HAYtechNAYAN: A Development of an Augmented Reality Application as Instructional Material for Cell Cycle

Authors:

John Danielle T. Castor
daniellecastor071@gmail.com / 09957308953
Research Interests: Engineering and Technology

Beatrice M. Zarate
beatricezarate.zarate@gmail.com / 09264273550
Research Interests: Technology and Graphic Design

Jonathan Matthew P. Entienza
jonathanentienza0@gmail.com / 09233433526
Research Interest: Computer Science

Allyah Elizabeth M. Orio
allyahelizabeth0@gmail.com / 09101685417
Research Interest: Business

Winslette G. Rivera
winsrivera@gmail.com / 09323926914
Research Interest: Medicine

HAYtechNAYAN: A Development of an Augmented Reality Application as Instructional Material for Cell Cycle

John Danielle T. Castor, Beatrice M. Zarate, Jonathan Matthew Entienza, Allyah Elizabeth M. Orio, Winslette G. Rivera, and Suzzeth U. Dizon*
Caloocan City Science High School
Caloocan City, Metro Manila, Philippines
daniellecastor071@gmail.com / beatricezarate.zarate@gmail.com / JonathanEntienza@gmail.com / allyahelizabetho@gmail.com / winsrivera@gmail.com

Abstract **- The purpose of the study is to develop an Augmented-Reality (AR) application to provide an interactive and modern way of teaching the Cell Cycle, as well as to determine the feasibility and usability of the application as an instructional material based on certain criteria. The Augmented Reality application, HAYtechNAYAN, was developed mainly using Blender 2.8 and Unity v2019.1.14f1 with Vuforia Engine. The researchers constructed Likert scale-based evaluation sheets parallel to the ISO 25010 protocol and the survey sheets formed by National Career Development Association that were then administered to 15 Science, Technology, Engineering, and Mathematics (STEM)-based high school Biology teachers from different institutions to evaluate the application's content and interface. The research findings indicated that every category got scores that were or were close to four which means that the application was very appropriate in different criteria, such as the Performance Efficiency, Reliability, Program Information, and User's Interaction. The obtained overall mean score, which was 3.83 was between 3.26-4.00, which then can be interpreted as very appropriate to be used according to the interpretation of mean scores basis by Lawsin (2019). With the obtained findings, the researchers concluded that the developed Augmented Reality application, HAYtechNAYAN, has a potential to be an advantageous instructional tool for teaching the Cell Cycle in high school level.**

Index Terms - Augmented Reality application, Cell Division, Instructional tool

Introduction

It is known that in education, there are certain topics that can be difficult and too complex to teach (Yip, 1998, as cited in Oztap, Ozay, & Oztap, 2016). Also, according to BADA & Olusegun (2015), teachers cannot simply transfer knowledge to learners. Lessons such as cell division, photosynthesis, and cell respiration are often considered as one of the least mastered and challenging to teach lessons by students and educators at different levels including secondary school (Yip, 1998, as cited in Oztap, Ozay, & Oztap, 2016). An assessment conducted in Valenzuela National High School found out as well that the majority of the least mastered lessons of high school students are related to microscopic life forms such as cells and microorganisms (Valenzuela National High School, n.d.). Since Cell Division occurs at a microscopic level and includes complicated terminologies and ordered processes, students find it difficult to visualize and understand the topic (Lham & Sriwattanarothai, 2018). Also, according to Smith & Kindfield (2013), teaching cell cycle is challenging due to it having complex structures and processes. The utilization of textbooks, and misleading experiences and teaching methods cause misconceptions and difficulties regarding Cell Division. As a result, improvements in the materials and teaching methods which include models, diagrams, and instructionals have been suggested to improve the teaching and learning quality (Oztap, Ozay, & Oztap, 2016).

As technology advances, educators find it advantageous to use modern strategies in educating the students as they provide a more holistic learning experience (Saeed, n.d.). The utilization of technology in classrooms provides a constructive educational experience that can be significant in the learning of scientific and non-scientific concepts (Khanlari, 2013). Also, Technology Enhanced Learning (TEL) has a potential to improve students' performance, understanding, and learning as they learn outside the conventional setup (Peart, Rumbold, Keane, & Allin, 2017).

Augmented Reality (AR) is the integration of digital elements to the real-world with the use of computer-generated inputs such as sound, graphics, or GPS data (Grier & Thiruvengada, 2012). AR can be categorized as marker-based, which requires sensors to detect symbols and figures; or marker-less, which is often referred to as location-based AR (Carrera, 2016, as cited in Arslan, 2016). Since smart devices are very common nowadays, education providers have adopted AR in subjects such as Mathematics and Science. However, AR has not been applied that much in

education due to the minimal support of the government and lack of awareness in AR (Shelton, 2002, as cited in Lee, 2012). Also, many questions its use and efficiency in education as it can be costly and time-consuming (Lee, 2012).

