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ASTROBIOLOGY: APP FOR KIDS

Software as a cognitive prosthetic for conceptualization of astronomical theories

It is well-known that children have difficulty conceptualizing astronomical concepts, such as gravity (Schoultz et al., 2001). We argue that a solution to this is to create effective and efficient prosthetics for aiding in their thinking and visualization, and exemplify this with an app that introduces astrobiology to children. The app was designed to be a hybrid between a game-like learning app and an encyclopaedic app. Similar difficulties arise in teaching mathematics to children (see for instance, Trouche, 2003). We predict that our app might have usage not only in children's astronomical education, but could also be used by people of all ages wishing to familiarize themselves with astrobiology, in an introductory manner.

Astrobiology is concerned with understanding the origins, distribution and evolution of life in the universe (Sephton, 2008). Drawing on a number of areas of scientific interest, including astrophysics, biology and geology, the multi-disciplinary nature of astrobiology lends itself particularly well to integrated science lessons within schools (Hanson and Redfors, 2013). In addition, some surveys (for instance, Zwama 2012) suggest that children are interested in some of the big astronomical and astrobiological questions. This could be inspired by popular television shows ("Doctor Who," "Star Wars," "Star Trek") but also by media interest in research and missions that have led to the discovery of exoplanets (especially those nicknamed "Super Earths") through to the Curiosity Mars Rover and the recent Rosetta-Philae mission to Comet 67P/Churyumov-Gerasimenko (Goesmann

et al, 2014). Astrobiology represents an opportunity to reflect on significant philosophical questions such as, "Where do we come from?", "How does life evolve in the universe?" and "Has life arisen elsewhere in the Solar System or beyond?" (Staley, 2003). It serves as a relatable boundary between advancing human knowledge and what is yet to be discovered (Brake et al, 2006). An example is given by Harrington and Johnson, 2013. Moreover physical devices such as toy rockets and "aliens" in a more popular culture form are also accessible from an early age and these pique children's interest in astronomy and astrobiology. Learning mobile apps should be classed somewhere in between, they should be fun and engaging to use (similarly to a toy, they should be seen as "playtime") but should also be implemented from solid scientific discoveries and teach current topics.

TECH-ASSISTED LEARNING

Tech-assisted learning is a well-established area and we could not do justice to its vast literature. It is advantageous to the teaching of concepts, such as astrobiology, as it facilitates engagement. Well-designed software allows a child to explore learning environments independently but safely, meaning that the independence will have no negative effect on the accuracy of the concepts learned. There are several advantages to focusing on software in the form of mobile applications; these are listed below:

- Mobile applications allow the child to learn anywhere rather than focusing the learning only in the classroom (Keengwe and Bhargava, 2013).
- With regards to teaching astronomical concepts, mobile technology is economically cheaper than a lot of

other services, for example imported workshops, planetarium trips, etc. This is particularly important with stretched educational budgets, particularly in areas of social deprivation (Sinha *et al.*, 2013).

- Touch-screen mobile devices are easy for young children to use (Bertou and Shahid, 2014).
- Apps such as ours allow personalization, hence parents and teachers can tailor learning with a personalized learning strategy, allowing the child to feel more empowered and responsible over their own learning.
- A carefully designed learning app will mask itself as a pleasurable activity for the child, thereby allowing seamless learning.
- Learning through the use of mobile technology is likely to have been encountered, at least in an informal setting, within the home and so children will already be familiar with this mode of learning (Song *et al.*, 2012).

Mobile applications can inspire various interest in science, computer science, geology, physics, and many others. Our particular focus is on Astronomy and Astrobiology, but we view these themes as prompts for engaging children in gaining skills to visualize difficult concepts, gain an interest in thinking about difficult concepts in general, not just applied to our theme and engaging in profound questions such as whether there is life in the universe beyond our planet. In addition, once children begin tackling these difficult ideas, they will become more environmentally aware; in particular, they will develop awareness of the balance in environmental systems.

