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EDUCATIONAL COMICS ON GENETICALLY MODIFIED ORGANISMS (GMO'S) AS AN INSTRUCTIONAL MATERIALS IN TEACHING BIOTECHNOLOGY FOR NON-SCIENCE MAJORS

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Abstract

Objective: This study aims to create a comics script and output on Genetically Modified organisms (GMO) and biotechnology topics for non-science and science major students enrolled in Molecular Biology and Biotechnology (MBB-1). **Methods:** This study is an experimental research design and document analysis. The researchers used a25 item test as an instrument in protest and post-test validated by experts. Statistical tools were used to analyze the results. The development of comic strips from library works and research was evaluated through an interview. The responses were coded, themed, and triangulated. **Findings:** Results revealed that almost 50% increase after the end of the semester. The analysis showed that the post-test scores were significantly higher than the protest scores, and the college to which the students belonged also had a significant effect on the test scores. College of Science students had significantly higher test scores compared to non-science courses. The outputs of the students are colourful and engaging. The outputs were a product of students' creative imagination, hard work, and teamwork. The comic strips and video-making encourage science majors and non-majors to research biotechnology and genetically modified organisms (GMOs). Reading articles, books, and other materials increase biotechnology's knowledge, process, and importance. The results and output of students exposed that arts always positively impact both science and non-science learners. **Novelty:** Science, technology, engineering, and mathematics or STEM interconnects with arts to enhance teaching and learning, as affirmed by many types of research; this is now informal Science. STEAM education is a strategy that helps learners enjoy science courses and boost interest among non-majors. Thus, science educators should always be innovative to make Science teaching interesting and fun for all types of learners.

Keywords: Molecular Biology and Biotechnology, Science Major, Non-science Major, Comic Strips and Video, Enhanced Learning

1. Introduction

The Philippines' science curriculum is overcrowded and stays from 8 AM to 4 PM, with limited science laboratory equipment. The National Achievement Test (NAT) results in 2014 were 69.21 and in 2010, 46.38 %, for elementary and high school, respectively. The results are below the national standard set by the Department of Education (DepEd). Another example is the international evaluation such as Trends in International Mathematics and Science Study (TIMSS) and Program for International Students Assessment (PISA). TIMMS results from 2003 high school (HS) II ranked 43rd out of 46 countries and 23rd out of 25 in fourth grades. In PISA, the Philippines ranked second to the last in Science with a score of 357 below the 489 point average [(1)]. Thus, very few took Science, technology, engineering, and mathematics (STEM) in college. But in general, the curriculum in all course have science subjects.

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One of the general education courses in college is molecular biotechnology (MB) for non Molecular Biology and Biotechnology (MBB) majors. As a result, MB in the Philippines is a complicated field of discipline for non-science majors and some science-related students. Teaching the course always pose a challenge to teachers handling the subject. With its interdisciplinary nature traversing the fields of biology, chemistry, physics, mathematics, and engineering as one of the minor subjects in the country's premier University – the University of the Philippines, students are expected to perform well. Even though most students enrolled in the University are valedictorians or top 1 in their respective schools, not all are science enthusiasts. Some of them enrolled in humanities, language, or management courses, but still, they have science subjects that are requirements to complete the degree.

In recent years, science teaching and learning shifted into a more exciting approach to encourage Filipino youth to engage in Science and technology. Many teaching strategies in science education lead to academic success for all science students [(2)]. The relationship between teachers and students plays a crucial role in learning [(3)]. The lack of motivation and low self-confidence in learning the subject is common among science learners, and Science is not about exam achievement. Creating an innovative strategy to allow an engaging and interactive approach is recommended in learning science courses [(4)]. Educational innovations are current trends to improve teaching and learning in recent years. Like, modeling-based instruction (MBI) is about science learners' ability to communicate scientific concepts clearly.MBI is a student-centered approach based on students' understanding and presentation of scientific ideas and solving them [(5)].

