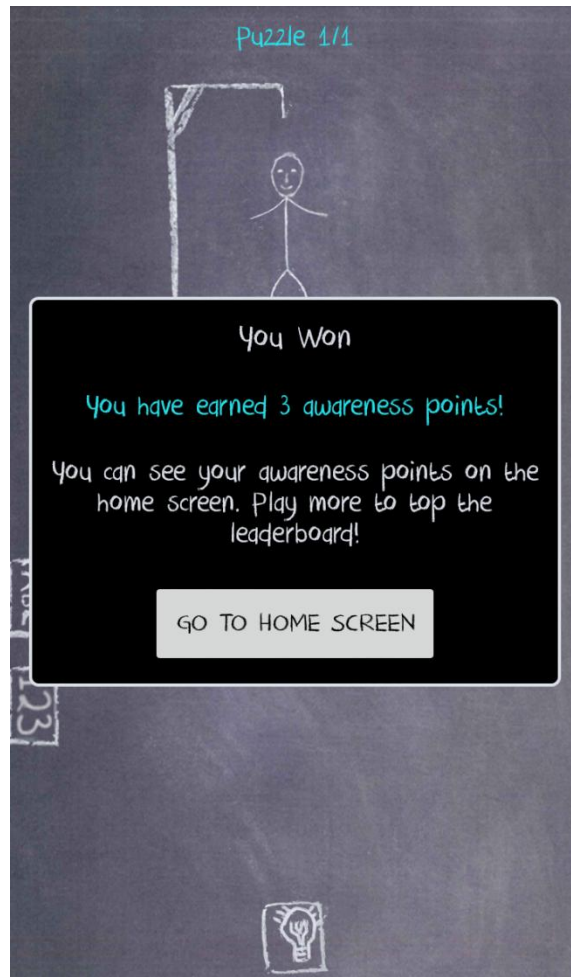


Figure 23. Puzzle success screen

This screen was added after evaluation of the game in an effort to improve the navigational flow.

Awareness points

Points for a puzzle depends on user's actions. If a user successfully solves a puzzle 2 points are given to the user. Minimum points for a puzzle is **2** and maximum is set to **5**. To gain more points there are three actions that user can perform to achieve maximum points for a puzzle. If user **opens clue** popup user is granted one point, similarly if user goes to the full article by **clicking the URL** in the clue popup another point is awarded. Finally, if **user provides feedback** another point is awarded. All the scores are accumulated to a final score that is displayed on the home screen.

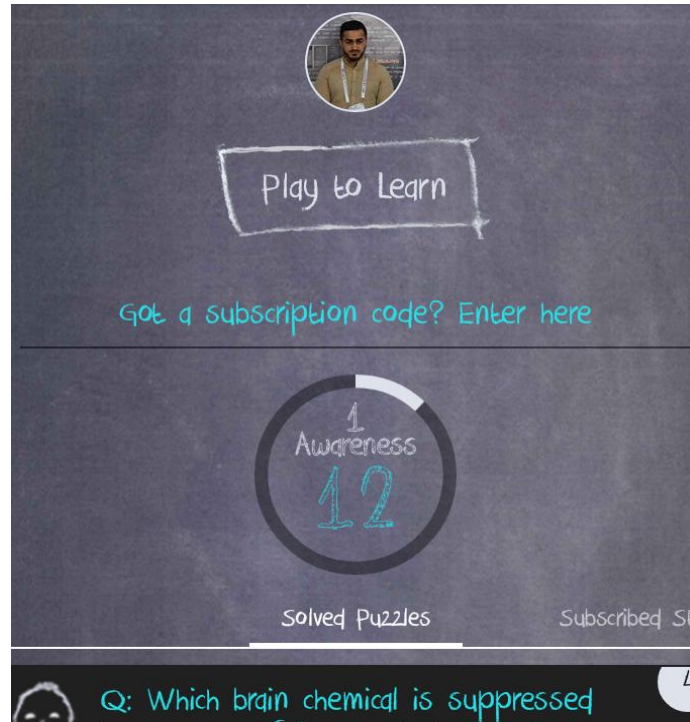


Figure 24. Awareness points

We refer these points as **awareness points**. Every time points reaches **100**, the user is advanced to the next level.

Solved puzzles

All the solved puzzles are displayed as a list on the home screen. These puzzles never show up in the new puzzles list.

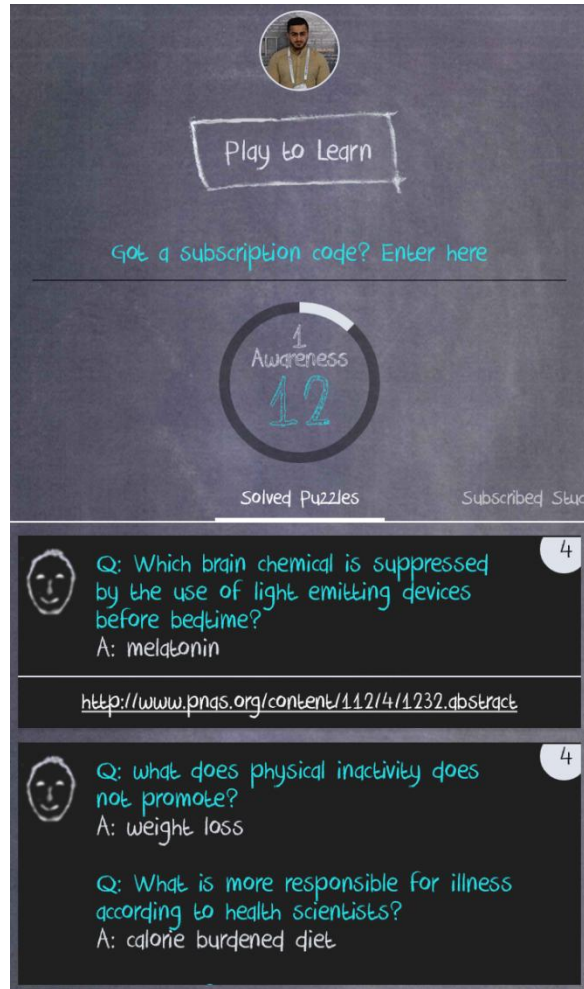


Figure 25. Home screen with list of solved puzzles

The relevant information from the solved puzzle is displayed for user's review whenever user feels like going through the puzzles solved in the past. Each solved puzzle item in the list contains questions with answers and URL to the full research article and the points user achieved in that very puzzle.

Subscription based study

User can subscribe to studies by using a subscription code. Studies are usually intended to be carried out on a certain number of audience in a controlled environment most of the time. But as we record all the responses on server, subscription code can be passed to anyone to participate remotely. The participants can play the puzzles that are part of the study as a normal puzzle explained before and can chose to test his knowledge without clue information.

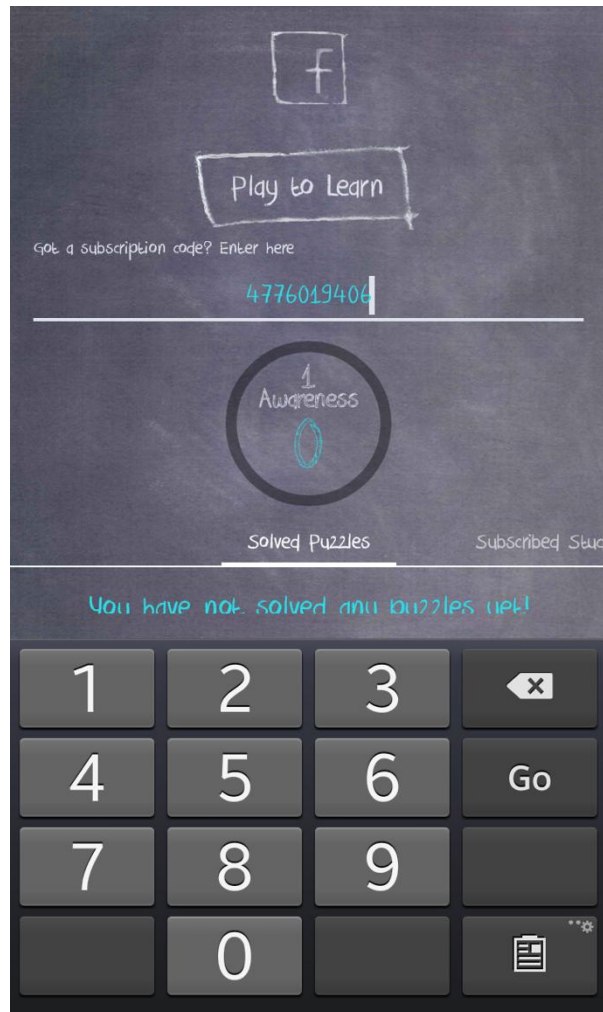


Figure 26. Using a subscription code

A subscription code is a 10 digit code. Once the code is entered user is redirected to a new screen. Also the study is added into the list of subscribed studies on the home screen.

Study screen

As studies are made up of many puzzles and puzzles can have 1 or many questions, all the questions and related research articles URLs are loaded as a list.

Cervical Cancer Screen reminder letters at
Cancer Registry of Norway

This study contains puzzle questions from the
reminder letters that are sent by CRN to women
of age 34 - 69 in order to remind and invite them
for cervical screening. Cervical cancer is growing and
it needs to be prevented. This study aims to find
how knowledgeable women and girls are

wqgasm@ifi.uio.no

Vil en HPV-infeksjon alltid gi symptomer av noen
slag?

Hint: ---

<http://www.kreftregisteret.no/no/Forebyggende/Masseundersol>

Hvor mange % av alle seksuelt aktive vil få en
HPV-infeksjon i løpet av livet?

Hint: -- -- --

<http://www.kreftregisteret.no/no/Forebyggende/Masseundersol>

Hvor lang tid tar det fra HPV-smitte til kreft
eventuelt oppstår?

SUBMIT YOUR ANSWERS

Figure 27. Study screen

Study title and a short description along with creators email address is displayed on the top. **hint** shows the number of characters in the answer to help the user. All the answers are stored on the server and user can modify them anytime he wants to.

Subscribed studies on home screen

All the subscribed studies are displayed on the home screen for quick access.

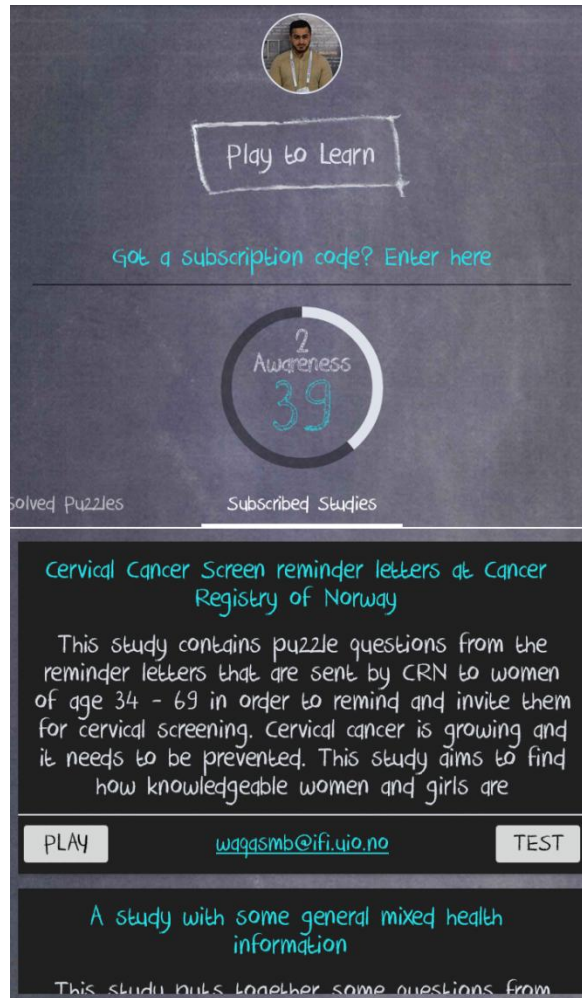


Figure 28. List of subscribed studies

This list shows study **title**, **description**, and creators **email address** along with two buttons: **Play** and **Test**. Subscribing and answering studies through tests do not contribute to awareness points. By tapping play button, user gets a filtered list of puzzles that are part of the study only. Tapping test button redirects user to the study screen where user can answer the questions without the clue information. The creator email address, if tapped, opens an email client and user can write an email to the creator.

3.5. Gamification elements in Scientific Hangman

Users need some motivation and entertainment to keep coming back to the game. To help users come back, the game has been designed in a way that mimics some classical learning approaches such as a **classroom blackboard and chalk** theme. Apart from aesthetics, we have

implemented a scoring system which helps me create a sense of competition among users. We display top players scores in a leaderboard. These are incorporated to build curiosity and introduce challenge between players. Players are also shown statistics collected from other players during puzzle selection process and to make players an integral part of the system they are asked for feedback after every puzzle. All this helps in increasing user engagement with the game

3.5.1. Leaderboard

The leaderboard is one of the most typical gamification elements. The leaderboard displays a list of players in ascending order. This helps me to create a sense of competition to be on top not just once but to stay there for a longer period by constantly playing puzzles. The points are accumulated from the current level and awareness point of the players.



Top Science Players		
1	sqgr@...	130
2	knownc...	80
3	waqas...	12
4	hmgul2...	11
5	nadjavi...	10
6	johnsh...	3
7	bxhXhX...	3
8	thomas...	2
9	www.m...	0
10	torstei...	0
11	mdthiq...	0
12	henry.g...	0

Figure 29. Leaderboard as gamification element

The current user is **highlighted** in a different color and can be seen on the 3rd position. The user awareness points go up gradually as builds the list of solved puzzles. More functionality

can be linked with the scoring system, for example, sharing a puzzle success on Facebook for extra score. This kind of social platform sharing can help me even expand the scope of the learning by sharing the puzzles information question, clue and research article URL with users outside of the game for the sake of science communication. This functionality is not part of the current version.

3.5.2. Puzzle statistics

Apart from leaderboard, to motivate users, we decided to help them with selection of a puzzle to play. We did this by displaying stats such as, **difficulty level**, **feedback**, **success rate** of puzzle along with an **insight text**. All this shows up in the insight popup. This was done to be more interactive and engaging with the end user. It tells the current user how other users did and whether the information in the puzzle has been useful or informative to them.

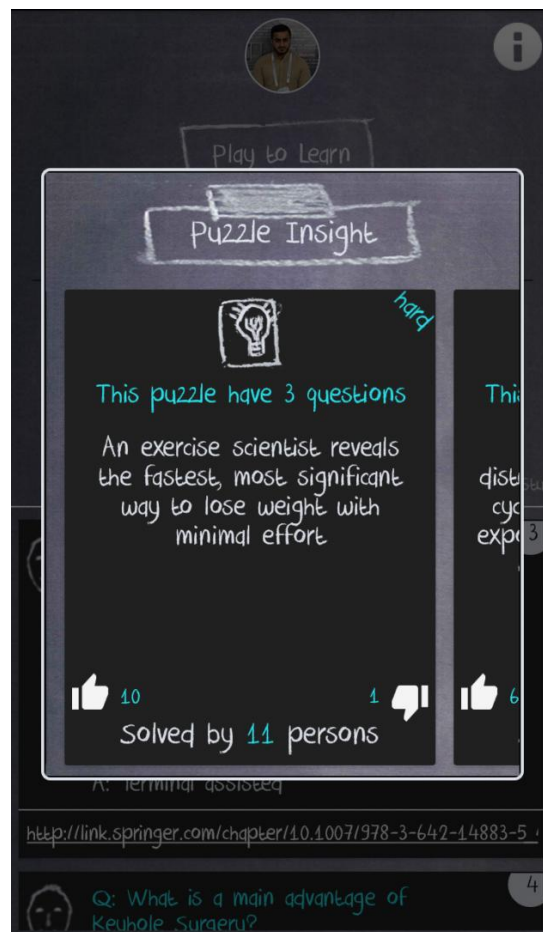


Figure 30. Puzzle stats to motivate user as gamification element

3.5.3. Feedback

Players get a chance to give feedback after solving a puzzle. This increases users engagement with the app, gives them the sense of being an integral part and not merely a subject and creates their connection with the designers and researchers behind the scenes [11]

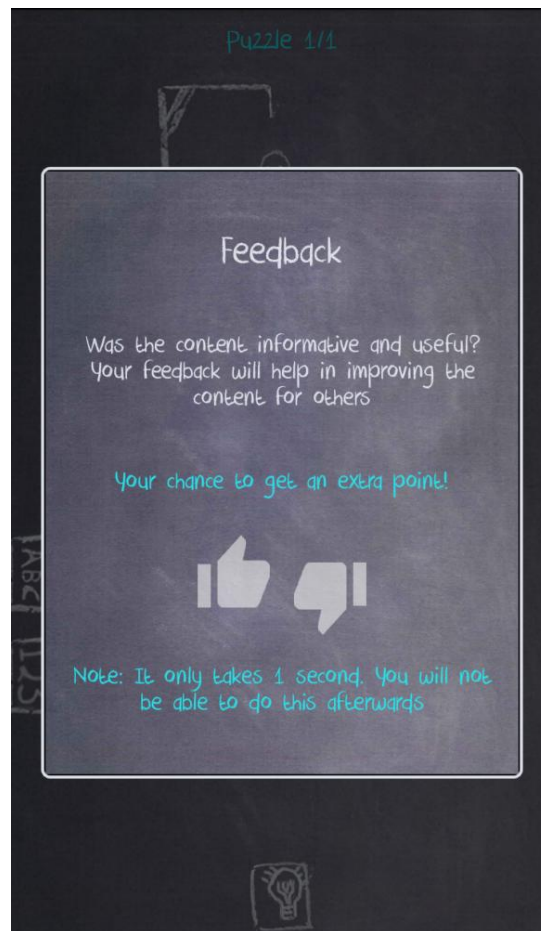


Figure 31. Feedback on puzzle as gamification element

As mentioned in the key functions sub-section of feedback is made very simple and time efficient so that users do not hesitate to respond.

3.5.4. Game Aesthetics

One purpose of the app is to present information in a form which is close to playing a game. To achieve that all elements of the game in terms of UI is designed to give a look and feel of a game. Hangman in itself is a well known traditional game known by everyone. Apart from

keeping the game element the UI mimics classical classroom theme. All of these things contribute to a better link between the concept and its implementation.

3.5.5. Discussion Related to RQ 1

We used web and mobile technology and built this framework to address RQ 1. The implementation details for both web and mobile are given in the next sub-section. The RQ 1 is stated as:

RQ 1: How can scientific evidence be simplified, gamified and communicated to general public?

This framework, through web console, lets a researcher from any domain e.g. health, climate, education, etc. to create questions-answers-clues and link them to their research. Researcher is a best person for this task as he understands his research better and in least time can come up with reasonably simple information to put in a puzzle. The web console allows the researcher to put multimedia content either a picture or a video to support the clue in addition to mandatory text. Sometimes an image or a video can be enough for the player to understand and find the answer. There are chances that multimedia content can gain more attention of the player as compared to reading the text. For this reason the clue text is limited to only 500 characters expanding to only few lines so that reading clue text is not boring for players. This also restricts the researcher from adding any irrelevant or extra information. The goal is to keep the **clue** information simple and precise. Using both multimedia content and limited text as clue lets the researcher to achieve this goal.