DESCRIPTION OF THE PROTOTYPE

The application was designed for Android (mostly written in Java with information from xml files)¹ as it is generally cheaper and therefore more accessible, and we have already discussed the importance of economically cheaper alternatives to teach astronomy to children in the previous sections. We decided to use 8-bit graphics so the app would reflect children's

¹ The source code can be found in <https://github.com/Caiismith/>

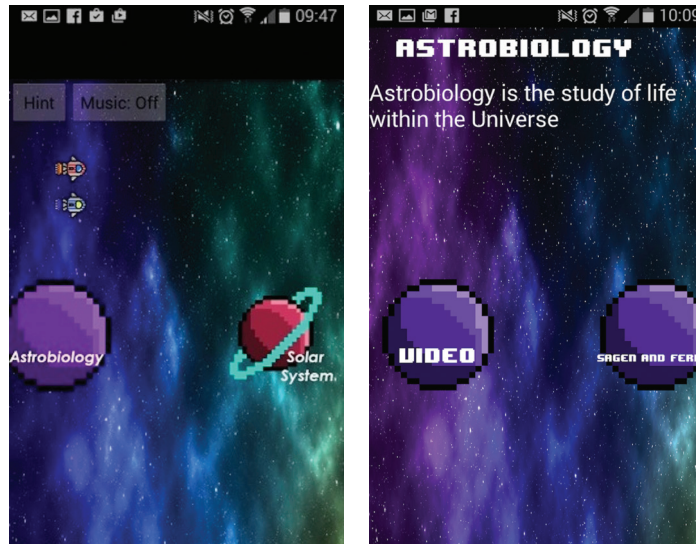


FIGURE 1. Main Menu and Video Screen Capture.

current interest in online games such as Minecraft and Roblox. This is intended to frame children's mental state to accept the gamelike components of our software and make learning less strenuous. The app is intended not as an astronomy encyclopedia, but as a learning platform with gamelike components. For instance, the quiz functionality teaches concepts and allows users to test their knowledge; on the other hand, the Drake equation section of the app is intended as a more fun component, with users altering parameters and trying to visualize the size of ours and neighbouring galaxies as well as the likelihood of life and intelligent life elsewhere.

The Main Screen as shown in Figure 1 above, serves as the central hub of the application in which the user is able to navigate to the relevant sections of the application. The user can also opt for background music. Each button is represented as a planet and the entire theme of the application is intended to immerse the user in the astronomical, and specifically astrobiological theme. From the outset, the user is encouraged to view the universe as something to explore and can do so by swiping through a panoramic presentation of a star system. From that page the user is able to choose "Life", "Astrobiology", "Our Solar System" or "Drake Equation." The 'Life' portion of the application asks gives the user the opportunity to consider,

"What is Life?" and "What is required to maintain Life?" The app guides the children through philosophical and basic biological considerations by presenting basic information in an accessible format supported by questions. This is not done in a booklike style; rather, it is done as a "thinking game," in fact the whole application contains a minimal amount of text. With the exception of the quiz, buttons are symbolized by planets and the intention is to engage children's imagination. This is something that cannot be achieved by a game-only or encyclopedia-only app, hence our focus on a hybrid.

Once these children have spent some time on these concepts, they are then offered the opportunity to discover extremophiles. This is intended to get children thinking about boundaries of life, so it is complementary to the previous issues that the application has been guiding them through.

The Astrobiology Section, on the other hand, acts as a nexus to further content related to the subject. The user is presented with a basic description of Astrobiology and asked whether they wish to engage in a quiz or in a learning activity. For the purposes of consistency throughout the app, each option is represented by a planet (see Figure 1). The children are given the choice of watching a video, Sagan and Fermi (encyclopedic page on Carl Sagan and Fermi's Paradox) and a

