Design Thinking in Science Education: Enhancing Undergraduate Students' Motivation and Achievement in Learning Biology

Ali Khaled Bawaneh* and Mashael M. Alnamshan

Abstract—**The purpose of this study was to investigate the effects of a design-thinking-based teaching method on optimizing students' motivation and understanding of cell biology. This method is based on creativity and creating solutions and is primarily human focused. It involves a five-step process: discovery, explanation, thinking, experimenting, and developing. In this study, the researchers employed empathy in redesigning the content after each class based on student feedback and reflections. The sample included 92 female students: 50 in a design-thinking classroom and 42 in a conventional classroom. Three instruments were developed: a teachers' guide, an achievement test, and a questionnaire on students' motivation toward learning biology. Data were analyzed using the mean, standard deviation, an ANCOVA test, and size effect. The results showed that there were statistically significant differences in students' increased motivation and achievement of biology in favor of the design-thinking classes. Although the results indicated that there was a statistically significant difference for teaching by the design-thinking method in improving students' achievement according to students' GPA, the results did not indicate a statistically significant difference in enhancing students' motivation toward learning biology according to GPA. Therefore, instructors and curriculum developers should restructure the contents of their courses according to the design-thinking model to optimize students' motivation and understanding of cell biology.**

Index Terms—**Design thinking in education, cell biology, optimizing motivation, learning biology, science education**

I. Introduction

Many decisions and solutions adopted by educational institutions rarely achieve their targeted aims; these solutions may fail because they are not education-based or tailored to the needs and interests of the institutions' affiliates. Consequently, these solutions are unable to precisely identify the real problem that needs to be addressed, and sometimes lack sympathy for the targeted group as well as the coexistence of them and their needs [1, 2].

On the other hand, while considering students' needs, educators should be realistic—for example, do not think students need a book, but take into consideration that students need to learn. This is the creative way of thinking—when thinking of students' needs and coming up with creative solutions [3, 4]. When asking students about their needs, design educators will rarely obtain a clear and sufficient answer that could lead to a solution. But through observing students' behaviors and experiences, as well as getting deep into their lives and environment, one may identify their needs [4, 5].

All over the world, schools and other academic institutions face huge challenges in the design process, starting from the design of teachers' daily schedules to the design of educational curricula. The challenges that teachers face is authentic, varied, and complicated. Consequently, they require different perspectives and new methods in addition to creative styles [3, 6, 7]. Design thinking is one of the creative tools or methods that can be used in teaching. Where it is effectively transferred to schools and universities, design thinking enriches teachers' expertise and students' competence, as well as the educational institution, and will reframe the teaching-learning process [7, 8].

Many studies have indicated that most challenges faced by teachers are those related to aligning students' present and future needs. Design thinking, which takes the future into consideration, may provide us with solutions that address both needs, in a way that enables teachers to consider the future of thinking and teaching. While educators and stakeholders are trying to make school and university classes sources of creativity and innovation, and because design thinking is compatible with student-centered learning, design thinking is one of the most important skills teachers need now and, in the future, [9, 10]. Through it, teachers would be able to improve the teaching process and face challenges in the learning environment. Furthermore, teachers could develop students' thinking skills, link teaching to real life, focus on practice, and design suitable enrichment programs. This need increases when teaching scientific content, which requires higher thinking skills, considerable mental effort, and practical application of the knowledge and concepts [10–12].

A. Design Thinking in the Educational Environment

Students' needs develop rapidly, in a way that sometimes exceeds the evolution of technological innovations that compete to attract them. Teachers, as educational experts, are considered the most knowledgeable of students' dynamic and developing needs, making design thinking a suitable base for designing teaching practices and activities that achieve these needs. Many studies have related the most important factors that guarantee the success of the design work from an educational perspective [8, 13, 14]:

- Identification of the target group: The concept of design thinking depends on identifying, acknowledging, and addressing students' needs, interests, and diversity. We should always start designing teaching practices from the students' perspective, because the design is meaningless when students are not considered.