This study's main purpose is to create comic strips in the context of biotechnology by non-science major students as potential instructional material. Furthermore, this is also to determine the effectiveness of the outputs in studying Molecular biology.

The Framework of the Study

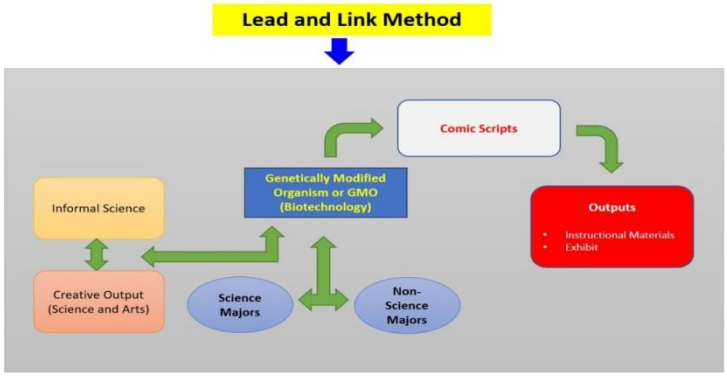

Figure 1.The framework of the study.

This study was about informal Science by integrating arts in learning biotechnology for non-science majors. Informal Science is about learning STEM outside the formal classroom, like films, science centers, botanical gardens, zoos, etc., as instructional materials for learning

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scientific concepts and ideas [6]. The USA is the leading country that advocates informal science learning, followed by the UK and Israel [7]. There are four types of institutions in the US linked to informal science education: universities and federal research, science education institutions, public and private science institutions, and all forms of media [8]. These institutions create opportunities and potential challenges to enhance informal science education for the public. Furthermore, science professionals' motivation to pursue a career in the biological field was to discover the natural world—zoos, nature centers, aquariums, etc. It provides rich experiences for teaching and learning various ecosystems [9].

Furthermore, arts and Science is another perspective of this study. Arts have a positive impact on learners. They exposed students to performing better with an arts education background in middle school, but most came from higher-income families [10]. Since this study was about the comic script, Science and arts were also significant perspectives. Education is focused on the development of humans. One factor possessed by a human is the creative elements but not fully utilized in science teaching. Creativity is viewed from various perspectives but highlights four characteristics; fluency, flexibility, accuracy, and originality [11]. Using a 3D rat model for teaching blood withdrawal revealed an effective method compared to the traditional approach. Thus, science, technology, engineering, and mathematics integrating arts are the current trends for years [5]. STEAM has become an emerging educational model, and through this, students' creativity and critical thinking skills are heightened than traditional delivery approaches. Also, STEAM guides students to solve problems, think critically, and work with others [12]. Schools around the country strengthen the STEAM track, but support from the national government is too limited.

Thus, this study was anchored on two theories, constructivism and creative theory. Constructivism Theory is used in education to help students learn based on their knowledge and experiences. Educators understand that learners bring experiences inside the classroom [13].Educators as constructivists are using a learner-centered approach [14]. Thus, constructivism is vital in this study.

On the other hand, a creative theory is rooted in writing and visual arts [15]. The creative theory uses thinking and application to innovations [16]. Hence, generating comic scripts in learning biotechnology concepts and ideas, the creative theory is also crucial in this study.

Genetically Modified Organisms or GMOs are plants, animals, and microbes in which the genetic material (DNA) has been altered in a way that does not occur naturally. The concept used genetic engineering techniques, which are often called "modern biotechnology" or "gene technology," sometimes also "recombinant DNA technology" [17]. It allows selected genes to be transferred from one organism into another and between non-related species. Humans started traditional practices to breed and cross breed plants and animals with desirable traits in 8000 BCE. And continue to become advanced as crops are more nutritious using genome editing, specifically the CRISPR tool [18]. Thus, it comes to be an integral part of the science curriculum, both basic and tertiary levels.