Other than clue text, it is mandatory to add a statement of 150 characters called **insight**. This information is shown to player at the time when he is still deciding which puzzle to solve. The insight text is there to achieve 2 goals, a) Attract player to take on the challenge and b) Pass on some interesting fact even if he chose to skip that puzzle.

To use clue and insight text in a reasonable manner depends on the puzzle creator. There is no standard procedure of creating a good puzzle. We only limit the text so that researcher is bound to add only relevant, precise and useful information required to answer the questions

which are part of the puzzle. It is up to the researcher to either make its understanding hard or easy for the player who can be, for example a 16 years old teenager or a 50 years old man.

On the other hand, mobile game communicates the information added by researchers to general public for example, **adolescents**. As stated above the player can be anyone from any educational background or age group which is why we use gamification elements to engage players. We give points based on their activity while solving a puzzle to create competition. Also, we let players to give feedback if they found the information to be useful and informative. This feedback reaches researcher who created that puzzle hence builds a flow of information between researcher and the player. Researcher can always use the feedback data to improve puzzles formation. The framework uses gamification elements to communicate the information and limits the amount of information to make it relevant and precise. However, simplicity of the information in puzzles depends on how researcher makes it. The usefulness and enjoyment factors of this framework to answer RQ 2 are discussed in **Chapter 4**.

3.6. Implementation details

In this sub-section, we will give an insight in how we implemented different parts of Scientific Hangman framework by using several popular technologies. We will include a couple of code samples along the way to give an overview of the implementation rather full details.

3.6.1. Node.js and ExpressJS

To build the server, web console and the web services, We used **Node.js**, a light weight, non-blocking platform to have as a server which is perfect for data-intensive real-time applications. We used a popular framework called **ExpressJS** that is built over Node.js. It is a minimal and flexible Node.js web application framework that provides a robust set of features for web applications. Also, building robust APIs is quick and easy through Express. It also provides a thin layer of fundamental web application features, without obscuring Node.js features. All these good things make it one of the most popular web application framework.

We use the concept of **Routing** from ExpressJS. It refers to determining how an application responds to a client request to a particular endpoint, which is a URI (or path) and a specific HTTP request method (GET, POST, and so on). Each route can have one or more handler functions, which are executed when the route is matched. For example, "/" is a route in the URL "<https://hangman-thesis.herokuapp.com/>" which serves user with index page for login and as a result redirects user to the home screen.

```
router.post('/createPuzzle', function(req, res) {
  var db = req.db;
  if(req.session.user){
    req.body.email = req.session.user.email;
    var type = typeof req.body.puzzleQuestion;
    var questions, answers, clues;
    if(type == "object"){
      ... ..
    } else {
      questions = [req.body.puzzleQuestion]; // single question: create array
      answers = [req.body.puzzleAnswer]; // single answer: create array
      clues = [req.body.puzzleClue] // single clue: create array
    }
    ... ..
    db.collection('puzzles').insert(req.body, function(err, result){
      if(err) {
        res.send({msg:err});
      } else {
        email.send({
          , ... .. ,
          to: req.session.user.email,
          cc: "",
          subject: "Puzzle submitted on Scientific Hangman"
        }, function(err, message) { console.log(err || message); });
        res.send({msg: '0'});
      }
    });
  } else {
    res.redirect('/');
  }
});
```

Figure 32. ExpressJS route POST method to create a puzzle (partial)

The code snippet in the Figure 32 is being used to create puzzles. It gets the user email address from the session to store the puzzle against it. It checks whether the puzzle data sent from the client contains a single question or an array of questions to process it accordingly. It adds the default values to the data and executes an insert query in the "puzzles" collection. On successful insert the method sends a confirmation email to the user and a success message to the web console. The database used to run the queries on is **MongoDB**, covered in the next sub-section. Another code snippet is given below which finds all the puzzles created by the current user to display on the home screen of the web console.

```
router.get('/getUserPuzzles', function(req, res) {
  if(req.session.user){
    var db = req.db;
    db.collection('puzzles').find({'email':req.session.user.email}).toArray(function(err, puzzles) {
      if(err){
        res.send({ msg: err });
        res.end();
      } else {
        if(puzzles != null && puzzles.length > 0){
          res.send({ msg: '0', data: puzzles });
        } else {
          res.send({ msg: '1' }); // list is empty
        }
        res.end();
      }
    });
  } else {
    res.redirect('/');
  }
});
```

Figure 33. ExpressJS route GET method to get user's puzzles

The route GET method in Figure 33 returns the JSON object of all the puzzles of the currently logged in user. The method first checks if the session is valid, if it is not it redirects the user to the login page of the web console. If the session is valid, it queries the "puzzles" collection and

asks for all the puzzles that have the current users email address as an attribute and returns the JSON documents as an array.

3.6.2. Android SDK

We used Android SDK to build Scientific Hangman mobile app. It is an open source platform and there are over 1 billion active android devices in the market. The code is written in Java and the UI is written in XML. We have 5 model classes:

- User
- Puzzle
- Study
- UserPuzzle
- UserStudy

Class diagram representing the structure of the classes and their relationship can be seen in Figure 34.

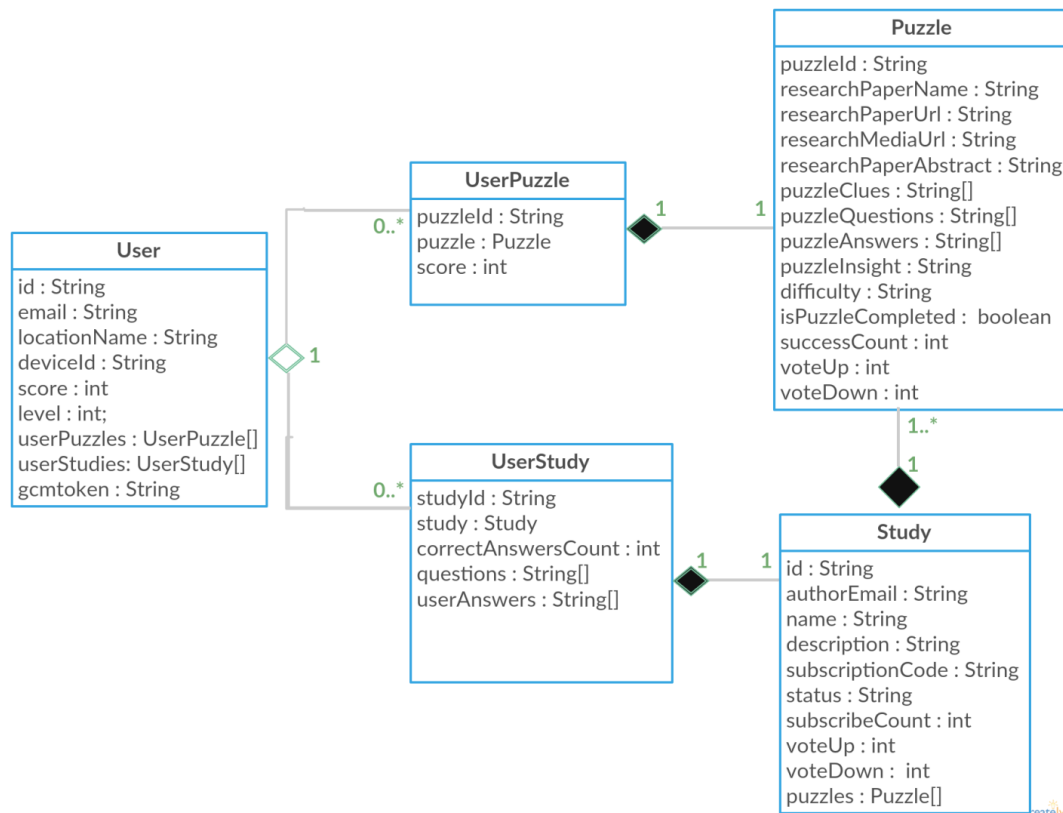


Figure 34. Android mobile app class diagram

UIs in android are designed using variety of xml elements including LinearLayout, RelativeLayout, ImageView, Button, ImageButton, ListView, RecyclerView, ScrollView and so on. Android provides a UI design tool to ease developers in designing tasks. A developer can easily drag drop UI elements and the xml code is automatically generated.

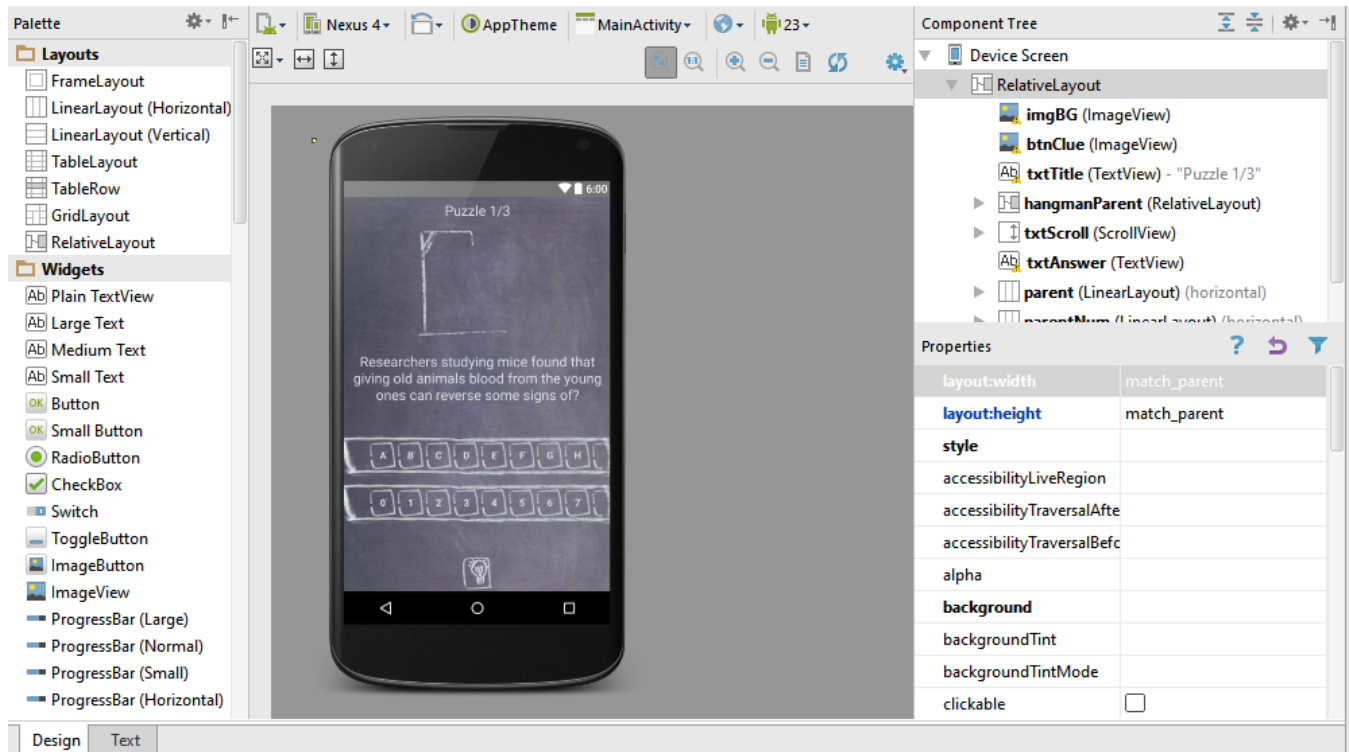


Figure 35. Android layout design tool

It also allows to set different attributes for the UI elements such as width, height, text, image source and so on. There is an option to change the orientation of the mobile screen to visualize the end result. It also contains different mobile screen sizes which comes in handy to visualize the screen without running the app on a real device.

3.6.3. RESTful web services

Scientific Hangman server, that is implemented using Node.js as explained above, provides web services which are used by web console and mobile app both. These web services allows web console and mobile app to talk to the server which communicates with the database. The

web services in Scientific Hangman are a set of relatively simple RESTful web services. REST (Representational State Transfer) is an architecture for developing web services that are scalable, have high performance and are accessible via simple interfaces [60]. Web services, for example, to fetch app player details for solved puzzles and subscribed studies, to store study answers, to record feedback by the player on a certain puzzle, to fetch the list of new puzzles and more. Following code snippet shows a "/votePuzzle" POST method on a router responsible to handle all requests generated by the mobile app.

```
router.post('/votePuzzle', function(req, res) {
  var db = req.db;
  var puzzleId = req.body.puzzle_id;
  var isUp = req.body.is_up;
  if(isUp === true) {
    db.collection('puzzles').findAndModify({_id: new ObjectID(puzzleId)},
      {},
      {$inc:{'voteUp':1}},
      {new : true},
      function (err, updatedPuzzle) {
        if(err){
          res.json({'error':err});
        } else {
          res.json({'data':updatedPuzzle['value']});
        }
      });
  } else if(isUp === false) {
    db.collection('puzzles').findAndModify({_id: new ObjectID(puzzleId)},
      {},
      {$inc:{'voteDown':1}},
      {new : true},
      function (err, updatedPuzzle) {
        if(err){
          res.json({'error':err});
        } else {
          res.json({'data':updatedPuzzle['value']});
        }
      });
  }
});
```

Figure 36. POST HTTP method to record puzzle feedback by a player

The method above runs a query on puzzle collection. It finds a puzzle, modifies it and returns the modified JSON object which is returned to the mobile app in response.

3.6.4. Database

Scientific Hangman implements **MongoDB** and it is hosted on **MongoLab** for now. MongoDB is a document-oriented database. Instead of storing data in the form of tables and rows, it stores data in JSON-like documents with dynamic schemas. Such databases are also favorable to use with Nodejs backend implementations [55]. Both web console and the mobile app perform database operations through web services that lives on the Node.js application hosted on **Heroku**. Node.js app when active is connected to MongoDB through a remote URL. MongoDB contains **collections** which store **JSON documents**. There are four collections to store Scientific Hangman data:

Web App Users

This collection stores web console users information. The following snippet shows its structure.

```
{
  "_id": {
    "$oid": "561bf283eca6051100f69e42"
  },
  "fullName": "Waqas Moazzam",
  "email": "waqasmb@ifi.uio.no",
  "password": "4f2b7fb20fbbf3ba6b4a711db72c0f408d6de4e0",
  "age": "27",
  "signupTime": "Mon Oct 12 2015 19:49:26 GMT+0200 (W. Europe Daylight Time)",
  "lastLoginTime": "Mon Dec 14 2015 18:51:02 GMT+0100 (W. Europe Standard Time)",
  "noOfPuzzles": 7,
  "noOfStudies": 4
}
```

Puzzles

All the puzzles created through web console are stored in this collection. The structure can be seen in the following snippet.

```
{
  "_id": {
    "$oid": "563001f7ad7fbd110043614e"
  },
  "researchPaperName": "Carcinogenicity of consumption of red and processed meat",
  "researchPaperUrl": "http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045%2815%2900444-1/fulltext",
  "puzzleInsight": "Processed meat has been classified as carcinogenic which is directly involved in causing cancer",
  "researchMediaUrl": "",
  "puzzleQuestion": [
    "What has red and processed meat been classified as?",
    "What kind of cancer can be caused from red and processed meat?",
    "What causes 64,500 cancers cases in UK every year?"
  ],
  "puzzleAnswer": [
    "carcinogenic",
    "colorectal cancer",
    "smoking"
  ],
  "puzzleClue": [
    "A review of 800 studies from around the world that found \"sufficient evidence in humans that the consumption of processed meat causes colorectal cancer\". The World Health Organisation has officially classified processed meat as \"carcinogenic\", alongside such notorious substances as tobacco, arsenic, and pesticides. The decision was made by the International Agency of Research into Cancer (IARC) based on the results collected from the review.",
    "According to the IARC review, for every 50 grams (1.8 ounces) of meat eaten on a daily basis - so two rashers of bacon a day - the average risk of developing colon cancer is 18 percent higher. Right now, your lifetime risk of colorectal cancer is about five percent. This means that if you eat 50 grams of processed meat every day, your risk for colorectal cancer increases by 18 percent of five percent - so your total risk is 5.9 percent.",
    "Researchers advice on diet stays the same: eat plenty of fibre, fruit and vegetables; cut back on red and processed meat, and salt; and limit your alcohol intake. It might sound boring but it\u2019s true: healthy living is all about moderation,\" says Casey Dunlop at Cancer Research UK. \"Except for smoking: that\u2019s always bad for you.\". Research has shown that 19 percent of all types of cancers are caused by smoking."
  ],
  "difficulty": "hard",
  "email": "waqasmb@ifi.uio.no",
  "status": "submitted",
  "voteUp": 2,
  "voteDown": 0,
  "successCount": 2,
  "createdAt": "Tue Oct 27 2015 23:00:07 GMT+0000 (UTC)"
}
```

Studies

Studies are made up by grouping 3 or more puzzles (max 7). Studies information along with included puzzle ids are stored in this collection. When studies are accessed included puzzle ids are used to fetch all the puzzles that are part of this study.

```
{
  "_id": {
    "$oid": "5630bc0bbbcc261100787f68"
  },
  "studyName": "Study on how daily routine and eating habits are effecting human health",
  "studyDescription": "The purpose of this study is to see how much people are informed about the choices they make daily regarding food consumption and other habits. At the same time the study discloses some facts from the scientific research as evidence",
  "puzzles": [
    "550216eec9e8101100c533b5",
    "563001f7ad7fbd110043614e"
  ],
  "email": "waqasmb@ifi.uio.no",
  "subscriptionCode": "6034443505",
  "status": "submitted",
  "voteUp": 0,
  "voteDown": 0,
  "subscribeCount": 3,
  "createdAt": "Wed Oct 28 2015 12:14:03 GMT+0000 (UTC)"
}
```

Mobile App Users

Information of mobile app users are stored in this collection. Only the ids are stored for solved puzzles and subscribed studies. The relevant information is gathered on the server from puzzles and studies collection when required.

```
{
  "_id": {
    "$oid": "55fc0a0a1ec2791100fc1669"
  },
  "location_name": "Oslo",
  "email": "sagar@simula.no",
  "device_id": "54cec4f71b32089e_1445951857544",
  "score": 0,
  "level": 1,
  "puzzles": [],
  "studies": [
    {
      "studyId": {
        "$oid": "5630bc0bbbcc261100787f68"
      },
      "correctAnswers": 0,
      "questions": [],
      "answers": []
    }
  ],
  "acheivements": "",
  "gcm_token": "fatnk7fLFXk:APA91bFVAG-
ofbFE2b3MGjufETx2lKHYUb6LBpoxFEPFfZ9VzinzJFDYZaNBpaUjn3zQDnDGyEoZuJeKhb3TX2DwU
ub1sigzKHamLLA7K8H6uTjWF9IMG4uVyE9D-p_ymZ8nu4sOO3v9",
  "last_login": "Thu Oct 29 2015 10:39:06 GMT+0000 (UTC)"
}
```

4. Preliminary Evaluation of Scientific Hangman

In this chapter we mention how a Focus Group (FG) study was conducted at Cancer Registry of Norway (CRN) to evaluate this concept in an early phase of this work. Then we explain evaluation of **SH** as a science communication tool by employing Technology Acceptance Model (TAM). We use this method of evaluation for web console and gamified mobile app. Then we continue with the results in the form of graphs and discuss prototype 1 and current version of the framework in their respective sub-sections.