Manuscript received July 1, 2022; revised October 6, 2022; accepted October 28, 2022.

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doi: 10.18178/ijiet.2023.13.4.1846

- Passion for the job: The team-learning system should have enough freedom and flexibility so that the members become passionate about what they are doing and the way they organize their work to come up with a good and creative outcome. It is important to take into consideration the fact that design thinking focuses on human values in addition to technological and economical ones.

Furthermore, design thinking can help teachers and students learn teamwork, instill an entrepreneurial mindset in them, and release their creative confidence.

B. Why Do Teachers Need Design Thinking?

Innovation is a positive change. For teachers to improve, positive change and moving forward are two basic elements for excellence. Design thinking helps teachers to be more successful through the change they make while designing—and with the people they work with within the design—various lessons, activities, and programs [13, 14]. Today, the teaching process faces many difficulties, but all these problems and challenges could be considered as a chance for both teachers and students to design new solutions to improve both school and university classes [15, 16].

By using design thinking, teachers could improve the teaching-learning process, creating an attractive educational environment. Moreover, communication with students and colleagues would improve, and problems in the educational curricula would be identified, as well as enabling educators to examine possible solutions and then set new plans for the educational content. Ultimately, procedures and results are shared with all concerned with facilitating the culture of creativity. Design thinking in the teaching–learning process also aims at making students happier, and socially and psychologically more satisfied and stable, by solving their problems, satisfying their needs, and achieving their interests, as well as finding out the best creative solutions to make their lives more convenient [14, 16, 17]. In cases where problems are not available or identified, design thinking aims at improving performance and productivity and enhancing loyalty. It also aims at developing the practices of teaching and learning and making them a common culture among colleagues.

C. The Problem of the Study

Cell Biology is an important subject among those delivered at the biology department of the College of Science at Imam Abdulrahman bin Faisal University (IAU) in the Kingdom of Saudi Arabia (KSA), and is a prerequisite for subsequent advanced subjects. The concepts and terms in this course are foundational, for horizontal and vertical integration, to accomplish all the requirements of the biology program in the College of Science at IAU. However, students find it difficult to memorize and understand these terms and concepts, as indicated through their reduced motivation and attitudes as well as their academic achievement, particularly when using traditional teacher-centered teaching methods in the class [3, 6, 18].

To overcome these challenges, enhance students' motivation and attitudes toward learning, and increase their achievement in the Cell Biology course, the researchers adopted a teaching method based on design thinking that is primarily based on sympathizing with the students and incorporating all the variables and factors affecting their learning, as well as using methods that are compatible with the students' interests and needs and fulfill their expectations. The researchers redesigned the content of this course in accordance with the design-thinking model, and this process was characterized by the linkage of scientific concepts and terms with the students' real-life situations, merging them with the students' knowledge and offering students a chance to practice different stages of thinking and scientific activities through five phases (discovery, explanation, thinking, experimenting, and developing) [17, 19, 20]. This study aimed to identify the impact of a teaching method based on design-thinking on enhancing students' motivation toward learning and increasing their achievement in a cell biology course by addressing the following questions:

D. Research Questions

1) Does the undergraduate students' achievement of cell biology content differ according to the teaching method (design-thinking or conventional teaching), and students' GPA?
2) Does the undergraduate students' motivation toward learning biology differ according to the teaching method (design-thinking or conventional teaching), and students' GPA?

E. Importance of the Study

The importance of this study is to aim to improve undergraduate students' achievement in cell biology and enhance their motivation toward learning biology by employing an innovative teaching method based on a design-thinking framework that seeks to activate empathy to its maximum potential. This study also attempts to inform university stakeholders—educators, planners, and curriculum designers—about these results. Thus, the stakeholders can consider the results of this study in the design of curricula and textbooks for various stages according to the design thinking model and hold workshops to train teachers and educators. The training can aid instructors to use these mechanisms appropriately in the classroom.