The purpose of this research was to develop an interactive and modern way of teaching Biology, and the structure and life cycle of cells by developing and implementing an Augmented Reality Application. Since according to Pengcheng, Mingquan, & Xuesong (2011), AR technology's visualization is interactive and interesting to both students and teachers, the study on the development of an Augmented Reality application for teaching Cytology aimed to create a unique teaching tool for teachers in providing knowledge to students of different learning styles. Furthermore, the study aimed to accomplish the following:

1. Determine whether the elements in the application interface such as the buttons are functional, complete, and accurate.
2. Determine whether HAYtechNAYAN has efficient and timely responses.
3. Determine whether the application can easily be learned, operated, and accessed.
4. Determine whether the developed application is reliable and always available.
5. Determine whether the application is easy to install and efficiently adapted in phones.
6. Determine whether the information included in the application are clear, concise, informative, and based on valid resources.
7. Determine whether the application can efficiently interact with the target audiences, which were Biology teachers.
8. Determine whether the application has the potential to be an advantageous educational material for teaching cell cycle.

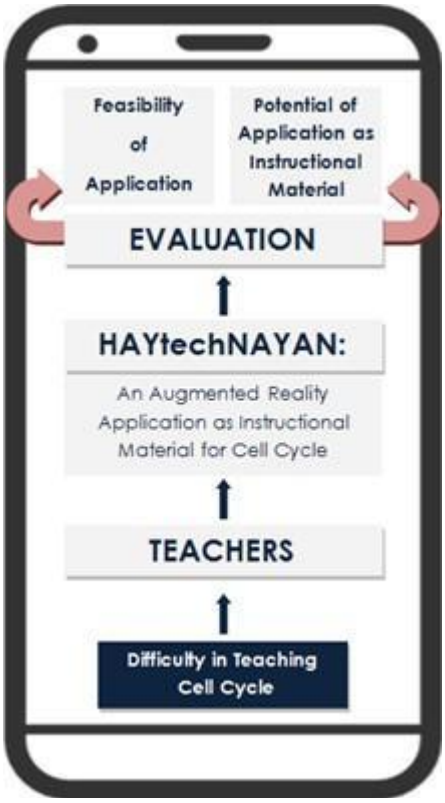


Figure 1.
Research Paradigm

In the 1990s, the impact and importance of AR were not given enough attention. However, there has been an increase in the number of studies and researches regarding its influence in different fields such as education, business, program development, and medicine (Chen, Liu, Cheng, & Huang, 2017). Currently, as technology progresses, Augmented Reality can be used by both professionals and non-professional individuals in their studies and works since many free-to-use applications and methodologies are now developed by many companies (Nam, 2009).

Figure 1 shows the research paradigm of the study which illustrates the problem, the participants and target beneficiaries, solution, and the purpose of the research study. According to Yip (1998) as cited in Oztap, Ozay, & Oztap (2016), difficulties in teaching and learning the cell cycle for high school teachers and learners are present. Also, students these days learn through experience and interactions ("Constructivism", 2018). To solve the issue, the use of technology such as Augmented Reality applications provides a potential solution as it can be advantageous for teaching regarding subject matters due to it involving a constructive approach that is suitable for the learning approach of students nowadays (Kerawalla, n.d). Supporting this were studies which used Augmented Reality in different fields such as in Astronomy (Fleck & Simon, 2013), Education and Business (Lee, 2012), and K-12 setting (Açkayir & Açkayir, 2016). In the stated studies, the researchers commonly obtained positive results such as

students having improved learning and concentration compared to tangible materials, and the AR application having a potential in supporting both learners and educators.

In the Philippines, many people have already adapted AR in various fields such as in business, transportation as well as in education. Several researches have already been conducted regarding the application of Augmented Reality in school settings such as the study of Pugoy, Ramos, Figueroa Jr., Rivera, Siritarungsri, Cheevakasemsook, Noimuenwai, & Kaewsarn (2016) regarding the limitations and developments of AR in Nursing; Collado & Santos (2015) regarding its use in physics; and Arce, Cabuyaban, Gaces, & Pagtaconan (2018) regarding the application of AR in teaching Earth Science. However, the number of researches about the integration of AR in Biology, specifically in Cytology, is very minimal.

In addition, although AR seems to be advantageous in education, conflicts are still present. First, there are studies which concluded that AR can cause cognitive overload to the users. Many users were challenged with the AR's usability, which is often caused by errors in the interface and lack of experience. Also, it should be noted that AR-based applications commonly require an internet connection and devices which are equipped with sensory inputs such as smartphones and tablets (Açkayir & Açkayir, 2016).

In the study of Açkayir & Açkayir (2016), they recommended improving the interface of the AR application while minimizing the size of the program. Arce, Cabuyaban, Gaces, & Pagtaconan (2018) also recommended making the application be compatible with multiple platforms. Lastly, Fleck & Simon (2013) also suggested maximizing the number of participants as it would improve the comprehension and validity of the research.

Materials and Methods

The research design used in the study was Quantitative Descriptive Research Design as the study involved numerical data, specifically the scores given by the evaluators, which were obtained through evaluation (University of South California Libraries, 2020). The software used by the researchers in developing HAYtechNAYAN were Blender 2.8, Unity v2019.1.14f1 with Vuforia Engine, and Visual Studio 2019 and C# Programming Language. Since the researchers implemented a marker-based AR, Adobe Photoshop CS6 was used in designing the markers. The programs were all free to use and were all downloaded from the official websites of the software. For the evaluation of the application, consents, as well as Likert survey sheets based on ISO 25010 Protocol and the criteria sheet formed by National Career Development Association were also constructed by the researchers. Microsoft Excel 2013 was then used for the statistical analysis and testing of the obtained data.