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In the Philippines, higher education institutions (HEIs) are mandated under the Commission on Higher Education (CHED), with one of the main goals being to pursue excellence [19]. Science is taught as preparation or minor subjects at the tertiary level in the Philippines to equip and prepare students for life after college as part of the community [20]. Science is a mandatory subject in any tertiary course in the Philippines. Science is the basic foundation of education; they can discover new things and increase curiosity through Science. Thus, instructors need to be creative and innovative to make Science easy, fun, and exciting [21]. For instance, the instructor used videos from the world wide web to study integrated science courses for non-science majors and proved it helped them remember conceptual ideas [22]. Reading through scientifically based activities or Cirsa on respiratory and excretion systems showed more effectiveness than conventional learning. Hence, learning Science is not purely about laboratory work but hands-on and active movements. Music, dance, poems, and others are now considered science teaching strategies [23].

According to many types of research, writing activities at home in science courses capture learners' interest [24]. Comics are a current pedagogical strategy [25]. Comics are generally perceived as "kids" reading material and have been used effectively with children in the classroom for decades. For many years' articles from articles reinforced by librarians and educators, the comic has value potential in the classroom because words and images can always support literacy development. Creating comics gives many learners tremendous benefits but less importance nowadays [26].

2. Methodology

This study used experimental design research for quantitative and document analysis for qualitative. The researchers employed the lead and link methods because they wanted to enhance the learning of both major and non-major in learning MBB1. The instructor and group leader act as a leader to conceptualize and understand the idea of GMOs. Then, knowledge acquired through in-depth research and discussion will link to create comic strips and videos about GMOs.

MBB-1 is a semestral general education (GE) course offered at the University of the Philippines- Diliman campus. This course is a lecture-based class designed for but not limited to non-science major undergraduate students. It deals with modern biotechnology's historical events, processes, products, issues, and concerns. At the end of the course, the students are expected to be (a) conversant with basic biotechnology concepts and (b) form their own opinions on current biotech issues.

Ninety-two students divided into three semesters (30 students per class with one class having 32 students) were made to develop a comic story of their assigned GMO. Each class had around 5-6 students from the College of Science (e.g., Biology, Chemistry, Physics). The students were randomly grouped into six sub-groups with 5-6 members and drew lots for their assigned GMO every semester. Out of these sub-groups, one group composed of science-major students served as the control group (Fig. 2).

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A 25-item pretest on basic molecular biology and biotechnology-based on a previously assigned comic story was conducted at the start of every semester to evaluate the students' knowledge and comprehension. At the end of the semester, a posttest was conducted to gauge the students' improvement after attending class lectures, video presentations, oral reporting, and comic scripts.

Students were made to do library work on their topics in four months. Each group's performance and output were monitored monthly based on the plot of their storyline, outline of the scripts they made, the technical information they provided, and their artwork. Each group interpreted their scripts on a comic form printed back to back on an A4-size standard paper. At the end of the semester, each group was provided with a 30-minute presentation and discussion about their creative work. The entire class and a set of three senior faculty, including the corresponding author, evaluated the presentation.

The evaluation criteria for their final output include a) technical elements – referring to the correctness of the scientific and technical (50% of the entire work) presentation of the assigned topic; b) attractiveness or the output is exceptionally attractive, and all graphics are related to the topic and make it easier to understand (20%), and c) originality or their output presents a novel idea and brilliantly executed (30%).

A dependent T-test was performed using STATISTICA 7.1, Stat Soft, Inc. Repeated Measures ANOVA was also performed using the same software to determine the factors that significantly affected the students' scores. The factors analyzed were the class in which the students belonged (whether Class 1, 2, or 3).The college in which they belonged (either College of Science or not), and the time the test was taken (either at the start or the end of the semester), are referred to as TEST.

3. Results and Discussion

In the first semester of project implementation, 20% of the students came from the science-major group that served as a control group, while 80% acted as the treatment group (Fig. 2-A). The control group is 23.33% in the second semester, and 76.67% of the class is the treatment group(Fig. 2-B). The last semester had 21.87% as the control group, and the remaining students (78.13%) served as the treatment groups (Fig. 2-C).