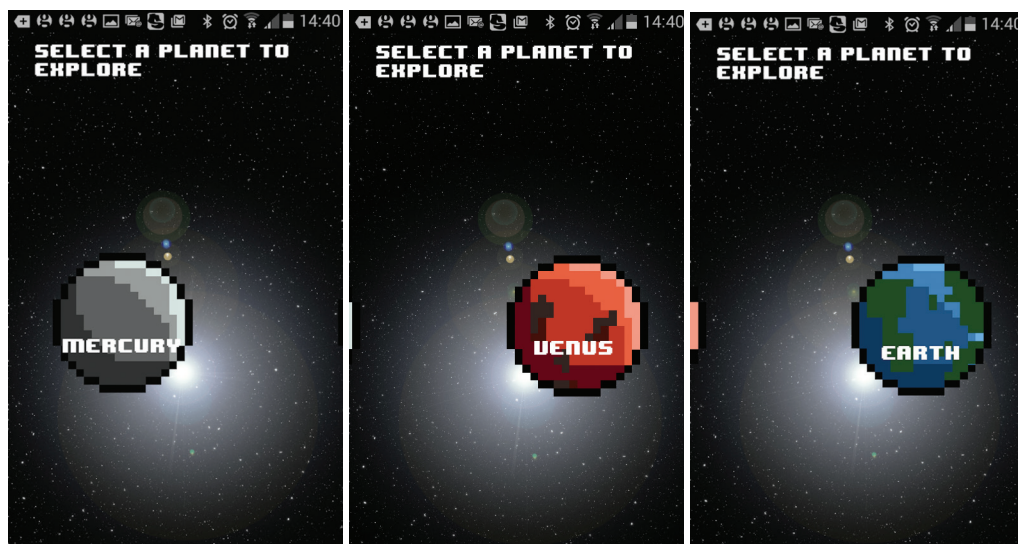


FIGURE 2. Examples from the Solar System section.

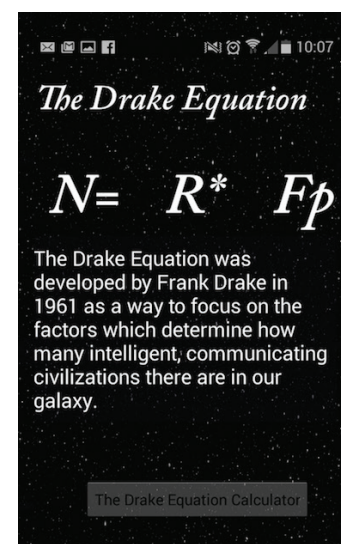


FIGURE 3. The Drake equation section.

quiz. The quiz contains questions related to the sections on Life, Astrobiology and the Solar Systems. Although the quiz is clearly developed as a learning-focused activity, the gamelike graphics aid in framing younger users to view it as a less strenuous, more pleasurable activity.

The Solar System Section allows the user to explore the planets of our solar system: when a planet is clicked on, the user will be able to access information on how the concepts of astrobiology can be applied to the planets of our solar system. Examples of some planets in the solar system section can be found in Figure 2 below.

The Drake Equation Section (Figure 3) allows the user to estimate (very approximately) the likelihood of communicative extraterrestrial life in the Milky Way Galaxy. We use the Drake equation not as an accurate scientific metric, but as a means to stimulate imagination in children and provoke their interest in astrobiology. The increasingly speculative terms of the equation and criticism are drawn further in the light of new discoveries and greater understanding (Burchell, 2006; Glade *et al*, 2012). However, we maintain it is adequate to use it, since determining likelihood of communicative extraterrestrial life at present cannot be done accurately. This portion of the app is to engage in imagining how many different planets there are in the Milky Way and beyond, and the Drake Equation is accurate in that respect.

The Drake Equation was chosen for its ease of reading and for how it is directly applicable in enhancing creativity in children, enticing their imaginations, an aspect that is essential when targeting a young audience. Each individual part of the equation is separate. The user is able to input the numbers for each part of the equation using spinners, which are drop-down boxes with an array of options for the user to choose from. Once all boxes are filled, the equation is calculated, with the answer being displayed in a text area at the bottom of the screen. The Drake Equation section also includes set values for the child to select, as it is perhaps too difficult for younger users to anticipate the range of values that they would likely need, and it could be particularly difficult, considering that there are billions of stars in the galaxy.