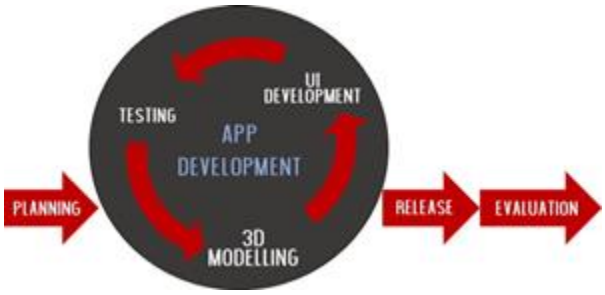


Figure 2.
Research Procedure

Planning

Based on Figure 2, AGILE Methodology, which is a design that has a potential for improving software project quality and outcomes, was utilized in the development of HAYtechNAYAN (Maruping, Venkatesh, Agarwal, 2009). The researchers first studied the concepts regarding Cell Division using K-12 learning materials such as books and guides, specifically the "Campbell Biology 10th Edition" by Reece, Urry, Cain, Wasserman, Minorsky, & Jackson (2014), and "Science for the 20th Century Learner 8" by Lim, Alastre-Dizon, Laurente, & Garicia (n.d.), then planned and integrated the contents to the application (Arce, Cabuyanan, Gaces, & Pagtaconan, 2018).

Application Development and Release

The development of the AR application itself involved the utilization of Blender 2.8 in creating and animating the 3D cell and organelle models, as well as Unity 2019.1.14f1 and Vuforia Engine in developing the 3D models and animations into an Augmented Reality Application. For the enhancement and development of the interface, as well as for programming the controls in the application, the researchers used Visual Studio 2019 and C# Programming Language. The researchers also designed the markers and the 2D graphics using Photohop CS6. Several trials and repetitions were conducted as the researchers checked for errors and improved the final application (Arce, Cabuyanan, Gaces, & Pagtaconan, 2018).

Application Evaluation

The researchers finalized the application for the evaluation of Biology Experts in terms of content and the application itself, respectively (Arce, Cabuyanan, Gaces, & Pagtaconan, 2018). An evaluation sheet utilizing a Likert scale with four ratings ranging from Strongly Disagree to Strongly Agree which corresponds to one to four points, with an attached consent was then constructed based on ISO 25010 Protocol and the evaluation sheet formed by National Career Development Association. The formed survey sheets include seven main categories: (See Appendix B)

1. Functional Stability (Functional Completeness, Functional Correctness, Functional Appropriateness)
2. Performance Efficiency (Time Behaviour)
3. Usability (Learnability, Operability, User Interface Aesthetics, Accessibility)
4. Reliability (Availability, Recoverability)
5. Portability (Adaptability, Installability)
6. Program Information (Conciseness, Grammar, Validity, Precision, Comprehension)
7. User's Interaction (Purpose, Materials, Instruction, Start/Exit, Appeal, Effectiveness)

The application then was administered to and evaluated by 15 Science, Technology, Engineering, and Mathematics (STEM)-based high school Biology teachers from different institutions using the created evaluation sheets by the researchers (). The scores given by the evaluators were compared and used to determine the feasibility and potential of HAYtechNAYAN as an instructional tool regarding the cell cycle.

Statistical Test

For the statistical analysis of the evaluations, means and standard deviations of scores given by the evaluators per category and sub-category in the evaluation sheets were computed using Microsoft Excel 2013. The basis for the interpretation of mean scores provided by Lawsin (2017) was used to interpret the computed means.

Table 1.
Table showing the basis for the interpretation of computed mean scores

MEAN	INTERPRETATION
3.26 – 4.00	Very Appropriate
2.51 – 3.25	Appropriate
1.76 – 2.50	Requires revisions
1.00 – 1.75	Not Appropriate

Results and Discussion

The results obtained from the evaluation were statistically analyzed and were used to solve for the means and standard deviations for each category and subcategory in the evaluation sheets, as well as the overall score of the application. The results presented were used to determine whether the developed AR application can be a potentially advantageous educational material regarding the cell cycle.

Table 2.
Table showing the means, standard deviations, and the interpretation of the category Functional Stability and its subcategories

	Mean	SD	Interpretation
FUNCTIONAL STABILITY	3.978	0.085205634	Very Appropriate
Functional Completeness	4	0	Very Appropriate
Functional Correctness	3.933333333	0.25819889	Very Appropriate
Functional Appropriateness	4	0	Very Appropriate

Table 2 shows that the Functional Stability and its sub categories Functional Completeness, Correctness, and Appropriateness got means within the range of 3.93-4.00, which then can be interpreted as very appropriate based on the basis of interpretation by Lawsin (2017). The standard deviations were also or close to zero which indicated that the scores given by the evaluators in the evaluation were or close to the means obtained. The interpretation can then imply that the evaluators found that the developed application included functional, complete, and appropriate elements such as the buttons in its interface.