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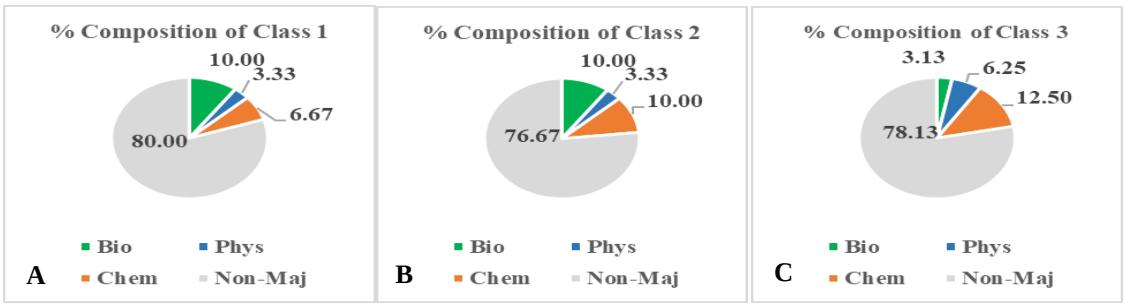

Figure2: Percentage (%) composition of students utilized in this project shows different distributions for every class at different semesters. A-C represents classes 1,2, and 3, respectively.

Many non-major students take MBB1 because it is one of the subjects in general education (GE) courses. As expected, very few know about biotechnology and the concepts of GMOs, and this will create a gap between science majors and non-majors during the teaching and learning process. Thus, instructors are creating teaching strategies and approaches that most students studying MBB1 will grasp the lessons regardless of courses. Few students in college major in Science because of the notion that Science is a tricky subject during basic education. The lack of materials and equipment in learning Science during formative years is one of the reasons for its weaker education systems. According to Pew Research Centers, policymakers and educators are puzzled that very few students engage in STEM courses in college. Also, around 33% aged 25 and older have a degree in the STEM field in the workforce. Results revealed around 23% state STEM subjects are not useful, and 12% said the subject is boring [(27)].

During the pretest at the start of the semester, 46.67% scored at 69-69%, and 6.67%got a below 50%, respectively, in Class 1 (Fig. 3-A). The class improved towards the end of the semester with 43.33%, the score range of 80-89%, and nobody got below 50%. In class 2, the highest percentage of 36.36% of the class got a score of 50-59%, and 16.67% got below 50%(Fig. 3-B). This improved to 46.67% of the class at a percentage range of 70-79%, and only one student (3.33%) got a percentage score below 50%. In the third class, 15 students (46.67%) fell under the highest percentage score of 50-59%, and five students (15.63%) obtained below 50% at a pretest. Towards the end of the semester, 15 students (46.68%) improved their scores within the 70-79% range, and only one student (3.33%) scored below 50% (Fig. 3-C).

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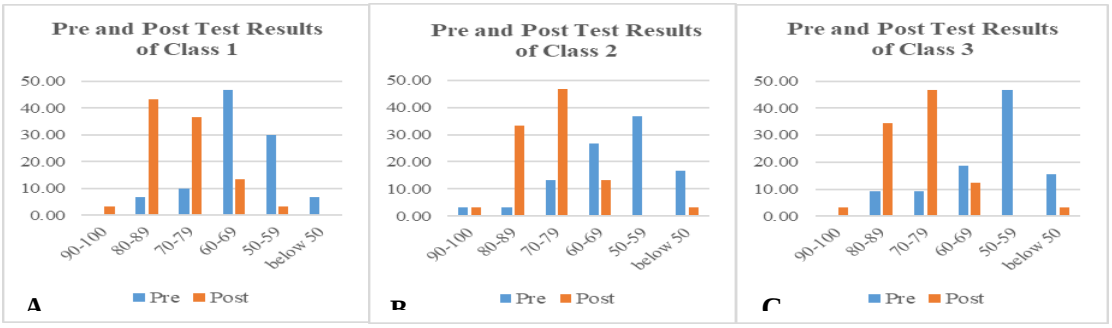

Figure3. Percentage (%) score distribution of students' pre-and posttest results from every class at different semesters. A-C represents classes 1,2, and 3, respectively.