USAGE OF THE SYSTEM

Ease of usage of the system is crucial to ensure educational aims are met, as already pointed out by Parlangeli *et al.*, 1999, where experiments showed how hypermedia systems that are difficult to use have a direct negative impact on learning. The usability of the prototype was tested by allowing participants to download the app and use it for two hours. The first hour we asked participants to follow instructions, and the second hour we asked participants to freely use the app, and this was followed

by an interview. Our participants consisted of six undergraduate students, all proficient in Android phones and in usage of Android mobile apps but unfamiliar with astrobiology and with only a rudimentary understanding of astronomy, for example, understanding that we live in a galaxy called the Milky Way, in a Solar System.

Prior to showing the application to participants, we asked them to name important aspects in mobile applications, we then gave them instructions to follow and analyzed how our app scored (on a typical 1-5 usability scale) against the aspects named by the individual participants. We first conducted a thematic analysis to obtain the main aspects, and then calculated average scores. The themes observed and their scores (approximated up to the nearest integer) can be found in Figure 4. The reasoning behind the chosen method was to test usability of our app, since learning is secondary to the main aim of enticing a desire to learn (and this cannot be ecologically validated by experimental sessions).

Some of the comments from users can shed some light into reasons why our app fared favourably or otherwise in particular aspects as specified in Figure 4. For instance, it scored particularly well on the theme of “animation.” Some comments from users included:

“The use of animation improved the learning experience significantly.”

“Theme felt continuous and suitable throughout the application.”

“Animation provided an application that felt less still and monotonous.” This is a bit ambiguous and we interpret this as a neutral comment with regards to the animation.

“Great imagery, the animation and sound improved the experience, but some more labels to explain things are needed.”

This last comment shows a positive in the animation and sound, but a slight negative on the usability of our app, although overall our app scored averagely on user friendliness.

Comment with regards to the appearance (scored as expected, and we interpret this as a positive for a prototypical interface) include:

“The images aided me in navigating and using the application. They [reference to images] was [sic] helpful.”

“Helped find the right place.”

Some interpretation is needed for this comment; given the context and discussion with the participant, we interpret this to refer to the images and general appearance of the app, and it is a positive comment.

More general comments such as “Fun to use” are more difficult to interpret, but we generally attribute these to user friendliness. With regards to user friendliness, we had some clearly negative comments, such as the one mentioned above about the need for more labels, as well as the negative comments below, which focus on usability only:

“Further use of language needed in solar system part.”

We assume that by language the user means labels.

“More labels in solar system section. Improve swipe navigation.”

We now recall our advantages list in Section 2 and highlight how our app has met them. The first three aspects (anywhere learning; cost of app against cost of more “typical” astronomical services; touch-screen usability for children) have been confirmed by external literature (Keengwe and Bhargava, 2013), (Sinha *et al.*, 2013) and (Bertou and Shahid, 2014), and are achieved by design and construction of our app; there is no need to verify it by our usability tests. The remaining aspects deserve some consideration. One of our

FIGURE 4: Results from first part of experiment

	Users' expectation of an application (most important factors)	Adequacy of each factor of our application	Distance between users' expectation and the adequacy of our application
Appearance	5	5	0: Our application scored at the same expected level for an application
Sound	2	3	1: Our application scored higher than the expected level for an application
Animation	3	5	2: Our application scored higher than the expected level for an application
Ease of Usage	3	3	0: Our application scored at the same expected level for an application
Interactivity	4	3	-1: Our application scored lower than the expected level for an application
Functionality	5	3	-2: Our application scored lower than the expected level for an application

hypothesis: that parents and teachers can tailor learning with a personalized learning strategy is something that needs to be verified by a comparison with ours and other mobile apps to see if this does indeed have an advantage. Our reasoning behind this is more folkloric, parents seem to favour these games, but a rigorous study is left for future work.

Another proposition we made is that it is important to mask the learning as a pleasurable activity and the positive comments with regards to images and animation, as well as the high scores (Figure 4) on elements relevant to game-design means we have been successful at this, including comments from users such as “Fun app.” Advantage as to familiarity in the mode of learning is justified by external literature (Song *et al.*, 2012), and due to this, we focused our studies on users already familiar with the particular platform that we developed on.