Table 3.
Table showing the means, standard deviations, and the interpretation of the category Performance Efficiency and its subcategory

	Mean	SD	Interpretation
PERFORMANCE EFFICIENCY	3.933333333	0.25819889	Very Appropriate
Time Behavior	3.933333333	0.25819889	Very Appropriate

Based on the table above, the Performance Efficiency along with its subcategory Time Behavior, got a mean of 3.93, and both category and its sub-category were deemed as very appropriate. The standard deviations obtained also were relatively low which then implied that the scores given were close to each other. The results obtained can then indicate that the application, based on the evaluators, was responsive and had timely processing times.

Table 4.
Table showing the means, standard deviation, and the interpretation of the category Usability and its subcategories

	Mean	SD	Interpretation
USABILITY	3.793333333	0.398939069	Very Appropriate
Learnability	3.733333333	0.457737708	Very Appropriate
Operability	4	0	Very Appropriate
User Interface Aesthetics	3.933333333	0.25819889	Very Appropriate
Accessibility	3.866666667	0.351865775	Very Appropriate

As Table 4 displays, the computed means were ranging from 3.73-4.00, which were under the range of 3.26-4.00, which then denotes that the Usability of the application was very appropriate in the aspects of Learnability, Operability, User Interface Aesthetics, and Accessibility. The standard deviations acquired also were close to zero which showed that the scores given were not spread out. With this, it can be implied that the application, according to the evaluators, can be used, learned, and operated by users easily, as well as contained appealing visuals in the interface.

Table 5.
Table showing the mean, standard deviation, and the interpretation of the category Reliability and its subcategories

	Mean	SD	Interpretation
RELIABILITY	3.633333333	0.549891764	Very Appropriate
Availability	3.466666667	0.833809388	Very Appropriate
Recoverability	3.8	0.414039336	Very Appropriate

The table above indicates that the Reliability of the application was very appropriate, with its computed mean of

3.63. Its sub-categories, Availability and Recoverability also got means that were under the range of 3.26-4.00, implying that the criteria were very appropriate. Although, the standard deviations obtained, especially on the subcategory Availability which was 0.83, were higher compared to the other category, signifying that the scores given by the participants were more spread as compared to the other criteria in the evaluation. However, the standard deviations computed were under one indicating that the average spread of the scores was below one. The obtained means, standard deviations, and interpretations then can signify that the application was reliable, always available, and can recover seamlessly after interruptions although some evaluators found that HAYtechNAYAN, by the time of evaluation, was not yet available on operating systems other than Android hence disagreed with the availability of the application.

Table 6.
Table showing the mean, standard deviation, and the interpretation of the category Portability and its subcategories

	Mean	SD	Interpretation
PORTABILITY	3.8	0.455129495	Very Appropriate
Adaptability	3.733333333	0.59361684	Very Appropriate
Installability	3.866666667	0.351865775	Very Appropriate

Table 6 shows the mean of the scores given by the participants in the category of Portability, along with its sub-categories Adaptability and Installability. The means solved were between 3.80-4.00 which can be pertained to as very appropriate. Also, the standard deviations presented were not far from zero, which indicated that the scores given by the experts were relatively condensed about the mean. The application then, based on the evaluators, was efficiently adapted on smartphones and can be installed with ease.

Table 7.
Table showing the mean, standard deviation, and the interpretation of the category Program Information and its subcategories

	Mean	SD	Interpretation
PROGRAM INFORMATION	3.84	0.294715359	Very Appropriate
Conciseness	3.866666667	0.351865775	Very Appropriate
Grammar	3.866666667	0.351865775	Very Appropriate
Validity	3.933333333	0.25819889	Very Appropriate
Precision	3.666666667	0.6172134	Very Appropriate
Comprehension	3.866666667	0.351865775	Very Appropriate

The table above indicates that the means obtained in the category Program Information and its subcategories Conciseness, Grammar, Validity, Precision, and Comprehension can be interpreted to as very appropriate since the computed means were ranging from 3.67 to 3.93, which were within the range 3.26-4.00. The standard deviations were also all relatively close to zero and below one, indicating a relatively small spread of scores among the criteria. With this, it can be implied that the evaluators agreed that the application was informative, contained updated and valid contents, and free from grammatical and spelling errors. The illustrations were also easy to be comprehended and precise although two of the evaluators commented that the animation of Telophase can further be improved. Also, the texts included were too lengthy according to the participants, which can reduce the interests of users.

Table 8.
Table showing the mean, standard deviation, and the interpretation of the category Usability and its subcategories

	Mean	SD	Interpretation
USER'S INTERACTION	3.756	0.376521675	Very Appropriate
Purpose	3.733333333	0.59361684	Very Appropriate
Materials	3.733333333	0.59361684	Very Appropriate
Instruction	3.933333333	0.25819889	Very Appropriate
Start/Exit	4	0	Very Appropriate
Appeal	3.6	0.507092553	Very Appropriate
Effectiveness	3.533333333	0.639940473	Very Appropriate

As shown in Table 8, the category User's interaction and its sub-categories got means which were ranging from 3.53-4.00, and were within the range 3.26-4.00, which then indicated that the criteria can be interpreted to as very appropriate. The standard deviations were also not far from zero which points out that the data were concentrated around the mean. Based on the obtained computed data, it can be denoted that the application, based on the 15 evaluators, was interactive, and included clear instructions and an appealing user interface. The developed program was also seen by the evaluators as efficient for the target users, which were Biology teachers who seek to teach the cell cycle.