4.1. Prototype 1: Focus Group Study at CRN

A Focus Group study was conducted to evaluate the concept of communicating scientific content to general public via a mobile game. Focus groups (FG) are commonly used as a qualitative research method in many research areas such as education, health, information systems etc [61]. FG creates an environment where participants feel safe to share experiences, ideas and beliefs in the presence of other participants which share the same belief or experiences [62]. Prototype 1 mentioned in section 1.1 of this manuscript was tested at CRN with a focus group.

4.1.1. Study Setup

In this study 6 women participated. We presented three different information letters to the women. The letters contained information regarding cervical cancer screening. One letter was to invite women between 25 and 64 to a cytology test¹¹. A second letter was a reminder letter for attendance. The game contained a total of 9 questions equally divided on 3 letters. Although the letters were not scientific articles, they were often ignored by recipients due to some of its technical content. The game was installed on a single Android device and was projected at a bigger screen for every participant to see. The women were separately given the smart phone and were asked to answer the questions based on the information they received

¹¹<http://www.cancerresearchuk.org/about-cancer/type/cervical-cancer/about/cervical-cancer-screening>

earlier in the letters which was also present in the game in the form of clue. They could read the information as many times as they wanted within the game. The game content structure in the form of question-answer-clue allowed them to divide their concentration from a full letter to finding answer to the question in hand. This process also made them read other information present in the letter as clue. We recorded the steps the women performed during the game for example how many times they opened the clue window to read the letters, how many right/wrong entries they made and the time they spent on answering the question. The purpose was to test their knowledge from those letters, to see how well they received the information mentioned in the letters.

4.1.2. Results and Discussion

The information letters were short and less technical as compared to scientific literature. All 6 women submitted the answers and were able to answer all of the puzzle questions in the game correctly, more or less consuming the same amount of time. This showed that the information flow was good and that the participating women understood the information as they only had to find answer to 1 question at a time. After the experiment we evaluated that the participants paid attention to the information letters to answer the puzzle questions because the information flow was created in the form of an interesting activity i.e. a game.

From their responses, we learnt that design matters to the user interacting with the game. Design should be appealing to generate a positive emotion which as a result can trigger increased interaction. The first impression of this prototype in terms of design was not positive. Participants were told that it is a game but they perceived it more like an application rather than a game. This was due to an out of context theme, screenshots can be seen in section 1.1 of this manuscript. On the other hand, the sense of achievement is critical. The harder the effort on achieving goals more likely it is that the user will lose interest. The goals must be according to the skills of the users to keep them interested. That means the information should be simplified enough so that the user do not lose interest. For example, the content used in this prototype was from the invitation letters, as stated above, having simple and less technical

information. The women found the information easy to understand which was also evaluated by the results they submitted through the game.

Moderator of the FG asked all the women if this kind of application will be useful in becoming knowledgeable about cervical cancer and HPV, to which majority of the women in the FG agreed. The problem we saw was the lack of willingness to download an app on their smart phone. We cannot be certain about the reason as it was a small group. One possible reason could be due to their age and lack of interest in mobile apps as compared to the popularity of smart phones and mobile games and applications in the youth.

Participants showed more interest on having such a quiz like application on social platform where they could compete with other users and share as well. As the game was in a very early stage with hardcoded game content, it did not have any gamification elements such as leader boards and social network integrations (such as sharing on Facebook) which could be used to evaluate their interest in the mobile app rather than on any social network.

The feedback we gathered from FG was very valuable in moving forward with the concept of science communication via a hangman game. We develop a content management system, web console, for creating game content and improved mobile app with sophisticated game aesthetics and gamification elements. These improvements have already been explained in Chapter 3 of this script.

.

4.2. Evaluation of Scientific Hangman Web Console

We used TAM to evaluate the web console. It was proposed by Davis in 1989 [5] and it can be defined as "an information systems theory that models how users come to accept and use a technology" [63]. This method was employed as technology adaptation has been a major area of research within Information Systems and user acceptance is a critical success factor in it [50]. TAM has 3 features of user acceptance: *perceived ease of use*, *perceived usefulness* and *intention to use a system*.

- **Perceived Ease of Use (PEOU):** "the degree to which a person believes that using a particular system would be free of effort" [5]
- **Perceived Usefulness (PU):** "the degree to which a person believes that using a particular system would enhance his or her job performance" [5]
- **Intention to Use (IU):** "the extent to which a person intends to use a particular system"

4.2.1. Study Setup

Web console was hosted on Heroku and it was accessible everywhere. An email was written explaining the purpose of web console and its use. The email explained the criteria to fulfill before answering the questionnaire. The web console also had a Youtube video URL showing the functionality of the mobile game. A signup restriction to use institute email id was added to make sure every participant taking part was linked to an institution. Participants were asked to create 1 or 2 puzzles in order to experience the process. We created a questionnaire via Google forms to collect responses from different participants. The questionnaire had 4 sections: personal Information, PEOU, PU and IU. Other than first section of personal information we used 7-likert scale system. We added a comment box at the end of the survey for participants to collect their useful suggestions or criticism. The entire questionnaire is shown in Appendix A. The comments left by participants can be read in Appendix B.

4.2.2. Study Results and Discussion

A total of **seven participants** from different research and clinical backgrounds took part in the study. We removed 2 participant's response as we observed they did not create any puzzle in fulfillment of criteria to answer the questionnaire leaving us with only five participants. The data representing diversity in participants is demonstrated below:

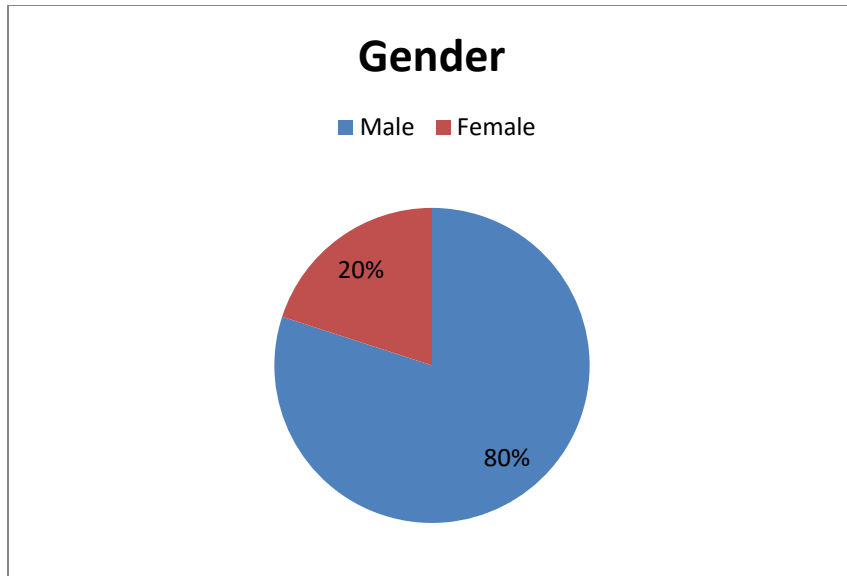


Figure 37. Study participants for Web Console divided over gender

80% (4 out of 5) participants were male and only 20% (1 out of 5) was female.

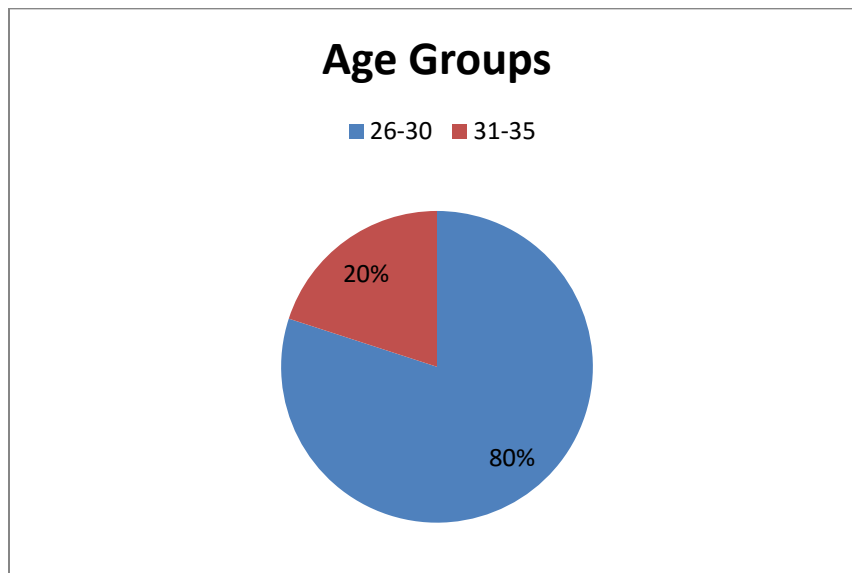


Figure 38. Web console participants age group

80% (4 out of 5) participants were aged between 26 - 30 and only 20% (1 out of 5) was in age group 31 - 35.

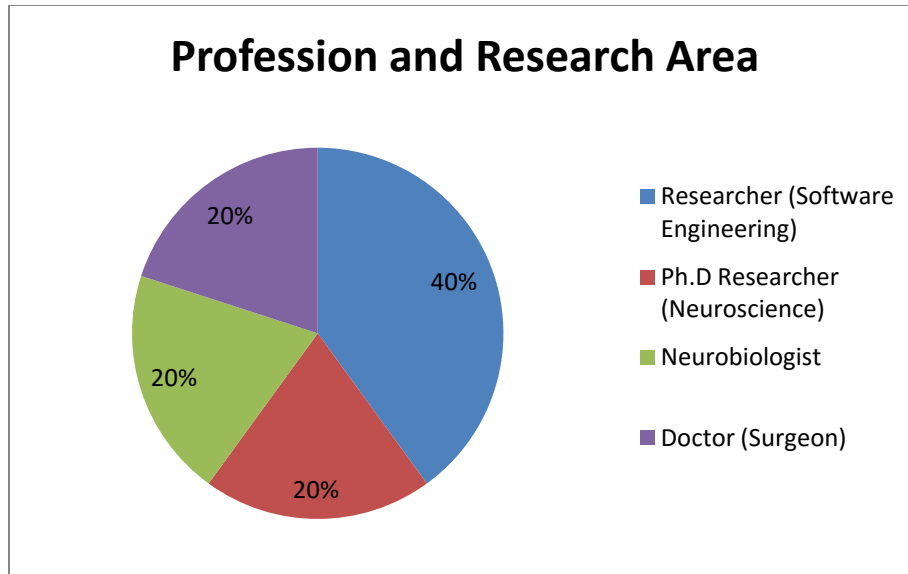


Figure 39. Profession and research area of web console participants

40 % (2 out of 5) participants were Researcher from Software Engineering domain, 20% (1 out of 5) from Surgery and 40% (2 out of 5) were from Neuroscience domain (counting Neurobiologist in Neuroscience domain). Following is a discussion on results sub divided into TAM features: PEOU, PU and IU.

Perceived Ease of Use (PEOU)

In this section we had 7 statements and a 7-likert scale system scaled from strongly disagree to strongly agree. 7-likert scale was used to allow the participants to be more granular in their response.

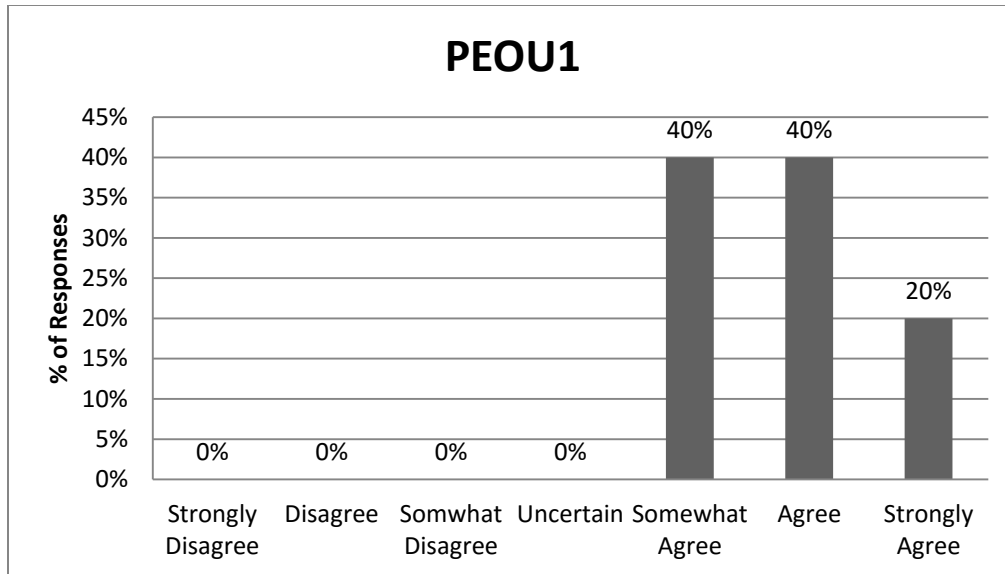


Figure 40. PEOU1 My interaction with the web console was clear and understandable

The graph shows 100% (5 out of 5) participants agreeing on clarity and understandability of the web console. As part of ease of use feature of the system and to help the first time users, we added a step by step walkthrough guide educating the participant about navigation and the purpose of each and every element in the web console.

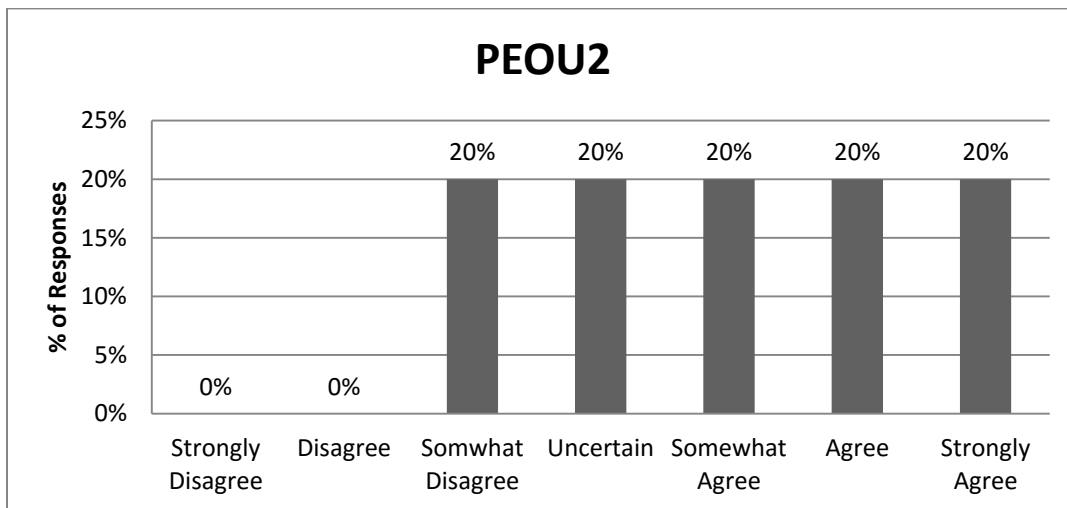


Figure 41. PEOU2 Interacting with the web console did not require a lot of my mental effort

60% (3 out of 5) participants more or less agreed that not much of mental effort was required in interacting with the web console. In conjunction to PEOU1 we find this true as all participants agreed that the interaction was clear and understandable. 20% (1 out of 5) disagreed and 20% (1 out of 5) were uncertain. We assume this difference with PEOU1 is due to misunderstanding

of 2 participants. They might have confused the creation of puzzle (which obviously requires some mental effort) with web console interaction. We cannot be completely sure about it as we did not collect comments on individual statements.

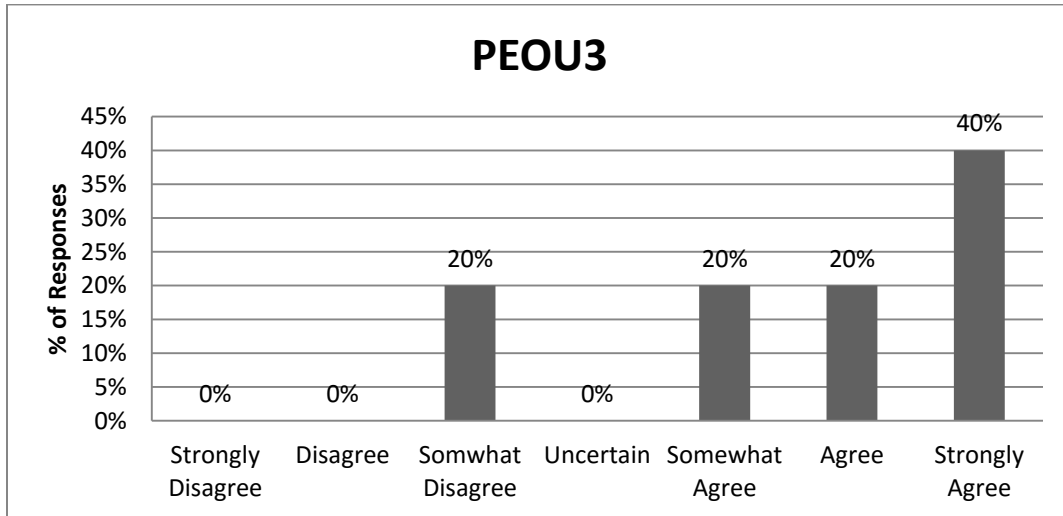


Figure 42. PEOU3 I found the web console to be trouble free

On the statement for web console being trouble free 80% (4 out of 5) participants agreed and only 20% (1 out of 5) participants disagreed.

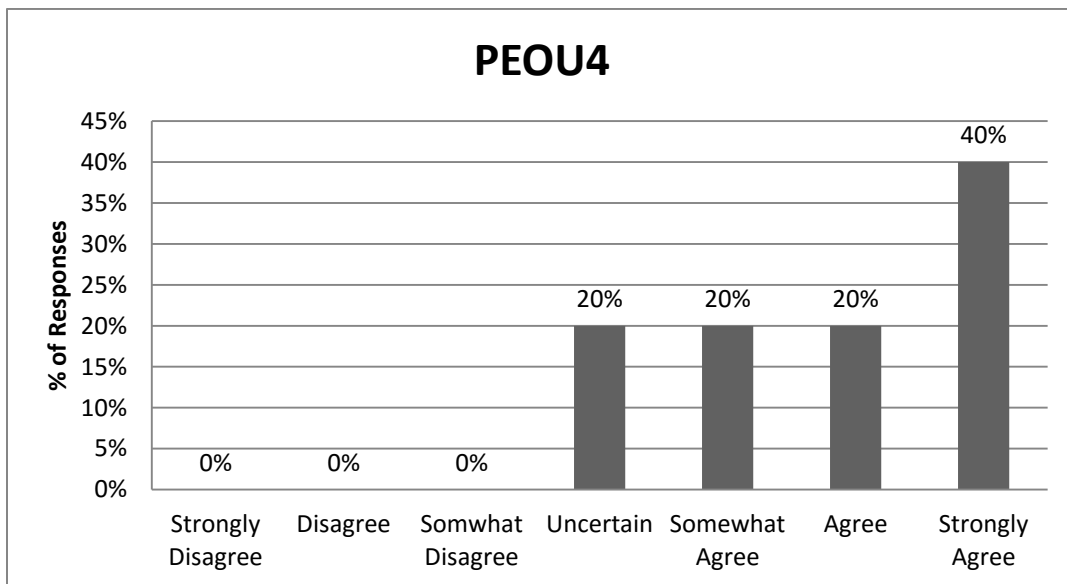


Figure 43. PEOU4 Learning the use of web console was easy for me

80% (4 out of 5) participants agreed that learning the use of web console was ease for them and only 20% (1 out of 5) were uncertain about this statement. The step by step walkthrough

provided on each page of the web console was descriptive and explained the use of each and every element. However, the walkthrough was not enforced on the user and user was free to start the walkthrough if needed.