Dependent T-tests showed that the posttest scores were significantly higher than the pretest scores at $p < 0.01$. This was the case for the scores of each class and the students' overall scores **(Table 1).**

Table1. Results of the Dependent T-test Analysis for the overall scores. The difference was significant at $p < 0.01$

	Mean	Std.Dv.	N	Diff.	Std. Dv. Diff.	t	df	p
Post all	77.86957	9.55173						
Pre all	59.91304	11.72548	92	17.9565	7.003787	24.5914	91	0.000000

Repeated Measures ANOVA was also performed using the same software to determine the factors that significantly affected the students' scores. Science majors performed better during the pretest because they already had background and knowledge about biotechnology. Since most science majors come from a special science class or top private institutions in the country, biotechnology was part of the science curriculum.

Results show that the class in which the students belonged had no significant effect on their test scores. On the other hand, the test's time significantly affected the students' scores at $p < 0.01$. This result was consistent with the dependent T-test**(Table 3)**.

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Table2. Results of Repeated Measures ANOVA for the overall scores. In red, factors are significant at p < 0.01, while factors in blue are significant at p < 0.05.

	SS.	df	MS.	F	p
Intercept	568149.4	1	568149.4	3774.260	0.000000
Class	78.2	2	39.1	0.260	0.771803
College	5256.3	1	5256.3	34.918	0.000000
Class*College	144.3	2	72.1	0.479	0.620958
Error	12945.8	86	150.5		
TEST	7100.2	1	7100.2	302.918	0.000000
TEST*Class	49.9	2	24.9	1.064	0.349642
TEST*College	145.1	1	145.1	6.192	0.014759
TEST*Class*College	9.5	2	4.7	0.202	0.817556
Error	2015.8	86	23.4		

In red, factors are significant at $p < 0.01$, while factors in blue are significant at $p < 0.05$.
The college to which the students belonged also significantly affected the test scores. College of Science students had significantly higher test scores than non-College of Science students at $p < 0.01$ (Figure 2). This was true for pretests and posttests, as shown by College and TIME's combined effect plot, which is significant at $p < 0.05$ (Figure 4).

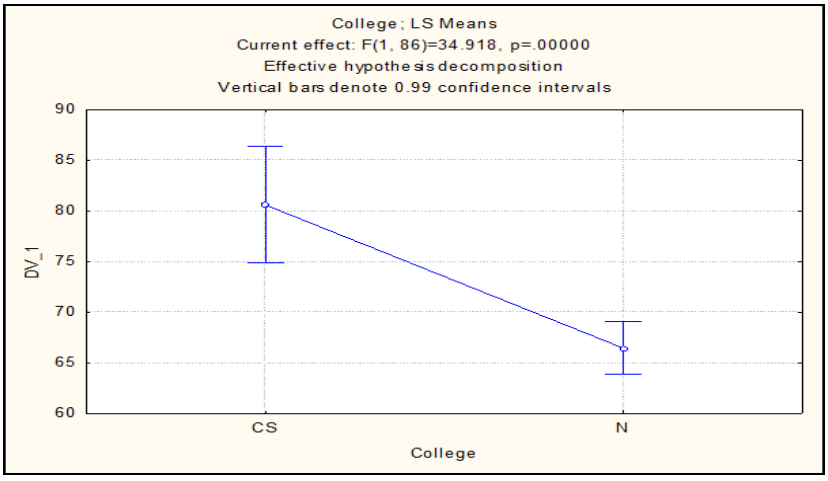

Figure 4.The plot of the effect of the factor College on the scores of students. CS refers to the College of Science students, while N refers to the non-College of Science students. The plot was generated with STATISTICA 7.1 (Stat Soft, Inc.).