Table 9.
Table showing the means, standard deviations, and the interpretation on the computed means for each category and the overall rating

	Mean	SD	Interpretation
Functional Stability	3.978	0.085205634	Very Appropriate
Performance Efficiency	3.933333333	0.25819889	Very Appropriate
Usability	3.793333333	0.398939069	Very Appropriate
Reliability	3.633333333	0.549891764	Very Appropriate
Portability	3.8	0.455129495	Very Appropriate
Program Information	3.84	0.294715359	Very Appropriate
User's Interaction	3.756	0.376521675	Very Appropriate
Overall Rating	3.819142857		Very Appropriate

Table 9 shows the means and standard deviations computed with the corresponding interpretation for each category in the evaluation sheet as well as the overall rating. As the table above shows, the computed mean scores were all approximately four and the standard deviations were approximating zero. These implied that the scores gathered were not that scattered and were close to the computed means. In addition, every category as well as the overall rating, based on Table 9, can be interpreted as very appropriate which then indicated that the majority of the evaluators graded the application with positive feedback and gave high scores for each category. Also, the results can infer that the application has the potential to be an advantageous cell cycle instructional material.

Summary comments were also provided by the application evaluators and based on their written comments, the major strengths of HAYtechNAYAN were its visual appeal, useability, smooth experience, and content. The weaknesses

of the application, on the other hand, were its availability, reliability, and the lengthy texts. The evaluators also suggested to further enhance the application by adding more animations, captions during the animations themselves, the ability to further manipulate the animations, and interactive quizzes.

The results obtained were supported by the study of Billinghurst & Duenser (2012), which also found out that Augmented Reality Applications can be a useful teaching material for high school levels due to its interactivity.

Conclusion and Recommendation

After careful analysis of the evaluation of the 15 STEM-based high school Biology teachers, the researchers concluded the following:

All of the elements present and included in the interface of the developed application were functional, complete, correct, and stable.

The application had accurate and timely processing times.

The application can easily be learned, operated, and used by the target users, and was also aesthetically appealing which provided a pleasing interaction for the students and teachers.

The application was reliable, always available, and can recover easily after interruptions. Although, some evaluators disagreed with the availability of the application as it can only run on android operating systems by the time of evaluation.

The application was appropriately adapted on smartphones and can be installed seamlessly.

The application was informative, and included current and valid data that were clear and free from errors. The illustrations also were precise and can easily be comprehended by the users. However, the application included texts that were too long which can be unappealing and uninteresting to some users.

The application interacted with the target users efficiently and appropriately with the use of clear instructions and an appealing interface. The program was also efficient for the intended users, which were Biology teachers who seek to teach the cell cycle.

The application can be a potentially advantageous educational and instructional tool that would be very appropriate to be used in teaching the cell cycle.

The study only focused on the evaluation of Biology teachers and not on actual testing on high school students. With this, the researchers recommend the future researchers to test the effectiveness of the AR application as a learning material on the intended high school students, which specifically are Grade 8 students. The researchers also recommend to minimize the amount of text in the application and to make the application be compatible with other Operating Systems such as iOS. It is also recommended to include interactive activities and quizzes, as well as make the application more manipulative. Lastly, it is recommended to maximize the number of participants who will be tested to increase the validity of the research study.

Acknowledgment

The researchers would like to recognize the people for their invaluable assistance throughout the conduct of the study. To Mrs. Suzzeth U. Dizon, the developers' research adviser, as well as Mr. Angelo Cabic who provided sufficient knowledge and assistance to the researchers. To Mr. Marvin Ignacio and to Mr. Ephraim John Guevarra whom the developers consulted regarding the software Blender, Unity and Vuforia. To Mr. Daryl Regis who gave advice in the programming in the AR application. To Paul Jacob S. Villarino who assisted the app creators in conceptualizing the app content. To Ethan Arocena, Jeruine Doon, John Raphael Bautista, Ernesto Camus and Jhonard Lazaro who helped the creators in programming and developing, and assisted with the evaluation of the application.

References

Akçayir, M., & Akçayir, G., (2016). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*. 1-29 doi: 10.10.16/j.edurev.2016.11.002.

Arce, C.L., Cabuyaban, J.J., Gaces, K.S., & Pagtaconan, W.C., (2018). ARSci: A 3d augmented reality-based learning tool in earth science. Asia Pacific Higher Education Research Journal, 5(1), 1-11.

BADA & Olusegun S., (2015). Constructivim Learning Theory: A Paradigm for Teaching and Learning. *IOSR Journal of Research & Method in Education (IOSR_JRME).* 5(6), 66-70.

Billinghurst, M., & Duenser, A., (2012). Augmented Reality in the Classroom. *Computer*. 45. 56-63. doi: 10.1109/MC.2012.111.