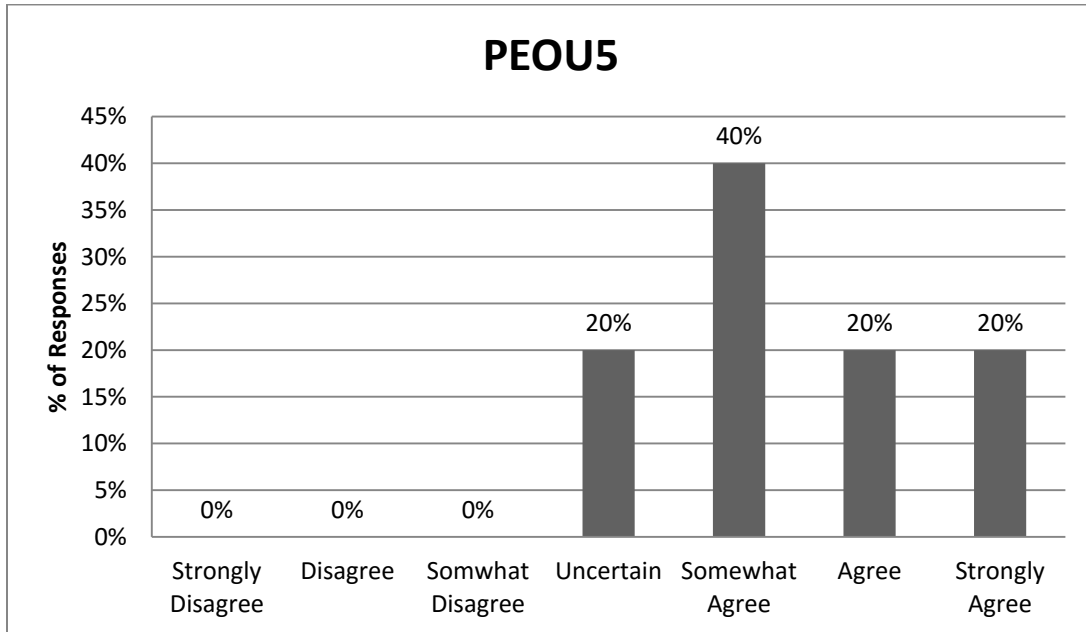


Figure 44. PEOU5 It was easy to do what I wanted with the web console

80% (4 out of 5) participants more or less agreed that they were able to perform their desired actions in the web console. Possible actions could be create a puzzle/study, check the details of puzzle/study and delete a specific puzzle/study. Only 20% (1 out of 5) participants were uncertain on this statement.

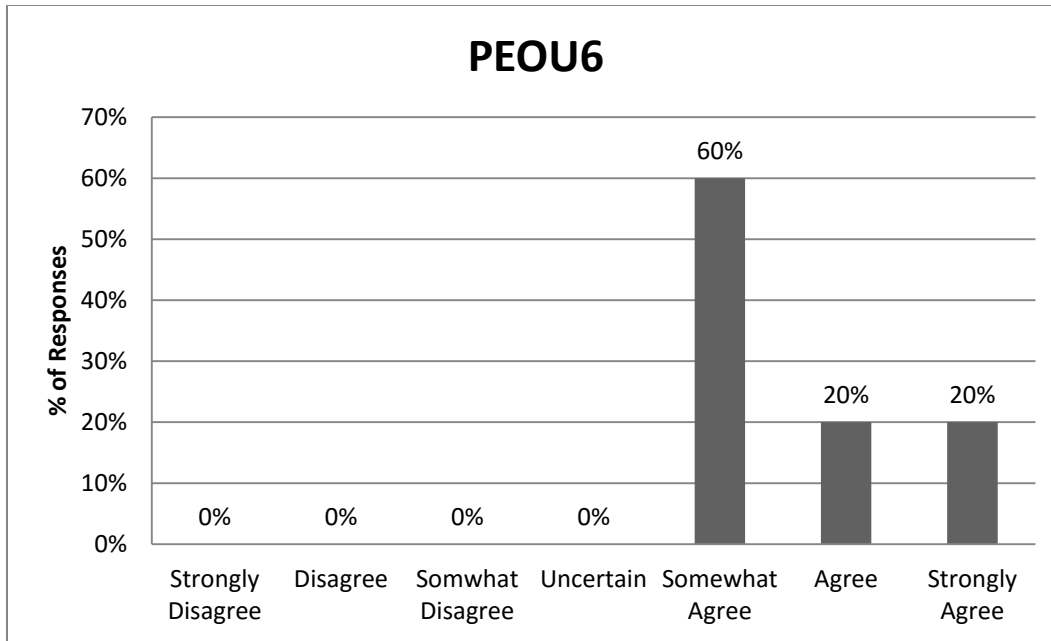


Figure 45. PEOU6 I found the web console easy to use

On a general statement about ease of using web console 100% (5 out of 5) participants more or less agreed.

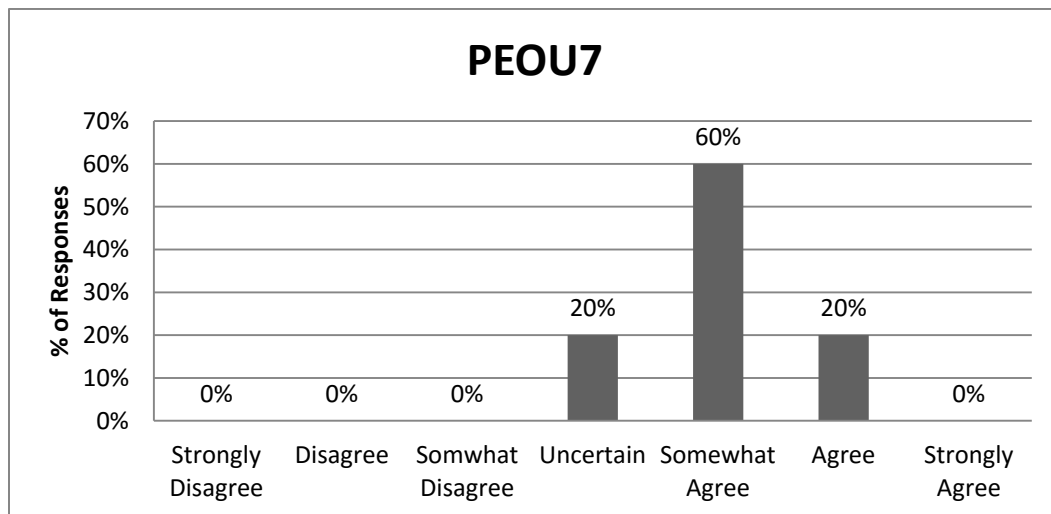


Figure 46. PEOU7 I found web console easy an easy way of communicating with general public

This statement was added to see if participants being researcher find this way of communicating their scientific research an easy way. It is related to ease of use in terms of putting simplified information through the console. 80% (4 out of 5) participants more or less agreed on this statement but 20% (1 out of 5) were uncertain. We only asked participants to

create 1 or 2 puzzles to understand the process. In order to be more certain in their response more interaction in terms of creating puzzles or studies was required.

More or less we see agreement on PEOU construct of TAM which means web console was easy to use and participants had good understanding of interaction.

Perceived Usefulness (PU)

This section had four statements and a 7-likert scale system scaled from strongly disagree to strongly agree. 7-likert scale was used to allow the participants to be more granular in their response.

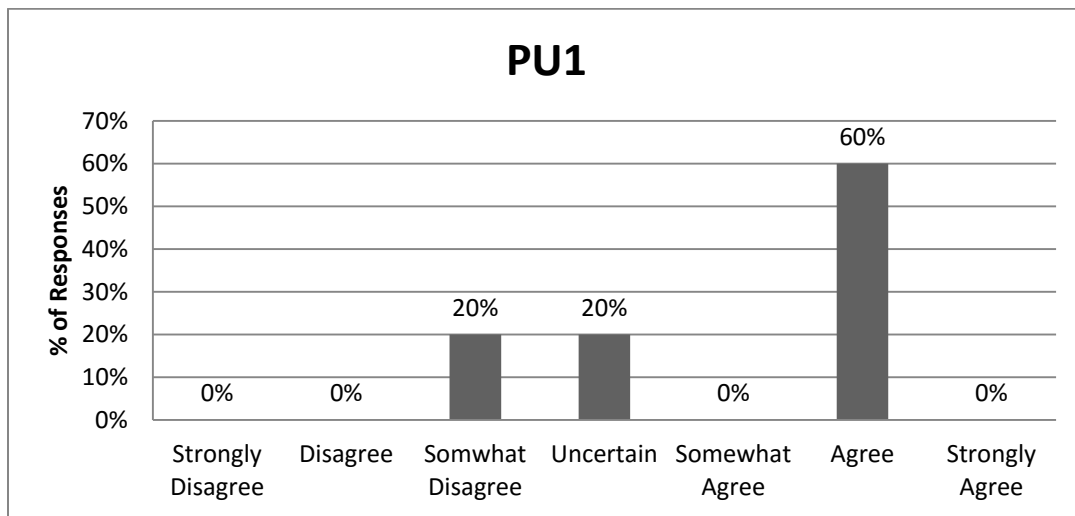


Figure 47. PU1 Creating puzzles based on scientific content through web console is a useful strategy

60% (3 out of 5) participants agreed that the strategy of creating puzzles based on scientific content is useful. 20% (1 out of 5) somewhat disagreed with the statement and only 20% (1 out of 5) were uncertain. As mentioned before, we did not collect comments on individual statements so we cannot say what they thought about this strategy or how they would have found it to be useful. We can assume that their research interests could be such that cannot be of general public interest. For example, a researcher studying cellular reactions post spinal cord injury could be of little importance to general public even if simplified.

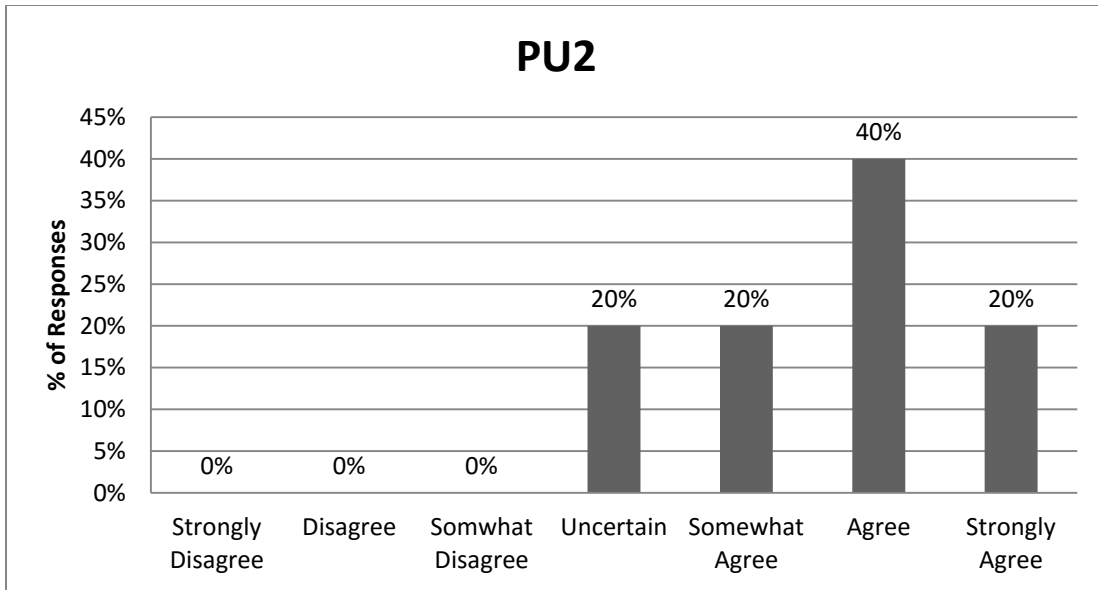


Figure 48. PU2 The question-answer-clue formation of puzzles is simple and useful way of communicating scientific evidence

Puzzles in mobile game are presented in question-answer-clue setting. The statement on this setting being simple and useful in communication received 80% (4 out of 5) agreement by participants and only 20% (1 out of 5) were uncertain about it.

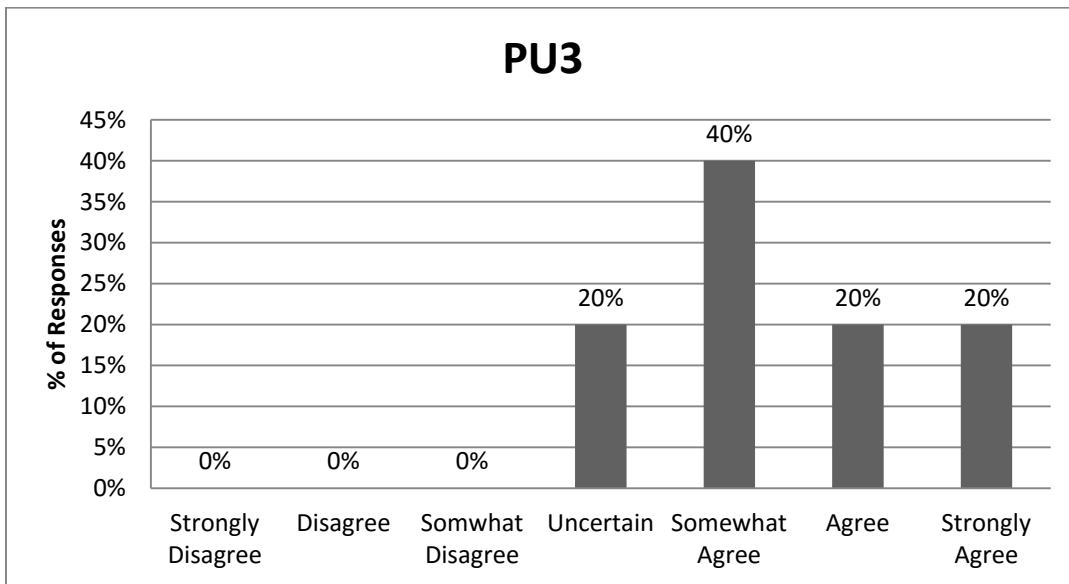


Figure 49. PU3 Grouping puzzles into studies is useful to conduct studies remotely and see responses in the web console

As web console evaluation was not controlled, it was feared that participants won't be able to allocate enough time to create 3 puzzles (min requirement to create a study) to group them

into a study. Hence, they were asked to perceive the usefulness of conducting studies through web console. It was assumed to be easy for researchers and being used to the idea of conducting studies. Moreover, a step by step explanation of creating a study was provided to give them an understanding of the purpose. 80% (4 out of 5) participants more or less agreed to the statement of studies being useful. However, 20% (1 out of 5) were uncertain about it.

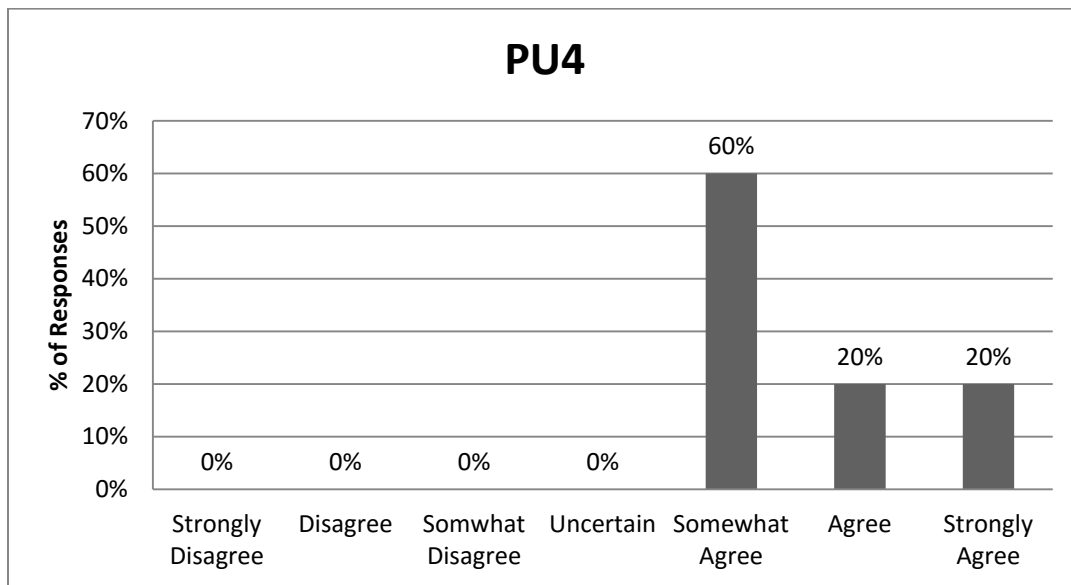


Figure 50. PU4 Scientific Hangman web console can be useful in creating a direct communication channel between researcher and the general public

The purpose of this framework is to build a direct communication channel between researchers and general public on domains of their interest. On a statement about usefulness of the web console as a direct communication channel between researcher and general public, 100% (5 out of 5) participants more or less agreed.

Responses on PU1 - PU4 have showed more or less agreement meaning the web console and puzzles as communication strategy was considered useful in general terms.

Intention to Use (IU)

Intention to use had two statements. It was also evaluated through a 7-likert scale system scaled from strongly disagree to strongly agree. It was used to allow the participants to be more granular in their response.