F. Limitations of the Study

There are some limitations to this study that merit careful attention. First, this study investigated 92 female science students at IAU, KSA. Second, this study is also limited to the Cell Biology course in the biology department, in the second semester of the 2020/2021 academic year. The level of validity and reliability of the study instrumentation may reduce the ability to generalize its results. Furthermore, this work is a case study. For deeper consideration, a longitudinal study should be conducted to appraise students' engagement and perseverance in demanding pre-class preparation of learning content for the whole academic year. Therefore, the generalization of the results may not be borne out for other students.

G. Operational Definitions

Design Thinking: A method that is based on creating solutions and creativity that primarily focuses on humans. It comprises a five-step process: discovery, explanation, thinking, experimenting, and developing. In this study, the researchers followed the five steps by attending some lectures with students and as students (sympathy), taking notes, considering the methods of improving content delivery tools, and then restructuring content in accordance with these methods, with the cooperation of the teacher in the experimental group. This procedure was repeated several times to obtain a teaching method compatible with the steps of design thinking and that addresses students' needs and diversity and enhances their learning and motivation.

Design Thinking is a practice that provides a solution-based method to solving problems. It is valuable for tackling complex problems across any discipline, including science, engineering, and medicine.

Achievement: The progress made in achieving the objectives of a dispensed course in biology entitled "Cell Biology" by undergraduate students during the 2020/2021 academic year. The achievement was measured by a score obtained by students in a test comprising 30 multiple choice questions (MCQs; see appendix 1). This achievement test was prepared by the researchers and delivered directly after the completion of the course.

Students' Motivation toward Learning: Personal academic motivation was approached through the viewpoints of the participants in the study and what individually motivated them toward biology learning. The present study adopted the methods of [21], and [22]. All the items were designed using a 6-point Likert scale (with strongly agree (6), agree (5), slightly agree (4), slightly disagree (3), disagree (2), and strongly disagree (1)) to measure students' motivation toward learning cell biology after adjusting it to the Saudi context.

II. Theoretical Framework and Related Studies

Design thinking can be considered "out-of-the-box" thinking because it encourages the exploration of alternatives by building up different creative solutions to problems. Simultaneously, it focuses on the users' needs, making it a "human-centered" approach that helps us address users' problems. It also encourages teamwork, investing in students' various thinking styles and skills. Al-Shorman and Bawaneh [23] asserts that design thinking is a learning method that focuses on developing learners' creative confidence, while Goldschmidt [12] calls for investing the great role of design thinking in building up inquiry-based teaching methods that motivate learning and enhance student integration.

The method of design thinking could be used to solve complicated problems by following the five phases suggested by the Hasso–Planter institution for Design at Stanford. Interestingly, this approach initially starts with using different ways of thinking (divergent thinking) for exploring as many possibilities as possible, while later, it encourages convergent thinking styles for assembling potential solutions [24]. These five steps are not always consecutive and could be parallel. These phases are [19, 25–27]:

Phase 1: Empathy. This phase aims at understanding the users and their needs and interests. To achieve this, attention and participation are required (in an interview, for example), as well as empathy with people to understand their experiences, and identify their values and motivations. It also aims at identifying the problems and challenges that appear in the targeted settings (e.g., universities or workplaces).

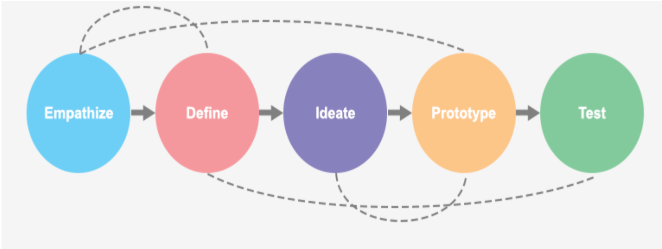

Fig. 1. Design thinking model introduced by the Hasso Plattner Institute of Design at Stanford.
(Available in https://www.linneinnovation.com/sv/sv-blog/118-workshops-metoder/119-design-thinking-sv.html)

Phase 2: Identifying the problem. In this phase, the information collected should be analyzed, categorized, and arranged in a way that facilitates the identification of the problem to be tackled.