Chen, P., Liu, X., Cheng, W., & Huang, R., (2017). A review of using augmented reality in education from 2011 to 2016. *Springer Science+Business Media.* 13-18. doi: 10.1007/978-981-10-2419-1_2.

Constructivism (2018). *University of Sydney School of Education and Social Work.* Retrieved from https://sydney.edu.au/education_social_work/learning_teaching/ict/theory/constructivism.shtml.

Fleck, S., & Simon, G., (2013). An augmented reality environment for astronomy learning in elementary grades: an exploratory study. IHM I3ORDEAUX, 14-22. doi: ff10.1145/2534903.2534907.

Grier, R.A., & Thiruvengada, H., (2012). Augmented reality - implications toward virtual reality, human perception and performance. *PROCEEDINGS of the HUMAN FACTORS and ERGONOMICS SOCIETY 56th ANNUAL MEETING*. 1351-1355. doi: 10.1177/1071181312561388.

ISO 25010. (n.d.). Retrieved from ncda.org.

Khanlari, A., (2013). Students' perception of the effects of educational technology on their learning and characteristics. International Journal of Science and Applied Information Technology (IJSAIT), 2(2), 58- 61.

Lawsin, N.L.P., & Garcia, G.S. (2017). DEVELOPMENT OF DIGITAL COURSEWARE IN TEACHING TRANSMISSION GENETICS.

Lham, T., & Sriwattanarothai, N., (2018). A board game to enhance understanding of cell cycle for grade ten bhutanese students. Rabsel - the CERD Educational Journal, 19(2). Retrieved from https://www.researchgate.net/publication/331987472.

Lee. K., (2012). Augmented reality in education and training. TechTrends, 56(2), 13-21. doi: 10.1007/s11528-012-0559-3.

Maruping, L.M., Venkatesh, V., & Agarwal, R. (2009). *A control theory perspective on agile methodology use and changing user requirements*. Information Systems Research, 20(3), 377-399

Nam, T., (2009). A conceptual framework of augmented design. 1487-1498.

Oztap, H., Ozay, E., & Oztap, F., (2016). Teaching cell division to secondary school students: an investigation of difficulties experienced by Turkish teachers. Journal of Biological Education 38(1), 13-15. doi: 10.1080/00219266.2003.9655890.

Peart, D.J., Rumbold, P.L.S., Keane, K.M., & Allin, L., (2017). Student use and perception of technology enhanced learning in a mass lecture knowledge-rich domain first year undergraduate module. International Journal of Education Technology in Higher Education 14(40), 1-11. doi: 10.1186/s41239-017-0078-6.

Pengcheng, F., Mingquan, Z., & Xuesong, W., (2011). The significance and effectiveness of augmented reality in experimental education. doi: 10.1109/ICEBEG.2011.5881654.

Pugoy, R.A., Ramos, R., Figueroa Jr., R, Rivera, R.M., Siritarungsri, B., Cheevakasemsook, A., Noimuenwai, P., & Kaewsarn, P., (2016). Augmented reality in nursing education: addressing the limitations of developing a learning material for nurses in the Philippines and Thailand. IJODeL, 2(1), 11-24. Retrieved from https://www.researchgate.net/publication/306893875.

Saeed, R., (n.d.). Definition of education; tradition and modern concept of education; aims of education. Retrieved from https://www.academia.edu/25724141/DEFINITION_OF_EDUC ATION_TRADITION_AND_MODERN_CONCEPT_OF_EDU CATION_AIMS_OF_EDUCATION_DEFINITION_OF_EDUC ATION.

Saltan, F., & Arslan, O., (2016). The use of augmented reality in formal education: a scoping review.EURASIA Journal of Mathematics Science and Technology Education 2017 13(2), 503-52.

Smith, M.U., & Kindfield, C.H. (2013). The American Biology Teacher. 61(5), 366-371

Technology in a Classroom – Augmented Reality is the Future of Education. Research. (December 10, 2017). Retrieved from https://www.cleverbooks.eu/technology-in-a-classroom/

University of Southern California Libraries (2020). Organizing Your Social Sciences Research Paper: Types of Research Designs. *Research Guides.* Retrieved from https://libguides.usc.edu/writingguide/researchdesigns.

Valenzuela National High Schoo1, (n.d.). Retrieved from https://valnaths.com/least-mastered.

Appendix

Appendix A: Raw Data

	A	B	C	D	E	F	G	H
FUNCTIONAL STABILITY								
Functional Completeness	4	4	4	4	4	4	4	4
Functional Correctness	3	4	4	4	4	4	4	4
Functional Appropriateness	4	4	4	4	4	4	4	4
PERFORMANCE EFFICIENCY								
Time Behavior	4	4	4	4	3	4	4	4
USABILITY								
Learnability	4	3	3	4	3	4	4	3
Operability	4	4	4	4	4	4	4	4
User Interface Aesthetics	4	3	4	4	4	4	4	4
Accessibility	3	4	4	4	3	4	4	4
RELIABILITY								
Availability	3	4	4	4	4	4	4	2
Recoverability	4	4	4	4	4	4	4	3
PORTABILITY								
Adaptability	4	4	4	4	4	3	4	2
Installability	4	4	4	4	4	4	4	3
PROGRAM INFORMATION								
Conciseness	4	4	3	4	4	4	3	4
Grammar	3	3	4	4	4	4	4	4
Validity	3	4	4	4	4	4	4	4
Precision	2	3	3	4	4	4	4	3
Comprehension	3	3	4	4	4	4	4	4
USER'S INTERACTION								
Purpose	4	2	4	3	4	3	4	4
Materials	4	2	3	4	4	4	4	3
Instruction	4	3	4	4	4	4	4	4
Start/Exit	4	4	4	4	4	4	4	4
Appeal	3	3	3	3	4	3	4	3
Effectiveness	3	2	3	3	4	3	4	3