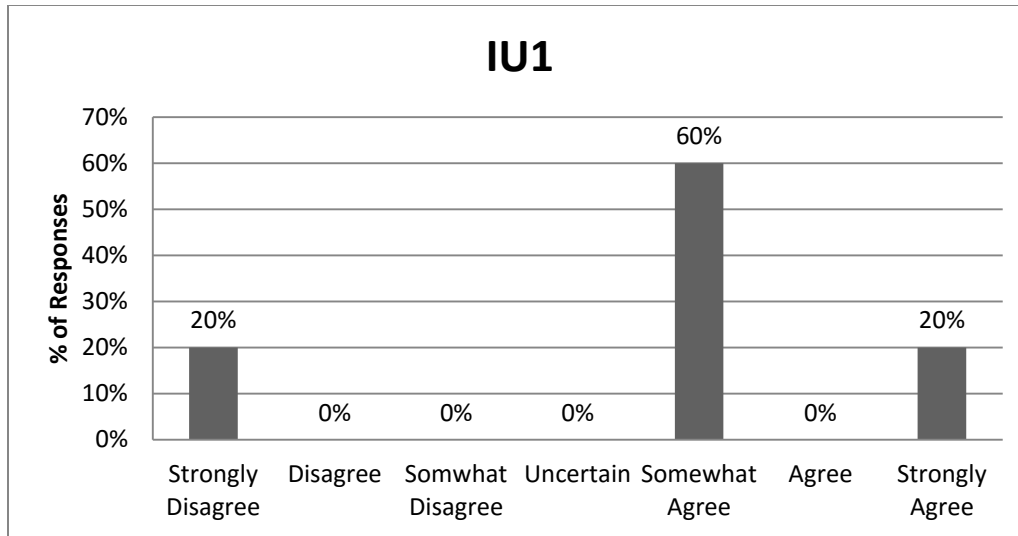


Figure 51. IU1. I as a researcher/doctor intend to continue using Scientific Hangman web console to create puzzles/studies based on scientific evidence

On the statement of participants' intention to continue using this web console, only 80% (4 out of 5) participants more or less agreed. However, 20% (1 out of 5) strongly disagreed. Again, this greatly depends on the research interests and background of a researcher. If research is of a nature that cannot be interesting and useful to general public then it is also not interesting for the researcher as it requires both mental effort and time. This difference could be more visible when study population is huge bringing diversity in research interests and background.

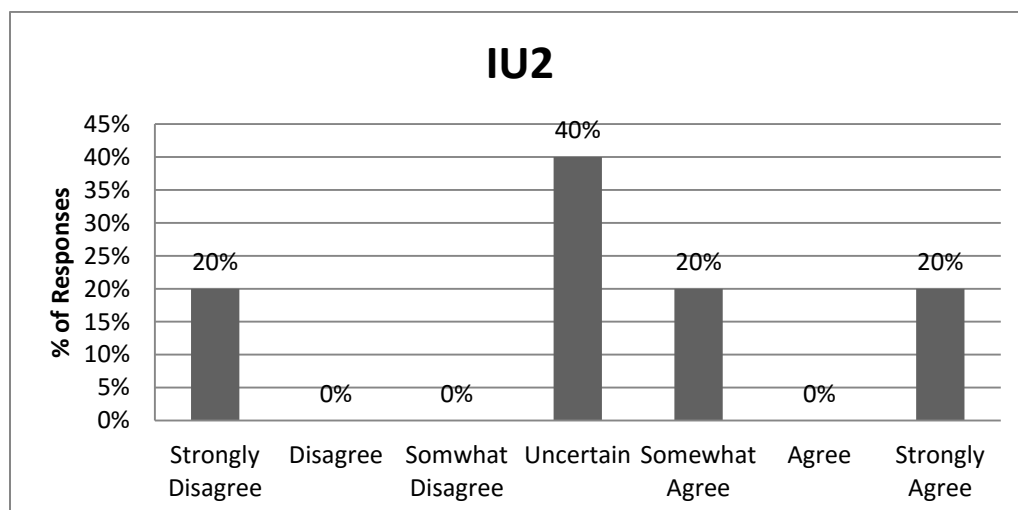


Figure 52. IU2 I as a researcher/doctor expect my use of it to continue in the future

A final statement on researchers/doctors expected use to continue in future only 40% (2 out of 5) participants agreed. Uncertainty was same as agreement and 20% (1 out of 5) strongly

disagreed. One limitation that relates here is of mutual benefit. The web console at the moment does not provide any sort of benefit to the researcher/doctor. The benefit could be of any type for example, ranking popularity of their research in general public. This could be considered as a gamification element for web console, also discussed in Chapter 5 Future Work section. At this point in time the web console provides basic functionalities to create puzzles/studies for a proof of concept but fails to give value to its end users.

4.2.3. Study Limitations

We find it important to mention few limitations in web console evaluation and encourage forthcoming master research students to overcome these limitations in order to achieve higher quality of results. The limitations are as following:

- The evaluation study had small number of participants i.e. 5
- Lack of gamification factors in web console to motivate researchers
- Lack of mutual benefits for researchers to make the system more interesting for them
- The evaluation was not controlled that might have created a difference in understanding of the tasks.
- Evaluation did not cover *creating a study* feature of the web console
- We lacked researchers from the domain of health, climate and education

This study was conducted in 1 week due to which we could not have much participants. Definitely more participants with diversity in research interests are required to ensure better results and effectiveness of the system. Also work on making the system interesting and valuable for researchers is also required to gain good results. The study should have been controlled as the understanding level of tasks through a large piece of text could vary among participants. Also, controlled evaluation could have also allowed testing of the feature "creating a study". The answers we received on statement related to "creating a study" are assumed to be participant's perception about its use and purpose. Nonetheless, we believe to have received good feedback on different aspects of the web console through TAM features which helps us to answer our research question in the next sub-section.

4.2.4. Discussion Related to RQ 2

The purpose of the evaluation is to answer the research question stated in **Chapter 1** which is as follows:

RQ 2: Can a communication channel between researchers and general public be useful and fun?

This research question holds both aspects of the framework that is web console and mobile game. We ask sub-research questions to use web console evaluation results to answer usefulness of the web console. The following sub question needs attention in this context:

RQ 2.1: Is web console useful in communicating simplified scientific evidence?

To answer RQ 2.1, let us recall results from each section of the questionnaire i.e. PEOU, PU and IU. The following table presents results of all statements grouped by agreement, disagreement and uncertainty.

Table 2. Web console evaluation results grouped by disagreement, uncertainty and agreement on TAM constructs

	Disagreed	Uncertain	Agreed
PEOU1	0%	0%	100%
PEOU2	20%	20%	60%
PEOU3	20%	0%	80%
PEOU4	0%	20%	80%
PEOU5	0%	20%	80%
PEOU6	0%	0%	100%
PEOU7	0%	20%	80%
Average of PEOU	5.7%	11.4%	82.9%
PU1	20%	20%	60%
PU2	0%	20%	80%
PU3	0%	20%	80%
PU4	0%	0%	100%
Average of PU	5%	15%	80%
IU1	20%	0%	80%
IU2	20%	40%	0%
Average of IU	20%	20%	60%

Table 2 highlights the following key points:

- **82.9% Participants agreed on perceived ease of use of the web console**
- **80% participants agreed on perceived usefulness of the scientific communication through puzzles**
- **60% participants showed their intention to use the web console in future**

To increase **Perceived Ease of Use** of a system, the actions available in a system should be made more accessible and as simple as possible. This is to avoid any type of mental effort to understand or find a way of making an available action. However, ease of use also depends on end user understanding of computer systems. For example, any user fond of using different apps mobile or web would become quickly used to any new app. This is due to the familiarity of common elements between applications. PEOU is high, 82.9%, but there are chances of low PEOU if there comes participants from domains which do not require much use of such systems. Educating such users could help them in understanding the system.

However, it is different in case of usefulness of a system. For a high **Perceived Usefulness**, the interest of researcher should align with the system. If for example, a researcher interested in rocket science is asked to use the system, there are some chances that he will not find it useful due to complex pieces of information from his domain. Such information for general public might not be as relevant as health or climate. However, such domains could be used for puzzles to trigger interest of game users in such complex domains. Bringing researchers with diverse research interest to evaluate this framework could result in a lower PU value. We have mentioned low number of participants as a limitation in previous sub-section. This should be tested with big study population.

We conclude that, this is a useful strategy of communicating scientific evidence in simplified form. But this might not hold true for all domains. A survey should be conducted to find out the kind of domains and information general public is interested in finding about.

4.3. Evaluation of Scientific Hangman: Gamified Mobile App

Due to gamification aspects of the mobile app, we evaluated it by employing another version of TAM proposed by Davis et al., in 1992 [4]. The only difference between the model proposed in 1989 and the model proposed in 1992 is an added feature in the latter. The new feature that was added in 1992 is *perceived enjoyment*. This construct was added to study recreational systems as done by Van der Heijden in 2004 [51].

Perceived Enjoyment (PE): "the extent to which the activity of using the computer is perceived to be enjoyable in its own right" [4].

4.3.1. Study Setup

The Android game was submitted to Google Play Store for the users to download and play. Another questionnaire via Google forms was created to collect responses of the participants for the mobile app. It had **five sections**: personal information, PEOU, PE, PU and IU. We used 7-likert scale system for the statements on TAM constructs. A comment box was also added at the end of the survey to allow participants to give their suggestions or critic about the game. The entire questionnaire is shown in Appendix C. The comments left by few participants can be read in Appendix D. We posted the questionnaire with live URI of game on Facebook but did not see much response. So we decided to contact few people from student housing at the University of Oslo. We also reached some researchers at Simula Research Lab to play and fill the questionnaire. There was no specific criteria to chose a participant as the intended users can be anyone in the general public. The only requirement was that user must be an Android phone owner as the game is currently only on Android platform. The participants were from different educational backgrounds. They were asked to play and score 20 to 30 before answering the questionnaire. A score of 25 means the player solved 5 puzzles at maximum and around 13 puzzles at minimum. This difference is due to the actions that user takes while solving the puzzle as explained in key functions in Chapter 3. They were also asked before hand to focus on the factors such as how easy it is to use the game, if it is enjoyable or not and if they consider the information presented through game puzzles to be useful and easy to understand.

4.3.2. Study Results and Discussion

A total of 11 participants from different educational backgrounds installed the game, played and fulfilled the criteria required to fill the questionnaire. Some of them also gave feedback on the game itself. All of the participants had fair idea of using mobile applications and games. The data representing diversity in participants is demonstrated below:

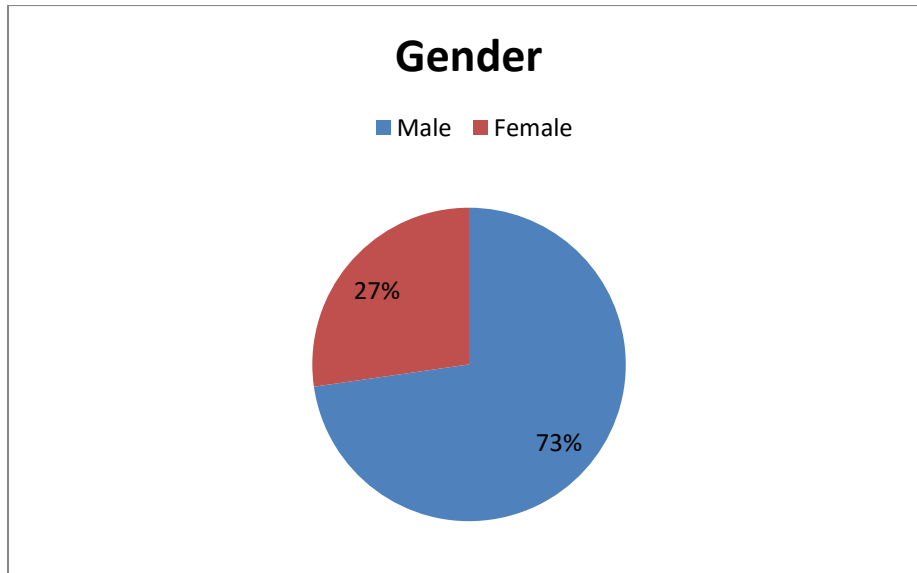


Figure 53. Study participants for Mobile Game divided over Gender

73% (8 out of 11) participants were male and 27% (3 out of 11) were females.

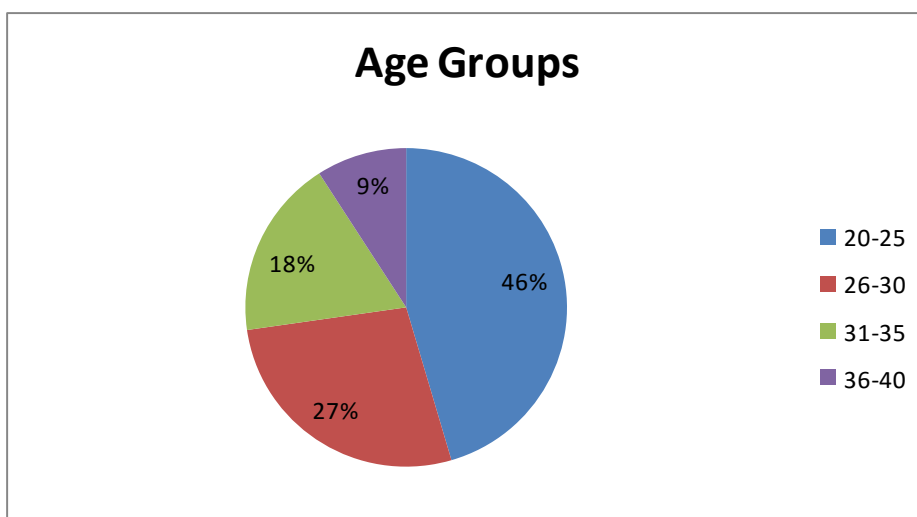


Figure 54. Mobile game participants age group

Most of the participants 46% (5 out of 11) were 20-25 years old. 27% (3 out of 11) participants were 26-30 years old.

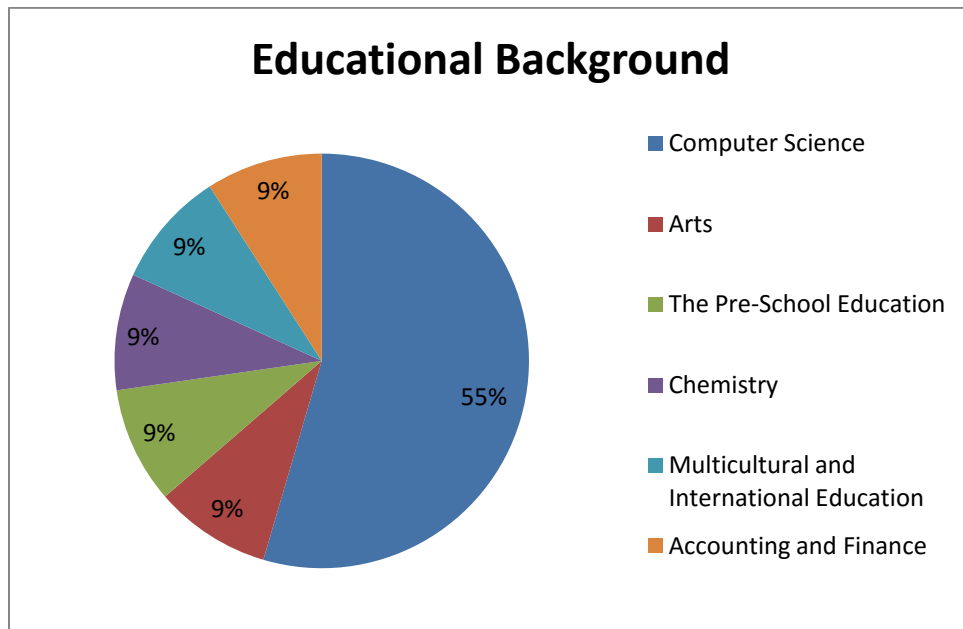


Figure 55. Educational background of mobile game participants

Out of all participants 9 were Master students and two were researchers from Software Engineering domain. 55% (6 out of 11) had Computer Science background, 18% (2 out of 11) had Education background (Pre-School Education and Multicultural and International Education combined). 9% (1 out of 11) were from Arts, Chemistry, Accounting and Finance backgrounds each. Following is a discussion on results sub divided into TAM features: PE, PEOU, PU and IU.

Perceived Enjoyment (PE)

In this section we had 5 statements and a 7-likert scale system scaled from strongly disagree to strongly agree and for negating questions it scaled from Strongly Agree to Strongly Disagree. 7-likert scale was used to allow the participants to be more granular in their response. Some questions can be seen as overlapping in terms of fun, enjoyable and pleasurable. These were to assess the quality of responses and to assure that there were no random responses.

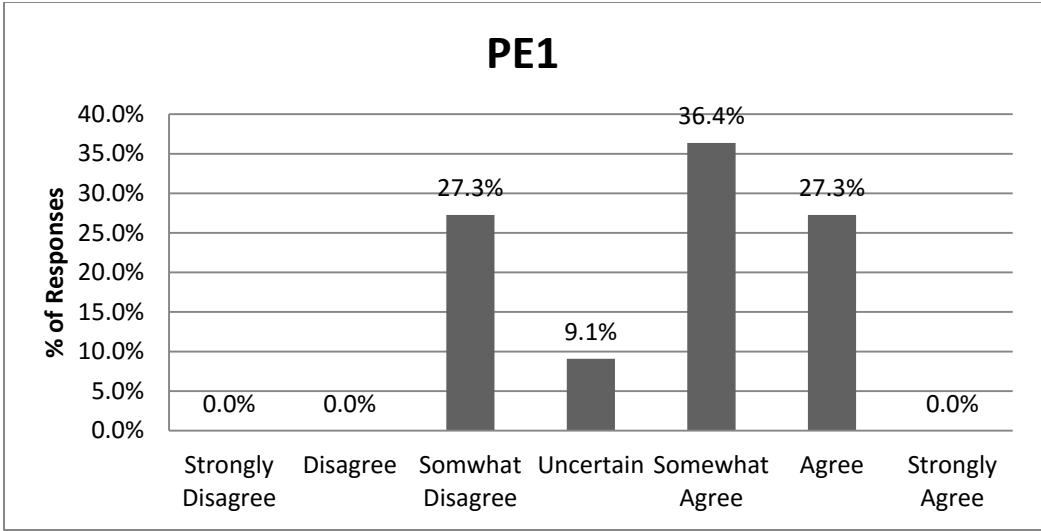


Figure 56: PE1 I found playing the game to be enjoyable

For the statement if the game was enjoyable, 63.6% (7 out of 11) participants more or less agreed to the statement.

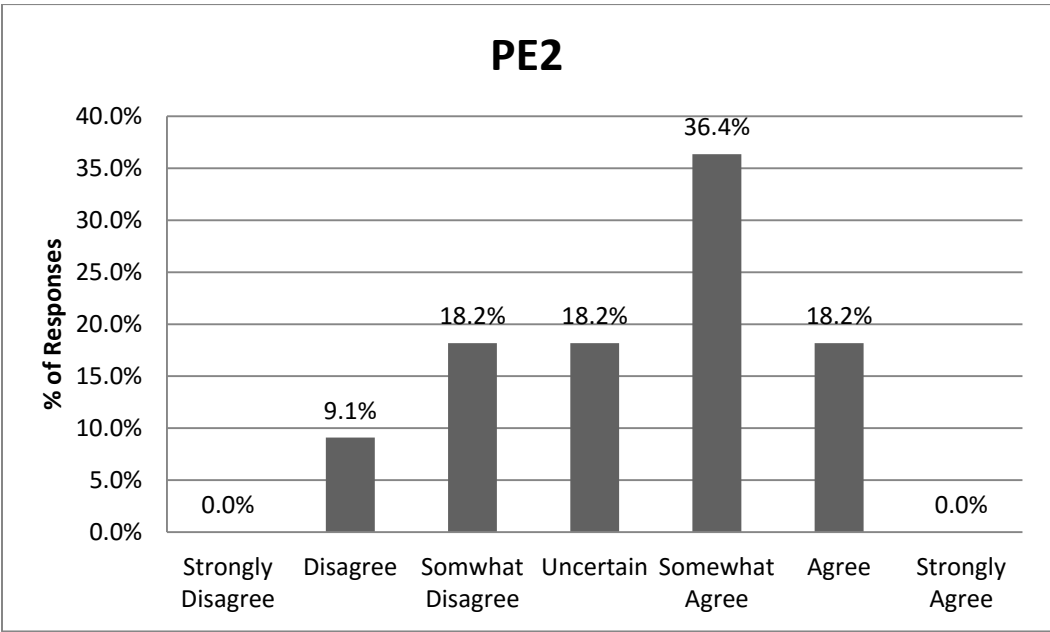


Figure 57. PE2 I had fun using the game

For the statement if they had fun using the game, only one participant completely disagreed and two somewhat disagreed. Two of the participants were unsure if the game really was fun to play or not. However, 54.5% participants (6 out of 11) tend to show agreement on the statement.