Phase 3: Forming the Idea using data from phase 2. We could start by brainstorming solutions to the problem—these initial ideas are typically rough or approximate. However, they should be valid methods capable of solving the targeted problem. What is important here is "thinking outside the box" and creating as many ideas as possible to form an appropriate model for solving the problem.

Phase 4: Forming the Prototype. During this phase, many initial models are designed to explore the suggested possible solutions, aiming to create something that can be shared with the users. Thus, it is important to start initiating the prototype, examining it, and determining whether to accept or reject it. At the end of this phase, a strong idea will be formed as to the solutions that would probably solve the problem, as well as identifying their limitations.

Phase 5: Testing. The best solutions resulting from the prototype phase (phase 4) are examined in the context of the real product, using real designers, assessors, and users. This process is recurrent because the results of these tests can sometimes be used to improve the problem and the suggested prototypes. This leads to more modifications and improvements in the prototypes being tested, and thus necessitates going back to previous phases. The testing process also offers a chance to gain a better understanding of the users as we observe them.

A. Design Thinking in Teaching and Learning

Design thinking includes five stages: discovery, explanation, thinking, experimenting, and developing. In the discovery stage, the designer looks for the problem, discovers it, and understands it by putting him or herself in the place of the targeted user, imagining the user's impressions and feelings. In the explanation stage, the designer identifies the problem's precise details, its dimensions, and the targeted aims based on the notes and information collected in the first stage [28]. In the thinking stage, the designer generates as many ideas as possible to solve the problem, and improves the suggested solutions in the experimenting stage, examining the ideas and cooperating with others to obtain collaborator feedback/suggestions. Finally, in the development stage, the designer extracts the results and develops the ideas, then moves forward depending on the experimental stage [8, 29, 30].

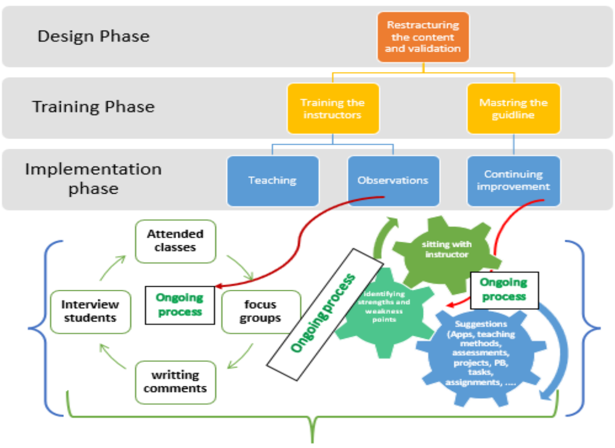

Chart 1: The theoretical framework.

According to teachers, this process could be implemented in lessons and projects to help students create and innovate their ideas. In this case, students will start learning how to adapt to problems and solve them after conducting research and analyzing its results. This will prepare them for a future that intensely focuses on user experience and creative solutions to user problems.