	I	J	K	L	M	N	O
FUNCTIONAL STABILITY							
Functional Completeness	4	4	4	4	4	4	4
Functional Correctness	4	4	4	4	4	4	4
Functional Appropriateness	4	4	4	4	4	4	4
PERFORMANCE EFFICIENCY							
Time Behavior	4	4	4	4	4	4	4
USABILITY							
Learnability	4	4	4	4	4	4	4
Operability	4	4	4	4	4	4	4
User Interface Aesthetics	4	4	4	4	4	4	4
Accessibility	4	4	4	4	4	4	4
RELIABILITY							
Availability	2	2	3	4	4	4	4
Recoverability	3	4	4	4	4	3	4
PORTABILITY							
Adaptability	3	4	4	4	4	4	4
Installability	3	4	4	4	4	4	4
PROGRAM INFORMATION							
Conciseness	4	4	4	4	4	4	4
Grammar	4	4	4	4	4	4	4
Validity	4	4	4	4	4	4	4
Precision	4	4	4	4	4	4	4
Comprehension	4	4	4	4	4	4	4
USER'S INTERACTION							
Purpose	4	4	4	4	4	4	4
Materials	4	4	4	4	4	4	4
Instruction	4	4	4	4	4	4	4
Start/Exit	4	4	4	4	4	4	4
Appeal	4	4	4	4	4	4	4
Effectiveness	4	4	4	4	4	4	4

Appendix B: Consent and Evaluation Sheet

Department of Education
National Capital Region
Schools Division Office – Caloocan City
CALOOCAN CITY SCIENCE HIGH SCHOOL
P. Sevilla Street corner 10th Avenue West Grace Park Caloocan City, 1400

Dear Participant:

We are Senior High School students of Caloocan City Science High School presently conducting a research entitled **"HAYtechNAYAN: An Augmented Reality Application for the Learning of Cell Cycle"**. We would like to invite you to participate in this research study by answering the attached evaluation sheet.

The aim of this study is to provide an alternative learning material for a better understanding of the cell cycle. The completion of the questionnaire will only take 5-10 minutes. There will be no compensation nor risk upon your response. The data and information you will provide is assured to remain confidential and will only be used for educational purposes. Copies of this study will be handed over to our Caloocan City Science High School Research adviser and teacher. If you decide to participate on this research, kindly do your evaluation truthfully and return the questionnaires to the researchers. Participation on this study is optional, you have the right to refuse at any time.

Thank you for your time and effort on taking part in our educational endeavors.

Sincerely,

JOHN DANNIELLE CASTOR
Research Team Leader

Noted:

ANGELO G. CABIC
Research Teacher

Evaluation for HAYtechNAYAN: An Augmented Reality Application for the Learning of Cell Cycle

Ma'am/Sir, please evaluate the aspects of our application using these different categories of criteria:

a) Functional Stability
b) Performance Efficiency
c) Usability
d) Reliability
e) Portability
f) Program Information
g) User's Interaction

For each features stated below, please **check the appropriate circle** of the response that best characterizes how you feel about the statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I. FUNCTIONAL STABILITY				
Functional Completeness • The set of functions cover all the specified tasks and user objectives. (Do all the elements/ buttons work?)	◯	◯	◯	◯
Functional Correctness • The system provides the correct results with the needed degree of precision. (Ex. When you click the gear button in the homepage, you will be directed to the settings of the app.)	◯	◯	◯	◯
Functional Appropriateness • The functions facilitate the accomplishment of specified tasks and objectives. (Do the buttons work according to their purpose?)	◯	◯	◯	◯
II. PERFORMANCE EFFICIENCY				
Time Behavior • The system has accurate and timely response and processing times.	◯	◯	◯	◯
III. USABILITY				
Learnability • The use of the application can be easily learned by the users.	◯	◯	◯	◯
Operability • The system can be easily controlled or operated.	◯	◯	◯	◯
User Interface Aesthetics • The user interface enables pleasing and satisfying interaction for the user.	◯	◯	◯	◯
Accessibility • The system has the capabilities to precisely display the specified goal. (Is the cell division properly and accurately displayed?)	◯	◯	◯	◯
IV. RELIABILITY				
Availability • The application is always available when needed to be used.	◯	◯	◯	◯
Recoverability • The system can reset to its previous state when it encounters an interruption.	◯	◯	◯	◯
V. PORTABILITY				
Adaptability • The application is effectively and efficiently adapted in cellular phones.	◯	◯	◯	◯