ANALYZING RESULTS

The choice of 8-bit images is a reflection of the current interest in online games, such as Minecraft, had positive impacts on users' perception of the appearance, sound and animation of our app. This encourages users to a frame of mind of “game play” making the usage more enjoyable, and

this could reflect why our app scored well in these components. However, the game appearance of the app also means users expected more game-like components, and were slightly disappointed by the level of interactivity in the app. This could also explain why the app scored lower under functionality. Another reason, obtained from interview with participants, is that being a mobile app, there was an expectation that the app would link to other (external) services within the same device. For instance, some users have expressed disappointment that under “Life” and “Quiz” there was no option to search for further information on Web browsers, users would need to exit the app, rather than open a browser within. This is something we will incorporate in future versions of the app.

While there are a plethora of astronomy-related apps available for iOS and Android platforms, a limited number specifically examine the key concepts of astrobiology. Many of these apps, e.g. Saganet (Blue Marble Space, 2014), are largely encyclopedic in nature. Astrobiology apps that include the Drake Equation include SETI Institute (SETI Institute, 2012), DrakeEquation (Lars Hansen, 2015), Enhanced Drake Equation (Hsu, 2012) and DrakeEQ (Onomaly LLC, 2014), whilst varying in levels of complexity,

are interactive in nature. These apps permit the user to adjust the parameters in the Drake Equation, either by using spinner or slider (DaddySoft, 2014) controls or by inputting values into text boxes (Hsu, 2012; Manas, 2013), in order to obtain a value for N . With the exception of the SETI Institute app, however, these apps are limited to returning a value for N but do not present the user with additional information to support further learning or promote consideration of the implications of the equation. While children could use any of the applications reviewed as part of this study, they are not targeted specifically at that demographic. Our app is differentiated from others, therefore, in that it brings together a learning platform with game-like components, with the intention of engaging young children in astrobiology. The 8-bit design of the user interface, reflecting current trends in online games, contains limited text, contrasting with the largely encyclopedic nature of some of the astrobiology apps we reviewed e.g. SETI Institute (2012) and Saganaet (Blue Marble Space, 2014).

CONCLUSION

We have presented a mobile application intended to aid mainly children (but also interested adults) in conceptualizing difficult notions related to astronomy, with a particular focus on astrobiology. We also evaluated the tools for usability by conducting a thematic analysis on aspects of relevance to Android users and measured how our application scored relative to expectations on the identified themes, and found that overall, the app scored fairly against users' expectations.

The application allows for personalized learning strategies to be built by teachers and parents in conjunction with the child. A suggested approach, based on our experience with children who enjoy more practical work is given below:

1. Entice the child's imagination first with the Drake Equation.
2. Get the child thinking about life, and learn about extremophiles within our app.
3. Link it to popular news articles and amateur science, for instance using a low-resolution microscope to understand Tardigrades. This is also a good point, if using Tardigrades, to highlight the recent

experiment that sent them (and other extremophiles) to space, and saw their return with a high survival rate and even fertilized eggs (Nasa 2011).

At this stage, the child will feel empowered, as they have learned a new topic, Tardigrades in this instance, all by themselves and can actually see the creatures. Different strategies can be adopted for the children who enjoy more practical work, and with different learning outcomes, for instance, learning about the planets, the solar systems, or the scalability of our universe.

Although apps, such as ours, aid in learning on a short-term basis (months) the

main outcome is not the immediate new concepts that the child learns. Rather, it is the contribution towards a life-long desire to learn.

FUTURE DEVELOPMENT OF THE APP

The app will be reiterated so the elements that scored negatively in Figure 4 are turned into neutral or positive. One other aspect we will incorporate during the redevelopment is some more considerations of the scale of the universe, for instance, teaching the Plank length (to teach users notions, such as orders of magnitude, and understand how small our planet is in comparison to wider-Universe measures). ■

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