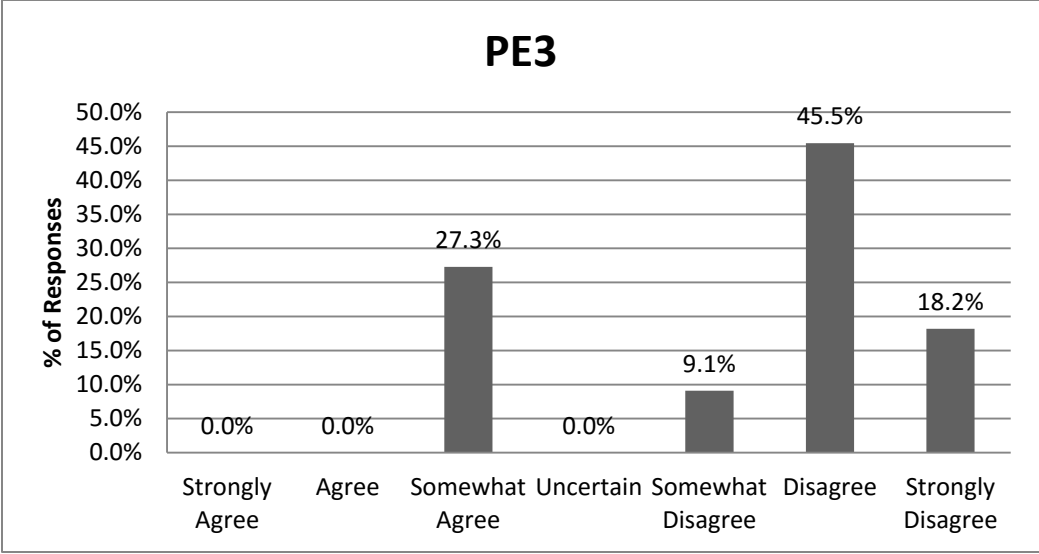


Figure 58. PE3 Using the game was boring

To have a balance for this negating statement we reversed the scale from strongly agree to strongly disagree. 72.7% (8 out of 11) participants disagreed as the game was more or less fun. So this response adds even more weight on the agreement in the previous statement. Only three participants somewhat agreed with the statement.

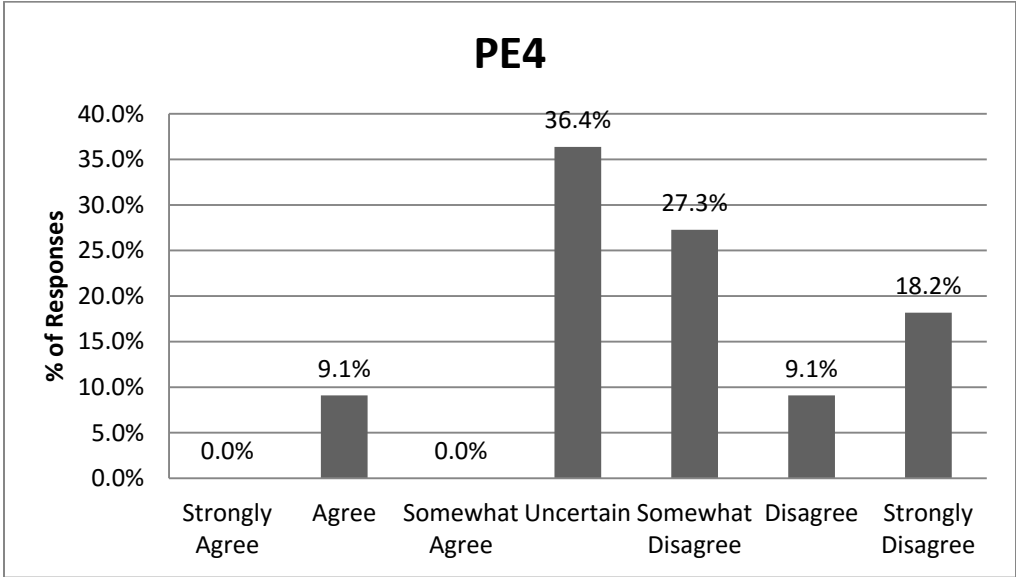


Figure 59. PE4 The game really annoyed me

To the statement, if game was annoying, 54.5% (6 out of 11) participants disagreed and only one participant agreed to this statement. Only 36.4% (4 out of 11) could not decide if it

annoyed them or not. We did not gather any comments on individual statements so we are unsure for the uncertainty.

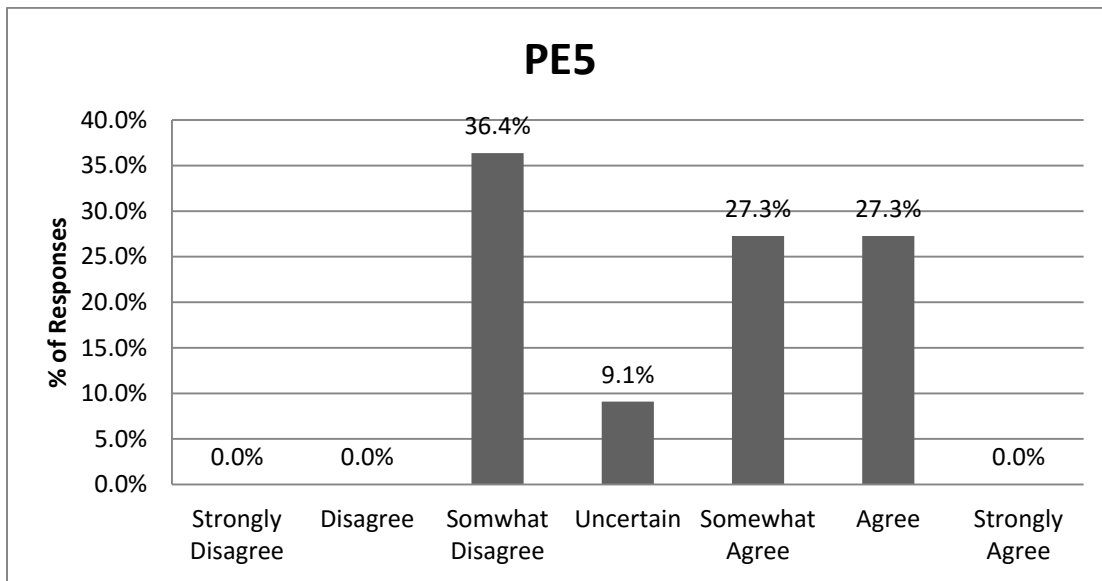


Figure 60. PE5 The game experience was pleasurable

54.5% (6 out of 11) participants agreed on the statement that the game experience was pleasurable. This response is similar to PE1 and PE2 as they overlap a bit in context of pleasurable, fun and enjoyable.

Perceived Ease of Use (PEOU)

In this section we had 7 statements and a 7-likert scale system scaled from strongly disagree to strongly agree. 7-likert scale was used to allow the participants to be more granular in their response.

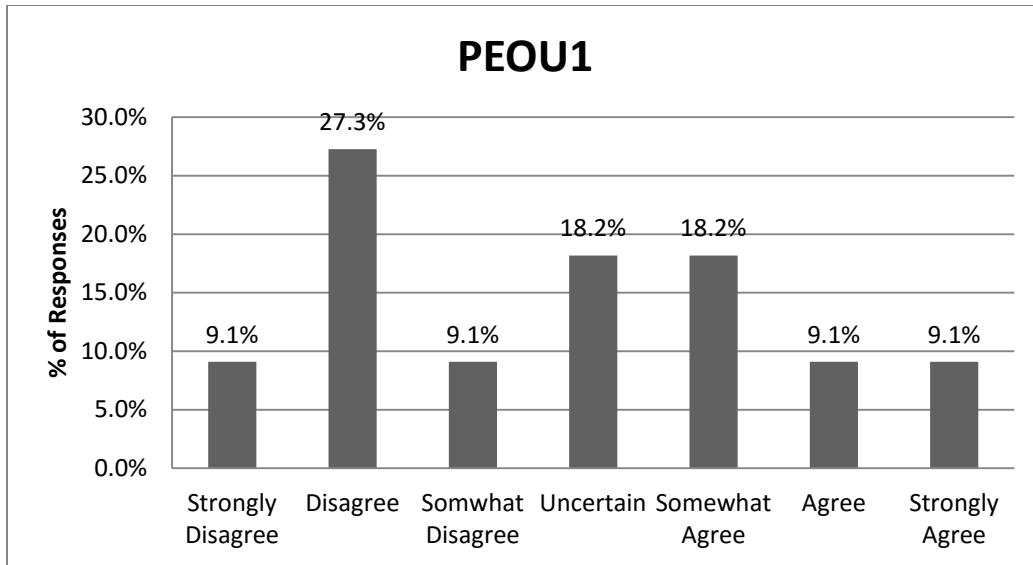


Figure 61. PEOU1 My interaction with the game was clear and understandable

The statement on clarity and understandability in interaction with the game had a very scattered response. We can see 45.4% (5 out of 11) participants disagreed, 18% (2 out of 11) were uncertain and only 36.4% (4 out of 11) participants agreed. After getting first few responses and comments we discovered that a walkthrough of the game was missing that could teach the first time user how to interact with the game. After finding the issue we quickly updated the app on Google Play Store with a fix so that rest of the participants in coming days could see instructions and walkthrough steps of the game to help them better understand the interaction process.

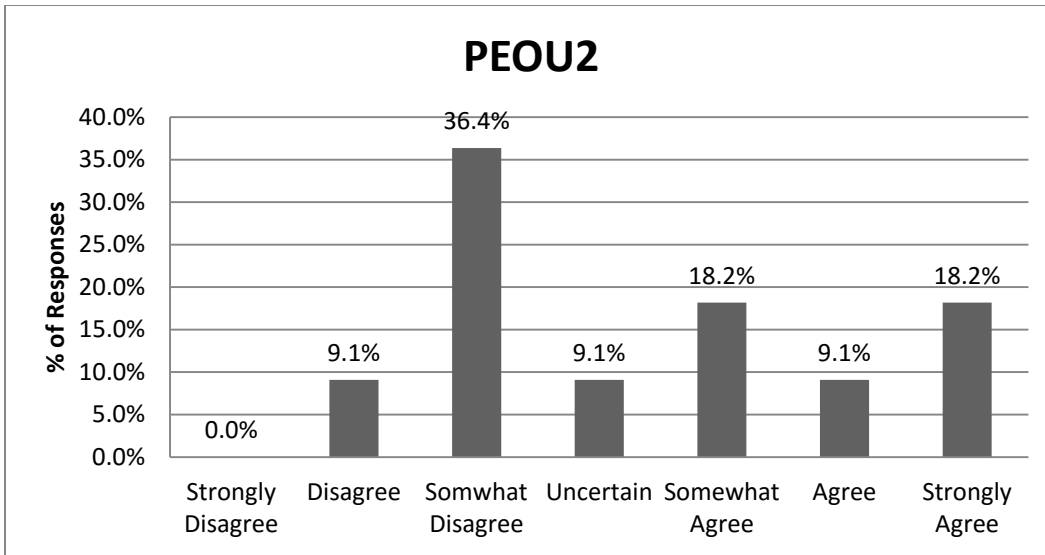


Figure 62. PEOU2 Interacting with the game did not require a lot of my mental effort

Another statement involving interaction with the game requiring mental effort had the similar kind of response as of PEOU1. 45.4% (5 out of 11) participants more or less agreed to the statement. However, 45.4% (5 out of 11) more or less disagreed. We assume it had the same issue of a missing game tutorial to guide users how to go about the game.

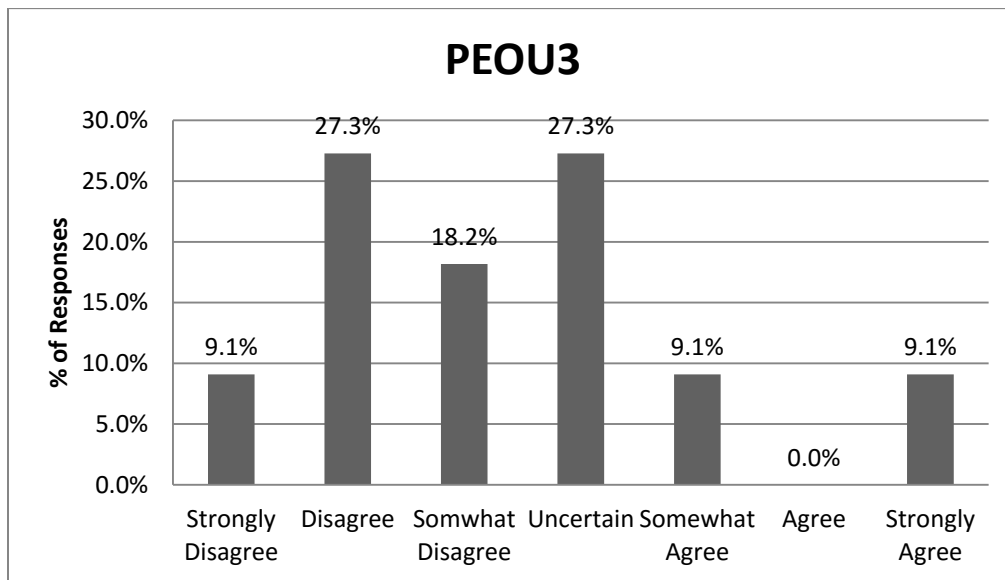


Figure 63. PEOU3 I found the game to be trouble free

More than half of the participants 54.5% (6 out of 11) disagreed to the statement that the game was trouble free. This was not due to some kind of game crashes or application not responding issues. It was only because of navigational flow between different screens. We wanted to use

the hard back button available on all Android phones. We failed to consider its **use is not well known for navigation** between screens. We fixed this by adding some pop-ups with understandable short messages to help user navigate after completing a certain task or action. Only 18.2% (2 out of 11) more or less agreed.

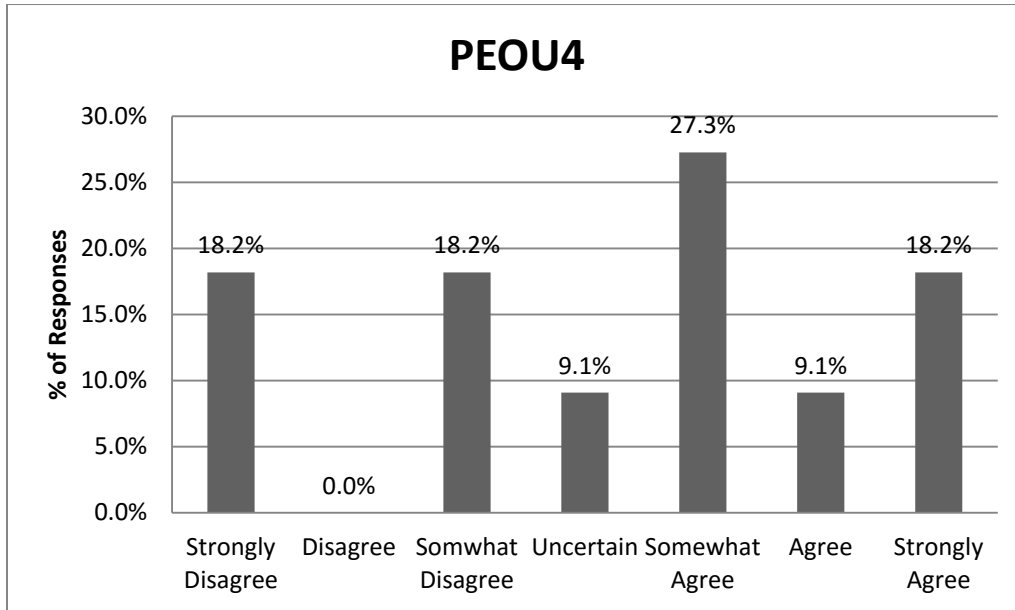


Figure 64. PEOU4 Learning to operate the game was easy for me

54.5% (6 out of 11) participants more or less agreed on the statement of ease in operating the game and only 36.4% (4 out of 11) participants more or less disagreed with the statement.

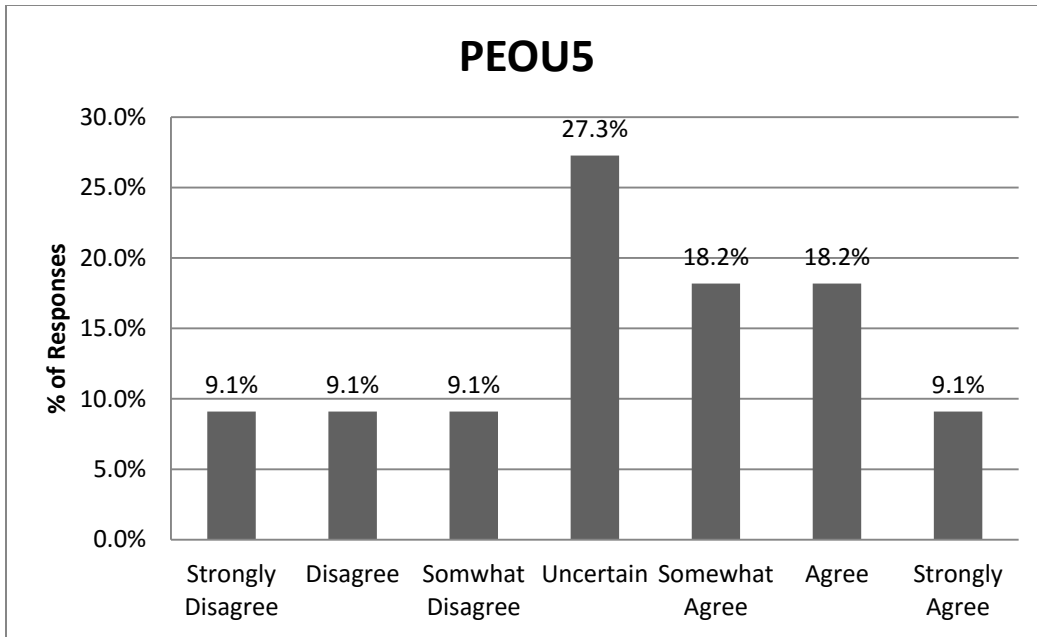


Figure 65. PEOU5 It was simple to do what I wanted with the game

45.4% (5 out of 11) participants more or less agreed to the statement on performing desired actions in the game. 27.3% (3 out of 11) participants were uncertain about this statement and the same amount of participants more or less disagreed. As we did not collect comments on individual statements, we cannot say what they wanted to do with the game that they could not in that context. We assume that it could be deleting solved puzzles and unsubscribing from studies. These actions were not made part of the game as removing puzzles and solving them again would have exploit scoring system.