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Integrating stories in science teaching contributes to knowledge and competencies among teachers and students. Also, science courses with stories become amusing, joyful, and exciting because creativity develops [24]. Science education is more effective in using meaningful learning and internalization than memorization. The group bared to visual arts significantly increased academic performance and integrated into all subject areas, developing confidence among students and advantages in the learning process [28].

The teacher selected one best works(Figure 5) and showed that major and non-major students worked interestingly. Almost all of them submitted a magnificent work, and they discussed GMOs in detail like experts. The colorful illustrations also added an impact to the outputs. The video presented were fun to watch. The animations were also stimulating to watch. The use of animated movies in learning Science developed higher motivation. Self-efficacy, curiosity, and enjoyment are connected to learners' daily lives and the future. Animations linked to optical, auditory, and kinesthetic are also applied in watching an animated film [29].

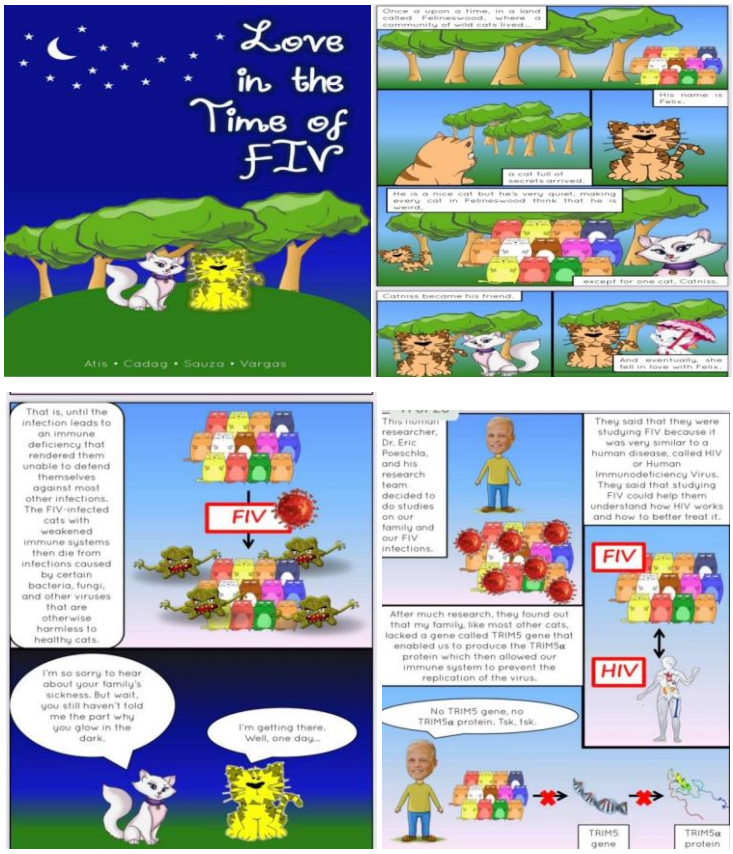

Figure 5: Sample of comics output of MBB1 students at the end of semester detailing how a genetically Modified Organism (GMO) is made.

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Online science magazines and science museum published comic in Korea and has gained positive recognition by graduate students and young scientist. Comics always give meaningful activities to science enthusiasts; thus, scientists are encouraged to improve comics for publications [30]. Moreover, at an early age, learners who are asked to read and create comics can invigorate the skills of inventions, the process of problem-solving, creative designs, and revision [26]. As part of higher-order thinking skills, creative thinking is crucial for learning [31]. The outputs were a product of students' creative imagination, hard work, and teamwork. Moreover, students create outputs outside the classroom; they visit libraries, science centers, etc. The concept of informal Science was employed.

Science, technology, engineering, and mathematics with arts or STEAM proved to increase science and non-science majors' comprehension.