Installability • The installation of the system is seamless.	◯	◯	◯	◯

VI. PROGRAM INFORMATION

• The information is clear, concise, and informative to the intended audience.	◯	◯	◯	◯
• The content is free from spelling and grammatical errors.	◯	◯	◯	◯
• The information is based from empirical data that are current and valid.	◯	◯	◯	◯
• The illustration of the cell cycle is precise and comprehensible.	◯	◯	◯	◯
• The content is organized and written in a language understandable to the users.	◯	◯	◯	◯

VII. USER'S INTERACTION

• The application's purpose is well defined and clearly explained to the users.	◯	◯	◯	◯
• The materials for users are readily available, easy to use, and engaging to users.	◯	◯	◯	◯
• There is a clear instruction that guides the users to run the program smoothly.	◯	◯	◯	◯
• Individuals can easily start and exit the program.	◯	◯	◯	◯
• The application is appealing and interesting. This encourages users to continue using the program.	◯	◯	◯	◯
• The program is effective with the intended audience and also others who seek to learn the cell cycle.	◯	◯	◯	◯

SUMMARY COMMENTS

Major Strengths:

Major Weaknesses:

Other Comments:

Evaluation prepared by (optional): _____

Date: _____

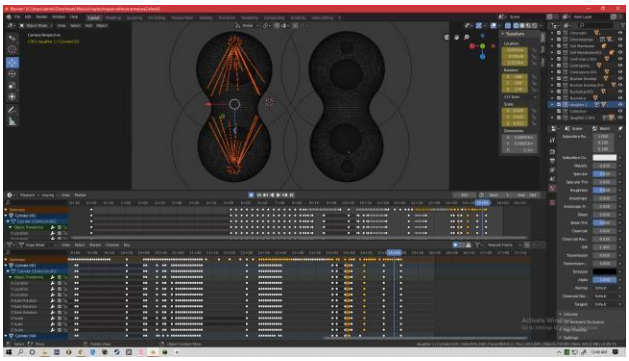
References:

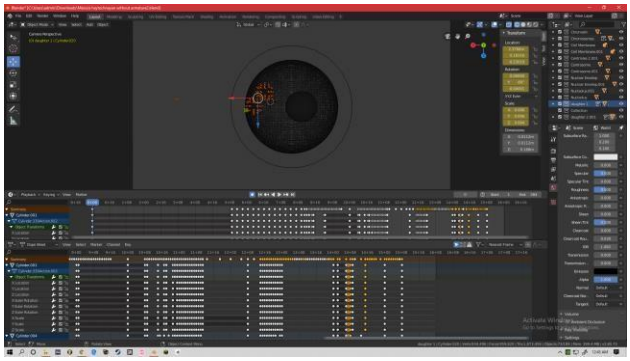
ISO 25010. (n.d.). Retrieved from https://iso25000.com/index.php/en/iso-25000-standards/iso-25010?fbclid=IwAR3lwmGRW9jWtu5mZQ-uzMX-FcGQN1quurgVRoFXdGvQE03LCVZ45tNTRUY&limit=3&start=6

Software Evaluation Criteria. (n.d.). Retrieved from https://www.google.com/url?sa=t&source=web&rct=j&url=https://ncda.org/aws/NCDA/asset_manager/get_file/3404/softwareevaluationcriteria.pdf&ved=2ahUKEwij7_HW5YnnAhWIfd4KHb7bCgoQFjAPegQIAhAB&usg=AOvVaw1BLdhcL6PkadukvxEFAbuh

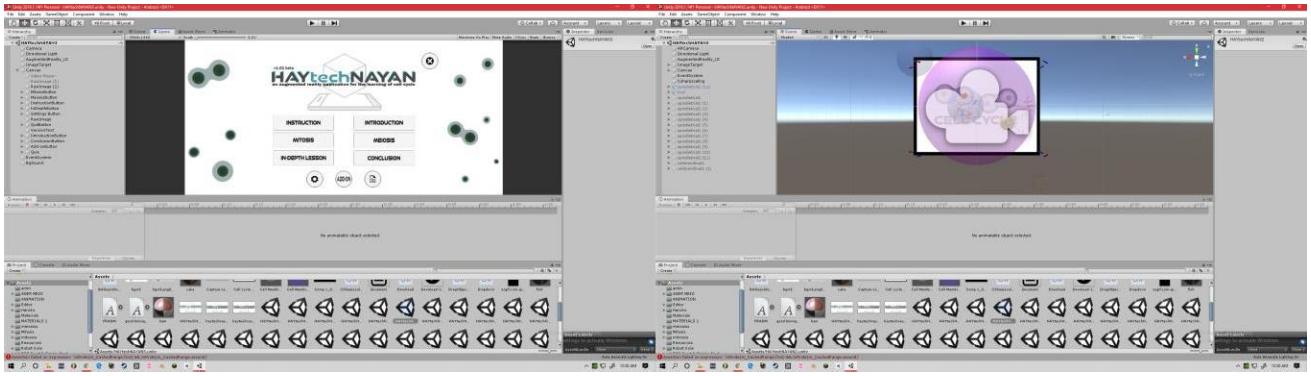
Appendix C: Application Development

3D Modelling and Animation





User Interface and Application Development



Application Testing

Appendix D: Documentations