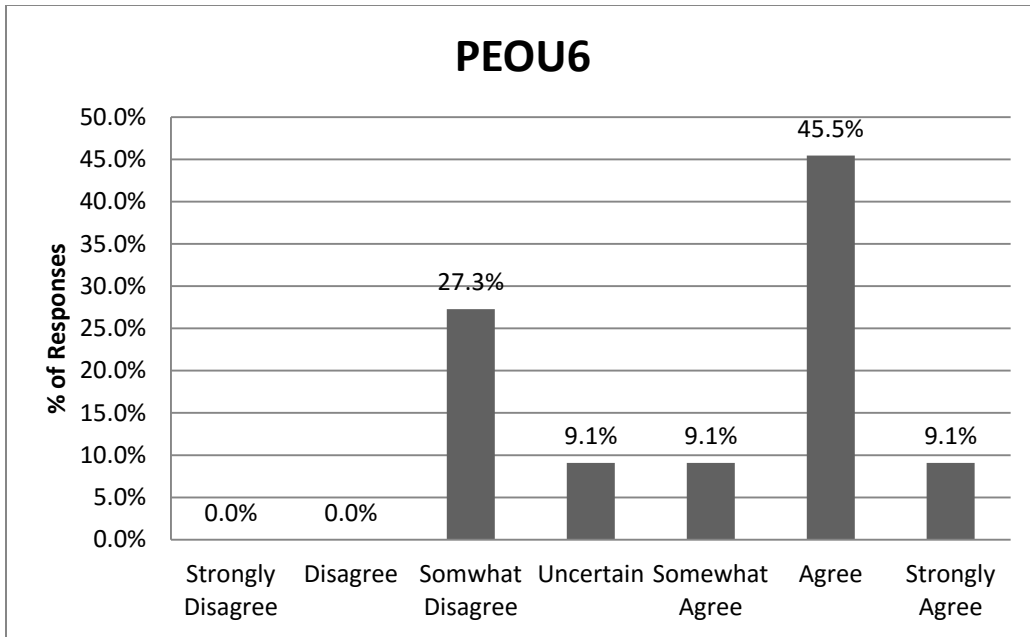


Figure 66. PEOU6 It was easy for me to become skillful at using the game

For the statement on becoming skillful at using the game, 63.6% (7 out of 11) participants showed more or less agreement. This was due to the criteria of scoring 20-30 before answering the questionnaire which made participants to solve many puzzles.

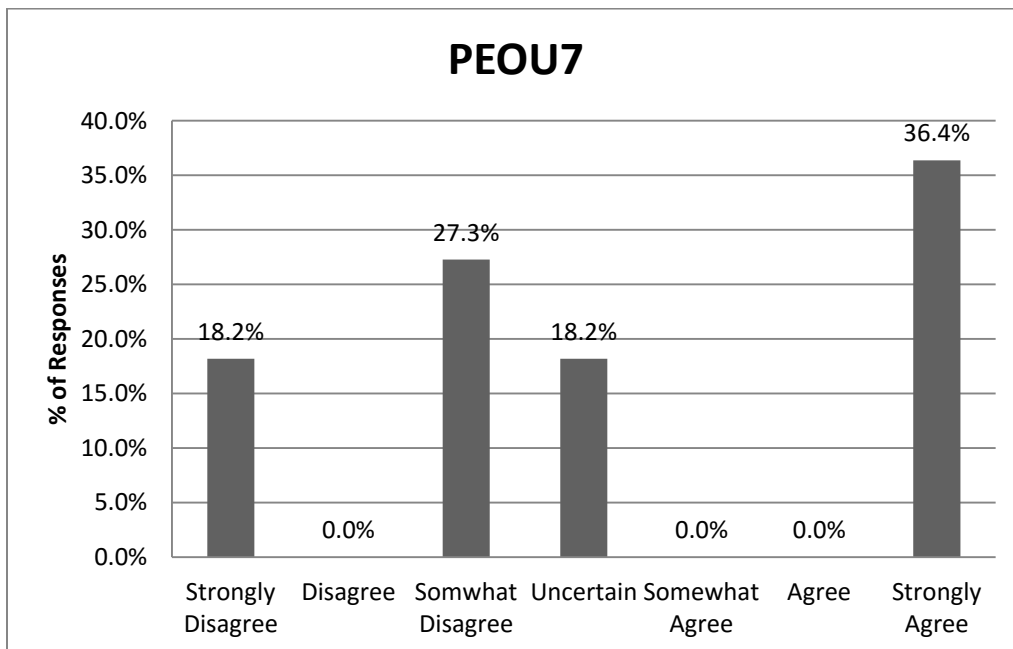


Figure 67. PEOU7 I found the game easy to use

On a general statement on the game's ease of use, 36.4% (4 out of 11) participants strongly agreed, 18.2% (2 out of 11) strongly disagreed, 27.3% (3 out of 11) somewhat disagreed and

18.2% (2 out of 11) were uncertain. More or less we see **more disagreement on the ease of use** aspect of the game.

Perceived Usefulness (PU)

This section had 5 statements and a 7-likert scale system scaled from strongly disagree to strongly agree. 7-likert scale was used to allow the participants to be more granular in their response.

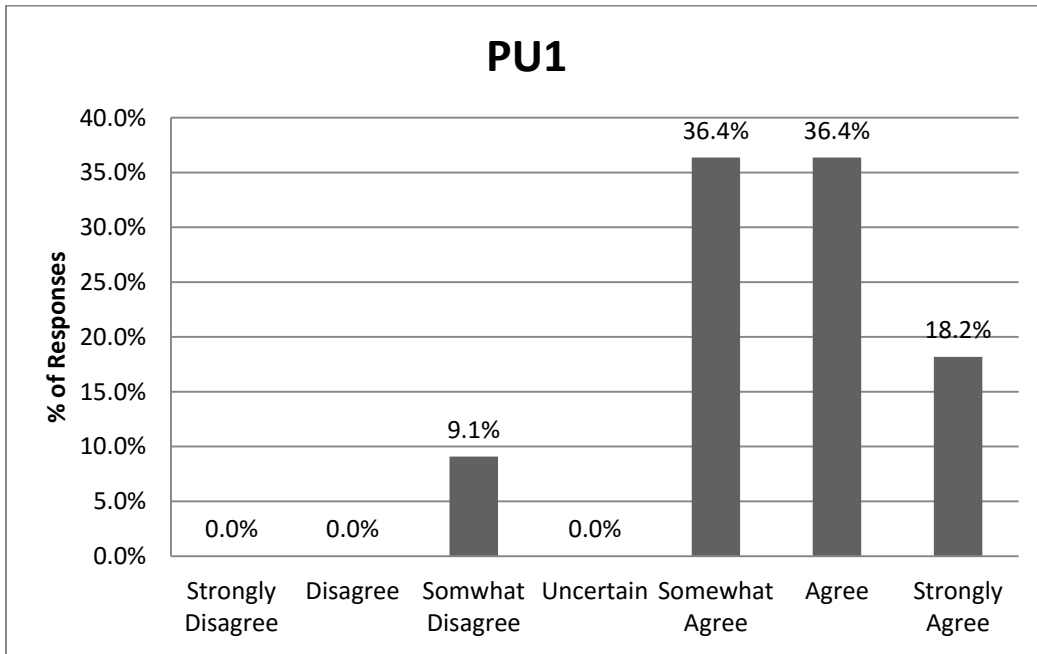


Figure 68. PU1 The game contributed towards my knowledge on scientific findings

The basic purpose of presenting scientific information in form of puzzles is to make a contribution to users' scientific knowledge. The statement on contribution towards scientific knowledge, 90.9% (10 out of 11) participants more or less agreed and only 9% (1 out of 11) somewhat disagreed. This shows the puzzles they chose to solve had useful information for the them.

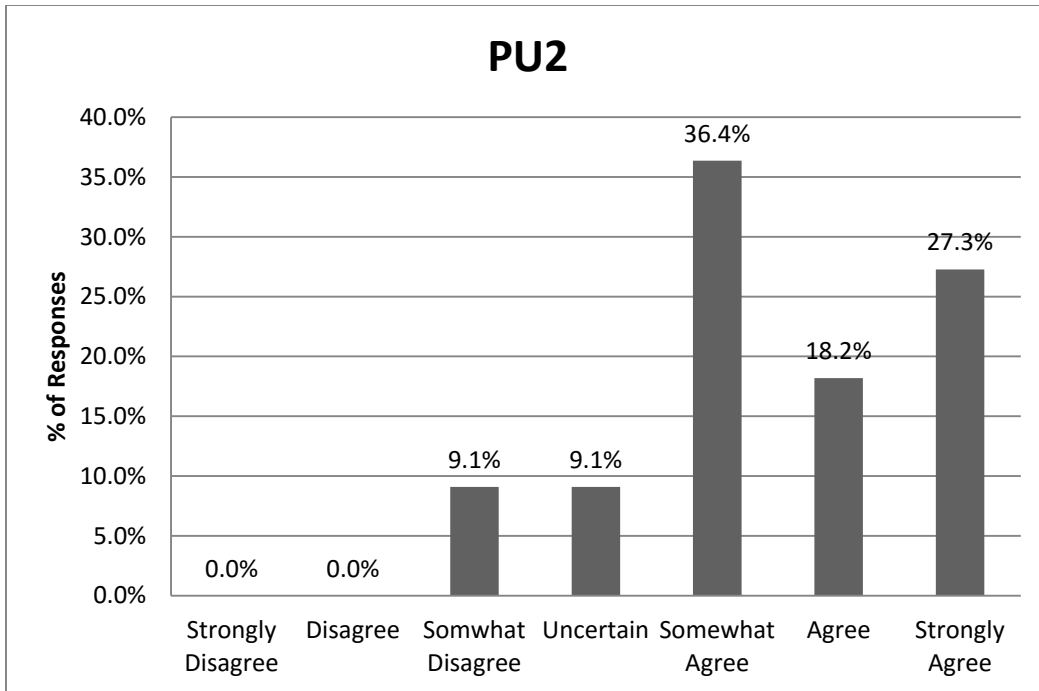


Figure 69. PU2 The game helped me think more clearly about scientific information

One of the purposes of presenting scientific information is to make people think more clearly by only focusing on the important parts of the research key findings. 81.8% (9 out of 11) participants more or less responded with agreement on this statement. Only 9% (1 out of 11) were uncertain and same amount of them somewhat disagreed (Figure 54).

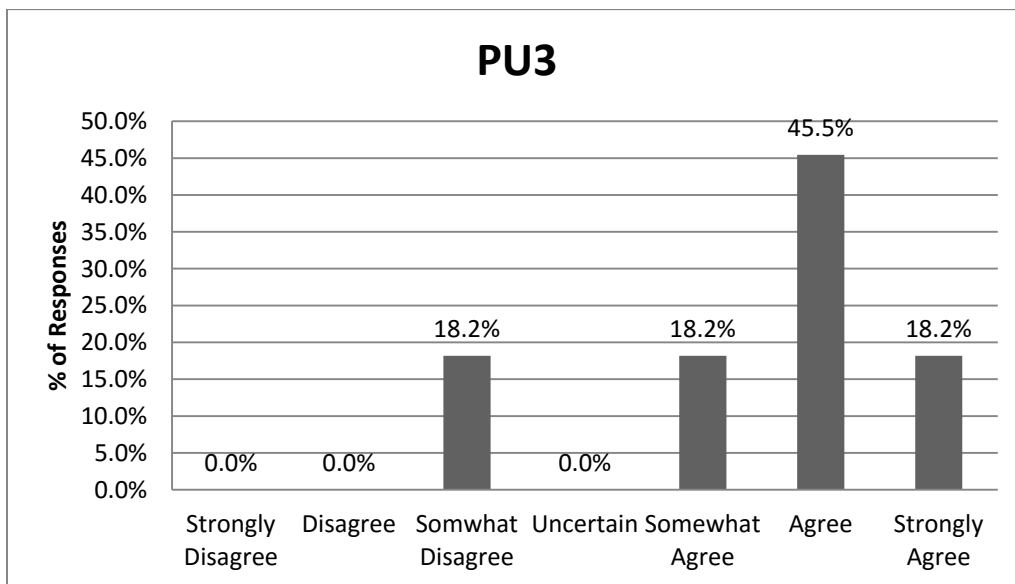


Figure 70. PU3 The game was useful in terms of finding about new scientific finding

A statement on usefulness of the game in terms of finding about scientific information showed more or less agreement by 81.8% (9 out of 11) participants. Only 18.2% (2 out of 11) somewhat disagreed on this statement.

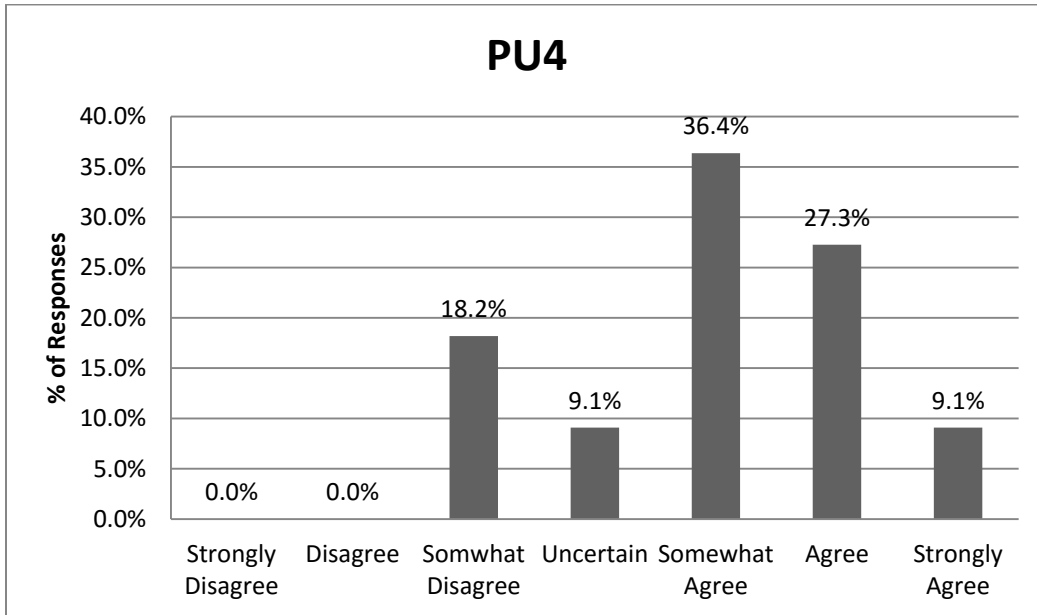


Figure 71. PU4 The game helped me focus on the important points of the research

Helping with focus only on important points of research returned in more or less agreement by 72.7% (8 out of 11) participants. Only 18.2% (2 out of 11) participants somewhat disagreed to this statement.

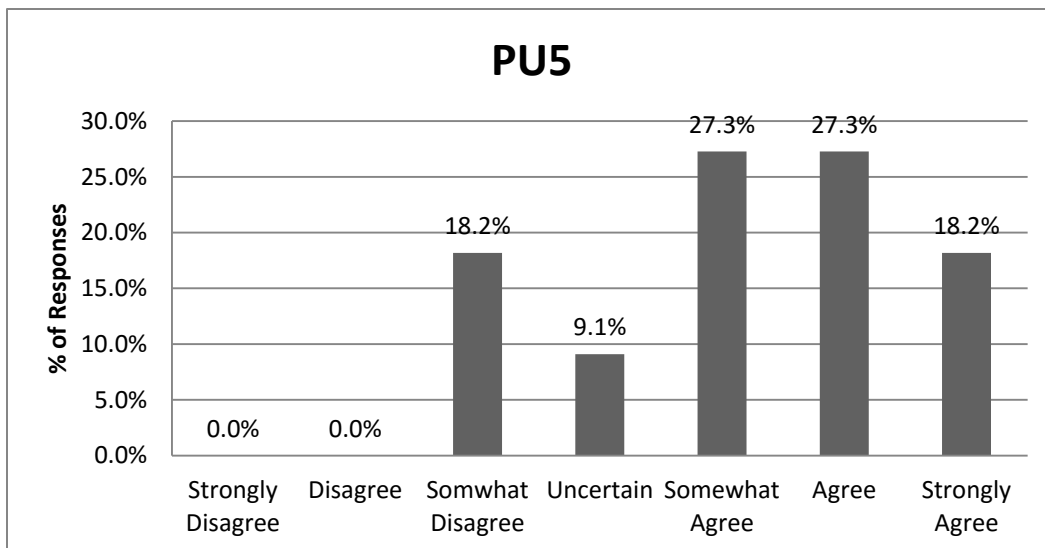


Figure 72. PU5 The game helped me relate scientific information with real life

As it is encouraged to add scientific information through puzzles which links to general public's daily lives such as from health, and climate. A statement was added on finding relevance between real life and scientific information. 72.7% (8 out of 11) participants were responded with agreement. Only 18.2% (2 out of 11) participants somewhat disagreed. Responses on PU1-PU5 have showed more or less agreement meaning the game was considered useful in general terms.

Intention to Use (IU)

Intention to use only had one statement. It was also evaluated through a 7-likert scale system scaled from strongly disagree to strongly agree. It was used to allow the participants to be more granular in their response.

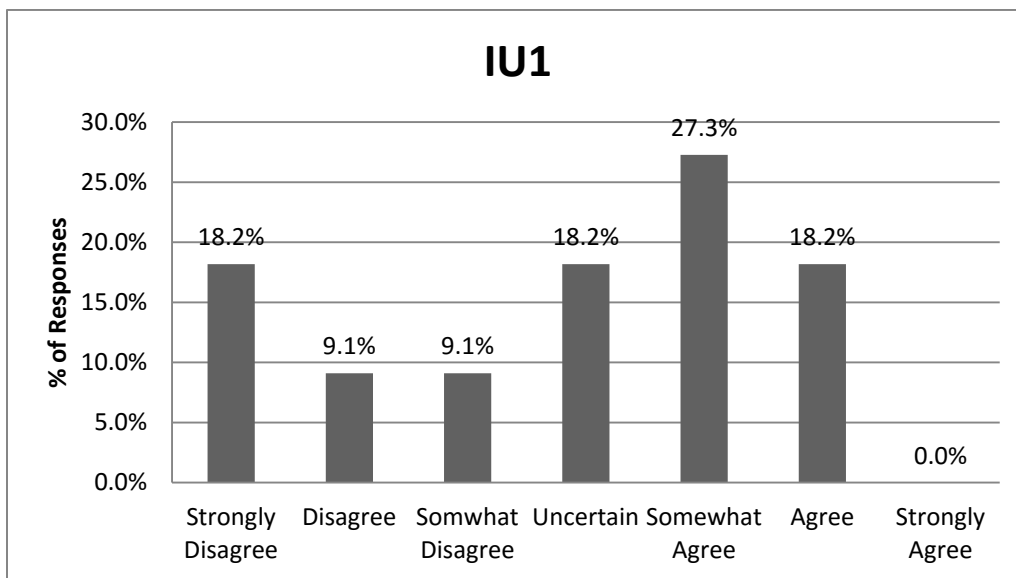


Figure 73. IU1 I intend to continue using it in the future

On a final statement on participants' intention to use this game in the future received somewhat equal responses in agreement and disagreement. 45.5% (5 out of 11) participants more or less agreed on using the game in the future. 36.4% (4 out of 11) more or less disagreed on this statement and only 18.2% (2 out of 11) participants were uncertain about their use to continue.