Furthermore, the student's responses to the given survey questionnaire revealed the activities allowed them to explore MBB and understand the process of biotechnology and GMOs. Despite their knowledge about the topics **(Table 4.)**

Hands-on activities allow students to explore independently and improve research work skills and knowledge. This structured activity offers the chance for students to experience authentic research investigation in a classroom setting [32]. Thus, with proper protocol and procedures in every activity, students will be able to complete assigned tasks with excellent outputs regardless of status.

Moreover, a study on digital comics in distance learning revealed positive outcomes among students. Also, using this innovation developed good behavior in learning the course [33].

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Table3. Examples of student responses on the exercise about comics strips and video project on biotechnology.

Questions	Responses
Enrich your knowledge and appreciation of biotechnology	• Enhance knowledge about biotechnology • Appreciate the process of biotechnology • Improve technical, creativity, and imagination as a non-science major in genetic engineering • Able to discuss the topic with my groupmates • Understanding the importance of biotechnology
Improve your competencies in a scientific or technical discussion	• Appreciate the value of research • Learn about MBB • Make challenging topics fun and interesting • Understand biotechnology through words • Able to discuss the process better with peers • The eye-opener for more concepts of biotechnology • Expose to the scientific world • Improve research knowledge and skills

Since childhood, stories have significantly played an essential role in our lives. A lesson taught in stories creates a fun and exciting environment for learners [(34)]. Comic book techniques in learning physics, such as story-based teaching programs, explanatory stories, and chemical stories, showed effective creative thinking development among students [(35)]. Using a student-centered approach in Science always exhibits a positive response among learners and increases knowledge about scientific concepts and ideas [(23)].

For the past decades, controversies on genetically modified organisms (GMOs) food have circulated in media outlets that focus on health risks and conspiracy theories. Experts and scientists supporting GMOs are criticized. According to some, they are traitors to their country for being an advocate and supporters of genetically modified food [(36)]. The government's lack of understanding and reinforcement causes chaos among anti GMOs.

The students' outputs were displayed in an exhibit during biotechnology week.

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4. Conclusion

Results revealed that almost 50% increase after the end of the semester. The analysis showed that the post-test scores were significantly higher than the pretest scores, and the college to which the students belonged also had a significant effect on the test scores. College of Science students had significantly higher test scores compared to non-science courses. However, there were non-science majors who also performed better than their peers. Also, after thorough research and diligently studying GMOs, the results of non-science majors significantly increase. The students' outputs are colorful and engaging, with excellent illustrations and anime. The outputs were a product of students' creative imagination, hard work, and teamwork. The comic strips and video-making encourage science majors and non-majors to research biotechnology and genetically modified organisms (GMOs).

The activities are science teaching techniques for most non-science majors in learning biotechnology, specifically GMOs. Reading articles, books, and other materials increases biotechnology's knowledge, process, and importance. The results and output of students exposed that arts always positively impact both science and non-science learners. Science, technology, engineering, arts, and mathematics STEAM enhances teaching and learning, as affirmed by many researchers; this is now informal Science. STEAM is an unrecognized strategy in science pedagogy. Science and arts are importantly linked to enhancing scientific understanding. This is a call to all science educators to advocate STEAM because various researches have proved that it helps improve the performance of science learners. Also, informal Science significant played a role in enriching the interests of science learners. Likewise, this is a preliminary study wherein the students' outputs will be utilized in the syllabus for teaching the course. The novelty of their outputs could serve as a benchmark for limitations of the study since this was conducted with only one faculty of the subject involved from the preparation of rubrics, editing of their initial works, questions, and preparation of their finished comics material. In addition, it is hoped that these outputs could be available in their digital form and could provide social media with a more pessimistic view. The online format could serve as an additional alternative to learning in times of pandemic or even for the improvement of online education. Although it is also a wrong preventive information could be risky and lead to some conspiracy theories, especially on health risks.

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