4.3.3. Study Limitations

We find it important to mention few limitations in this study and encourage forthcoming master research students to overcome these limitations in order to achieve higher quality of results. The limitations are as following:

- The evaluation study had a small number of participants i.e. 11
- The study only spanned over 1 week
- The evaluation only had 4 users outside of science background, namely: Arts, Education and Accounting and Finance.
- *Subscribe a Study* feature of the game was not tested by the participants
- The study lacked participants from age groups below 20.

We are certain if the number of participants was higher we could have overcome the limitation on age group and educational background. However, to overcome the limitation on age groups below 20 a broad study setup was required targeting secondary schools and colleges for diverse population. Also, the evaluation being done remotely did not allow us to test "subscribe a study" feature of the game. However, a study only filters out puzzles for its subscribers and allows them to test their knowledge. The timeframe for the evaluation and approaching deadline did not allow us to overcome these limitations. Nonetheless, we believe to have received good feedback on different aspects of the mobile game through TAM features which helps us to answer our research question.

4.3.4. Discussion Related to RQ 2

The following sub research question extracted from **RQ 2** is more reasonable to use mobile game evaluation results to answer usefulness and fun aspects of the game.

RQ 2.2: Can a mobile game be fun and useful in understanding of scientific findings?

To answer **RQ 2.2**, let us recall mobile study results of different statements from each section of the questionnaire i.e. PE, PEOU, PU and IU. The following table presents results of all constructs grouped by agreement, disagreement and uncertainty.

Table 3. Mobile game evaluation results grouped by disagreement, uncertainty and agreement on TAM constructs

	Disagreed	Uncertain	Agreed
PE1	27.3%	9.1%	63.6%
PE2	27.3%	18.2%	54.5%
PE3*	27.3%	0.0%	72.7%
PE4*	9.1%	36.4%	54.5%
PE5	36.4%	9.1%	54.5%
Average of PE	25.5%	14.6%	59.9%
PEOU1	45.5%	18.2%	36.4%
PEOU2	45.5%	9.1%	45.5%
PEOU3	54.5%	27.3%	18.2%
PEOU4	36.4%	9.1%	54.5%
PEOU5	27.3%	27.3%	45.5%
PEOU6	27.3%	9.1%	63.6%
PEOU7	45.5%	18.2%	36.4%
Average of PEOU	40.3%	16.9%	42.8%
PU1	9.1%	0.0%	90.9%
PU2	9.1%	9.1%	81.8%
PU3	18.2%	0.0%	81.8%
PU4	18.2%	9.1%	72.7%
PU5	18.2%	9.1%	72.7%
Average of PU	14.6%	5.5%	79.9%
IU1	36.4%	18.2%	45.5%

*PE3 and PE4 statements were in negation. To accommodate them in the table, values from disagreed have been replaced with agreed and vice versa.

The table above highlights the following key points:

- **59.9% participants agreed on enjoyment aspects of the game**
- **42.8% participants agreed on ease of use of the game but 40.3% disagreed**
- **79.9% participants found the game to be useful in context of scientific findings**
- **45.5% participants showed interest in using the game in future. However, 36.4% disagreed**

We combined responses of all statements from a section and calculated an average. Average for PE, PEOU and PU can be seen in the table above. This was to get refined results on all 3 features so that we can continue the discussion by having a single value result to answer RQ 2.2.

As shown in **Table 3**, 59.9% of participants agreed on the statements on **Perceived Enjoyment** and only 25.5% of participants disagreed. We can say that the game was able to please the majority of participants and it achieved the enjoyment goal that a gamified application must have. This is in the context of look and feel of the screens, art work used and very simple mechanics of classical hangman game. As we had an educational purpose we followed a theme of blackboard and chalk and gave it a very natural look of a classroom like style. Throughout the development process we received feedback from different people that the design of the screens is very pleasant and it catches users' eye.

On the statements for **Perceived Ease of Use**, Table 3 shows almost a balance in agreement and disagreement. One deciding factor for ease of use is the user experience and navigation flow. We improved the navigation flow a little after receiving first few responses. We find this to be the culprit of making 40.3% participants to disagree on ease of use statements. User experience has no boundaries and there is always room for improvements. Such improvements can be made by self perceiving about the end users' needs or by getting feedback from real users by letting them use a beta version of the system and iterating over it.

We can see, in the Table 3, **Perceived Usefulness** averaged to very high agreement. 79.9% participants agreed that the purpose of the game is useful and it can contribute to learning about scientific findings. This overall agreement includes 72.7% (8 out of 11) of participants who agreed on PU5 which was about relevance that could be made between scientific information presented through puzzles and users' daily life as puzzles can be designed around domains of health and climate.

Based on the above results, we can answer **RQ 2.2** from perspective of general public that gamified mobile app is useful in communicating scientific evidence while being pleasurable and fun. However, PEOU needs more work which can contribute towards IU agreement which is not

very high. Only 45.5% (5 out of 11) of participants agreed on using this game in the future, 36.4% (4 out of 11) of participants disagreed and 18.2% (2 out of 11) participants were uncertain about it. PEOU and PE can be strong determinants of IU as shown by Van der Heijden in 2004 [51]. Hence, improvements in PEOU and PE can result in higher IU.

5. Future Work and Summary

In this last chapter we briefly write about future work directions in order to improve this framework. Both components web console and gamified mobile app has a lot of room for improvement in many areas. We will end this chapter with a detailed summary of our work and conclusion.

5.1. Future Work

5.1.1. Interest Based Customization

As the players can be from any age group, educational background and may have different interests. It is important to let player chose what kind of puzzles interests him. There should be a settings screen showing keywords from different domain. player should be able to chose select keywords based on his interest. As a result, the puzzles get filtered. With such filters if player has interest in puzzles related to obesity, diet, sleep and exercises he will not need to search these in hundreds of other puzzles. The list will automatically get filtered showing only relevant puzzles.

5.1.2. Social Integration

We find social platform integrations very important in terms of making Scientific Hangman a better framework and science communication tool. In the future, we would like the app to function with social platforms such as Facebook and Twitter. These integrations will require the user, based on his interest, to login using their social accounts in order to make use of social features such as sharing on Facebook. This will allow us to collect some social parameters, with users' permission, such as location, email, gender, interests, friends and more. Using these parameters we can filter out puzzles as par user's interests. We can also classify puzzles for different age groups based on difficult levels. Sharing on social platforms can also help with competition and the spread of information from the user in game to his social circle on Facebook, for example. Also having such social parameters can allow researchers to create

studies for a target population based on some criteria such as age, gender and location. For example, creating puzzles about HPV and cervical cancer, grouping those puzzles into a study and publishing it only for female users in Norway with age more than 24 could be helpful in having great insights on how the targeted population receives the information.

5.1.3. Cloud Messaging Service

One of the features we want to see in SH is the push notification service such as Google Cloud Messaging (GCM). This lets the server send a message to all devices with the SH mobile app or it can target a set of users based on some criteria. If there is a new puzzle or if a researcher wants to inform users about a new study so that interested people could take part in it. These kind of actions can be provided in the web console where a researcher creates a study, sets a criteria (based on social parameters mentioned in previous sub-section) and pushes the message with study subscription code. This could ease the process of sending studies out to any number of users with different set of criteria. This can also come in handy when creating puzzle competitions between friends (information collected as part of social parameters) as it automates the notification process between users.

5.1.4. Extended Gamification

Gamification has been an important part of SH as it has the power to influence motivation and engagement in users. Perceived enjoyment has shown high percentage in the evaluation of the gamified mobile app. We currently have good game aesthetics and leaderboard as gamification elements. To improve enjoyment feature in the future, having badges would be great as it helps with ranking different users based on their awareness level. Also having puzzle competition mentioned in previous sub section could play role in gamification as it will create a multiplayer game scenario over the network hence increasing engagement. Also, making SH a more social app contributes towards gamification.

Based on good response on the enjoyment feature of the gamified mobile app we think having gamification elements in web console can also be of great help in motivating and engaging

researchers/scientists. This could be done by linking web console to social platforms, creating scoring system and leaderboard to rank researchers and their popularity among masses. The scoring, for example, can be calculated based on likes/dislikes of a puzzle.

5.2. Summary

In this manuscript, we have described the work done in partial fulfillment of the requirements for the degree of Master in Informatics: Programming and Networks. We started this work with a limited scope of gamifying cervical screening reminder letters sent by Cancer Registry of Norway to women in an effort to invite them for the screening. After looking at results of a study presented by a report [15], *Public Attitude to Science*, published in 2014 and *Special Eurobarometer 401* (European Commission, 2013) [16] we were convinced to expand the scope for sake of science communication. Communication that is backed by scientific evidence available in form of Scientific primary (publications, journals) or secondary articles (news articles which links to a publication). The reports mentioned above had key findings such as, **individual's low interest in science, people feeling uninformed as they hear too less about science and society suggesting to hear about science directly from the researchers/scientists instead of journalists**. Having these key findings in mind we wanted to create a communication channel between researchers and general public. To fulfill this purpose we built Scientific Hangman: A framework to gamify scientific evidence for General Public. This framework has a web console and an android gamified mobile app. In chapter 1, we introduced the problem, lay down research questions, briefly mentioned the framework with little background context, the problems faced during the work and the evaluation method used.

In **Chapter 2**, we shed more light on the background and explain the need of such a framework based on a report published by European Commission in 2014 [18] on science education that offered a 21st century vision of Science for Society. We also presented some problems faced by science education as mentioned in that report. We gave some details on the use of gamification. Furthermore, we studied an existing systematic mapping of gamification applied to education [14] to find out the levels gamification have been used in the context of education.

We mentioned some notable examples of gamification in general. We ended Chapter 2 by explaining Technology Acceptance Model and our reason behind using it as evaluation strategy.

We presented all the details of the framework in **Chapter 3**. We started with an overview of the framework explaining different components. We continued with functional and non functional requirements, actors and user stories. We explained, with figures, the key functions of the web console (for researchers/scientists), from signing up to creating puzzles to creating studies and looking at study responses and stats (basic). Afterwards, we gave all details of the gamified mobile app (for general public). We explained its features and its use. We ended this chapter by giving some implementation details of the web console, mobile app and the database.

In **Chapter 4**, we started by explaining the qualitative Focus Group study conducted at Cancer Registry of Norway to evaluate the first prototype of the Scientific Hangman mobile game. We briefly explained the study setup and discussed the results. The improvements that resulted from the Focus Group study were evaluated next. We used Technology Acceptance Model (TAM) proposed in 1992 by Davis et al., in [4] to evaluate perceived enjoyment, ease of use and usefulness of gamified mobile app. However, an earlier version of TAM proposed in 1989 by Davis in [5] was used to evaluate perceived ease of use and usefulness of Scientific Hangman web console. We explained study setup, explained the results, mentioned study limitations and discussed the results in context to research questions to conclude the work.

The evaluation of web console study showed good results, 82.9% and 80% on **Perceived Ease of Use** and **Perceived Usefulness** respectively. But at the same time we have also highlighted few limitations on the kind of domains it might not work on, which should be further evaluated. The results of mobile study, showed 59.9% and 79.9% agreement on **Perceived Enjoyment** and **Perceived Usefulness** respectively. However, it lacked on **Perceived Ease of Use** constructs by only gaining 42.8% agreement and 40.3% disagreement making it almost a balance. Every system has room to improve and we see a lot of improvement opportunities in this framework by enhancing user experience, navigational flow and enjoyment factors as mentioned in **Chapter 5** section 5.1. Both web console and gamified mobile app can be improved to produce better results. We encourage forthcoming, research students interested in Information Systems

and Gamification to improve this work. Outcome can be refined by conducting studies on large populations having game users (general public) from all sort of educational backgrounds and age groups and web console users (researchers) with diverse research interests.

Appendix A. Questionnaire to study Scientific Hangman web console

This is the questionnaire used to collect responses on web console. It has 4 sections: Personal Information, Perceived Ease of use, Perceived Usefulness and Intention to Use. The last 3 sections comply with Technology Acceptance Model which is our evaluation method. The questionnaire only required 5-10 minutes to complete. All the responses will be held anonymous. The questionnaire can also be seen [here](#) on Google docs.

Section 1 - Personal information

1. What is your gender?

Male

Female

2. What is your age?

3. Where are you from?

4. Which country are you living in?

5. What is your profession?

6. What is your research area or interests?

How much do you agree or disagree to the following questions

The following questions are to evaluate ease of use, usefulness, and intention to use Scientific Hangman Web Console. Please recall your experience using the web console and answer these statements.

Section 2 - Perceived Ease-of-Use

PEOU1. My interaction with the web console was clear and understandable

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree

Agree Strongly Agree

PEOU2. Interacting with the web console did not require a lot of my mental effort.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU3. I found the web console to be trouble free.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU4. Learning the use of web console was easy for me.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU5. It was easy to do what I wanted with the web console.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU6. I found the web console easy to use.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU7. I found web console easy an easy way of communicating with general public

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

Section 3 - Perceived Usefulness

PU1. Creating puzzles based on scientific content through web console is a useful strategy.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU2. The question-answer-clue formation of puzzles is simple and useful way of communicating scientific evidence

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU3. Grouping puzzles into studies is useful to conduct studies remotely and see responses in the web console.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU4. Scientific Hangman web console can be useful in creating a direct communication channel between researcher and the general public

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

Section 4 - Intention to Use

IU1. I as a researcher/doctor intend to continue using Scientific Hangman web console to create puzzles/studies based on scientific evidence.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

IU2. I as a researcher/doctor expect my use of it to continue in the future.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

What are your thoughts about Scientific Hangman: Web Console? (Optional)

Appendix B. Comments from web console study

2 out of 7 participants left feedback in form of comments:

1. I could not test the studies part since I had to create three puzzles. Nonetheless, the flow of interaction was very well designed. I only encountered a small issue with reordering/deleting the questions after I create them. Overall, I found it to be a well designed platform and very promising to convey scientific information to the general public.
2. Needs some tweaks but a really good idea.

Appendix C. Questionnaire to study Scientific Hangman mobile app

Following is the questionnaire used to collect responses on gamified mobile app. It has 5 sections: Personal Information, Perceived Enjoyment, Perceived Ease of use, Perceived Usefulness and Intention to Use. The last 4 sections comply with Technology Acceptance Model which is our evaluation method. The questionnaire only required 5-10 minutes to complete. All the responses will be held anonymous. The questionnaire can also be seen [here](#) on Google docs.

Section 1 - Personal information

1. What is your gender?

Male

Female

2. What is your age?

4. Which country are you living in?

5. What is your profession?

6. What is your research area or interests?

How much do you agree or disagree to the following questions

The following questions are to evaluate ease of use, usefulness, and intention to use Scientific Hangman Web Console. Please recall your experience using the web console and answer these statements.

Section 2 - Perceived Enjoyment

PE1. I found playing the game to be enjoyable

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree

Agree Strongly Agree

PE2. I had fun using the game

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PE3. Using the game was boring.

Strongly Agree Agree Somewhat Agree Uncertain Somewhat Disagree Disagree
 Strongly Disagree

PE4. The game really annoyed me

Strongly Agree Agree Somewhat Agree Uncertain Somewhat Disagree Disagree
 Strongly Disagree

PE5. The game experience was pleasurable.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

Section 3 - Perceived Ease-of-Use

PEOU1. My interaction with the game was clear and understandable.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU2. Interacting with the game did not require a lot of my mental effort.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU3. I found the game to be trouble free.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU4. Learning to operate the game was easy for me.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU5. It was simple to do what I wanted with the game.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU6. It was easy for me to become skillful at using the game.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PEOU7. I found the game easy to use.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

Section 4 - Perceived Usefulness

PU1. The game contributed towards my knowledge on scientific findings.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU2. The game helped me think more clearly about scientific information

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU3. The game was useful in terms of finding about new scientific findings

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU4. The game helped me focus on the important points of the research.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

PU5. The game helped me relate scientific information with real life.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

Section 5 - Intention to Use

IU1. I intend to continue using it in the future.

Strongly Disagree Disagree Somewhat Disagree Uncertain Somewhat Agree
 Agree Strongly Agree

What are your thoughts about the game? (Optional)

Appendix D. Comments from mobile game study

7 out of 11 participants gave us very useful and interesting feedback in form of comments. We made some quick improvements based on these comments.

1. The subject area is quite limited at the moment. I felt some repetition in the puzzles. The answers were not designed to be clear according to what a regular person thinks. They are too complex and so are hard to guess. There were several easier ways to answer the questions which were ignored. Navigation was difficult. The UI reflects some effort but not good enough at all. The rules and scoring have not been explained. There are no clear instructions for the players. The introduction or clues for the puzzles are inconsistent and often have too much information instead of the basic material needed to solve them making them complicated and a bit boring especially the study data.
2. You've clearly put a lot of effort in the development of this app and in general it looks good! Visually it is quite pleasurable, UX is OK and I have not encountered any major bugs. I have however experienced some major usability issues. There are several screens, where the phone's back button is the only way to move... forward. Like in the hints or in the screen after a single quiz. It took me a moment of clicking around the screen to figure out that I need to use the back button. IMO it would be nice to have a "Continue" or "Exit" button in these screens. The puzzle insight screen is well designed and the big black buttons are screaming to be clicked - except they are not buttons. The user needs to click the text. In the evaluated version, you have included a couple of games/studies that were immature - lacked proper hints and/or had strange sets of questions and answers - questions in Norwegian, answers in English etc. I think you should try to find the optimal length of an answer. Too short answers (like "20 to 25") are trivial. On the other hand, too long answers contain most of the alphabet's letters, making it nearly impossible to loose.
3. The questions should be designed to promote higher order thinking
4. The game presents an interesting idea to bring attention to a specific problem/question that concerns ,often everyday life, followed by a link to scientific evidence that

addresses the question. The causal link that is built between a common question and scientific research in an engaging manner is immersive. The game still needs improvements in interactions, gamification elements and has great potential in performing both focus group studies and large scale studies to help scientists propagate their knowledge.

5. It would be better to replace the letter slider with either the phone keyboard, or a fixed keyboard. In this way the user doesn't need to constantly scroll to find letters. Also, the hint pop-up covers the whole screen, it would be better to show that information under the hangman and the word to guess, since there is a lot of unused space in that screen.
6. Poor user experience, navigation was not clear it was self effort to understand how game work but after spending time for learning I found it useful to update my general knowledge about science and daily life.
7. Easy to use, many new useful scientific informations

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