B. The Instructional Method Based on the Design-Thinking Model in the Current Study

To achieve this study's aims—examining the impact of an instructional method based on a design-thinking model on enhancing students' motivation and performance in a cell biology course—the researchers designed the content of this curriculum according to the design-thinking model. The design was based on their expertise in both fields and other science curricula and teaching methods, as well as their work as trainers for the design-thinking program in the leadership center at the IAU. Then, the researchers attended lectures with students—as students, not as teachers. Two of the new teaching assistants were invited to attend to experience the experiment and cultivate sympathy with the students. Additionally, students were asked about their interests, aspirations, and expectations for the course. After each lecture, the researchers held a meeting with the teaching assistants and the real teacher of the experimental group to explain the practices conducted during the lesson and identify the challenges that students suffered from, and that had reduced their motivation toward learning. Based on that, the researchers worked to modify the teaching plans in light of the developments gleaned from the lectures, adjusting them to meet the desires and needs of the students based on the best suggestions and ideas raised, such as using new digital applications like Kahoot and Slido, designing educational games, and conducting a case study related to the lesson. After that, the teaching plans were directly implemented inside the classroom. Furthermore, the researchers generated ideas on how to solve new problems and improve the mechanisms of delivering the content in accordance with the students' interests and needs. Video clips were created, and students were directed to many websites that covered the course topics. In addition to that, the students were assigned parts of the content to present in subsequent lectures (i.e, the students had to give the presentations).They were also asked to do homework in groups (4–6 students), in addition to being advised to contact local and international experts in the field of cell biology to benefit from the experts' experience. The method of the flipped class was implemented. The experimentation and development processes were carried on after each lecture with the addition of a practical or activity. At the end of the semester, the students conducted a pilot project in the Science College Hall, entitled Science Bakery for Plant & Animal Cell Pizza, where pizza was baked in two different shapes using ingredients that simulate the plant and animal cells and their components. The students explained the project theme and its relationship to the content. The project was successful due to students' cooperation, based on recorded student responses and reflections, which asserted the importance of working in groups to conduct different projects related to the course. Chart 1 shows the theoretical framework.

III. Previous Studies

A teaching method based on design-thinking depends on reformulating the content to address authentic problems that are related to students' real lives. Naturally, this requires using the knowledge and skills the students have acquired while searching for solutions. In this regard, a study by Huq and Gilbert [30] suggested an alternative approach to teaching methods through using design-thinking—as well as collaboration with students, teachers, and owners of companies and factories—to enhance students' learning and satisfaction. The study related the great role this instructional approach assumed, which focused on the integration of entrepreneurship and teaching methods through merging the concepts of construction, justice, fairness, humor, and role-playing in entrepreneurship courses to achieve better learning outcomes and enhance student satisfaction.

The study of Mumford, Zoller, and Proforta [31] aimed to use the strategy of design-thinking as an alternative teaching-learning strategy to improve elementary students' critical thinking skills in South America. The study included quantitative and qualitative data and found that a teaching method based on design-thinking enhanced students' learning and developed their critical thinking skills. That is because it adopted student-centered learning and increased cooperation among students. Similar results were found in a procedural study conducted by Harth and Panke [8] in Taiwan to investigate the efficacy of using the Stanford model of design-thinking in university teaching. Their study found that this method improved teaching by enhancing student collaboration, deepening student discussions, and creating an interactive learning atmosphere. This in turn enhanced positive interaction and communication among students and teachers, as well as increasing students' motivation for learning.

A study by Lyncha and Kamovichb *et al.* [32] examined the efficacy of a training program based on design thinking that was oriented to enhancing the entrepreneurship skills of students at an engineering and science college. The study collected the participants' reflections; despite the challenges, the findings referred to the importance of the program in developing creative thinking skills and unconventional methods for running projects. Linton and Kilnton [33] Conceptualize entrepreneurial learning through design thinking-based approach. They argued that by employing design thinking method, learning from a "through" approach can be achieved. This approach enables student-centered learning and focus on skills more applicable. It is also argued that the creativity is central and finding structure is an unstructured process. Design thinking emphasizes a practical approach where students step outside the classroom. In the same context, Demuyakor [34] examined the impact of a design-thinking-based teaching method on teaching student's entrepreneurship. This method focused on students' thinking skills and considered students the core of the teaching–learning process. Therefore, it was a non-linear teaching method, involving an integrative process that was branched and overlapping, intending to create innovative solutions to problems. The study's teaching methods focused on practicing learning outside the classroom; the authors asserted that students' real interaction and experience with real life, and directly dealing with authentic feedback, are very important for developing students' learning and enhancing their reflections.

A study by Shamsuddin and Rozee *et al.* [25] indicated that students liked to learn through using design-thinking, and that helped them acquire the skills of communication, building up a vision, and problem-solving, in addition to enhancing self-confidence. That was confirmed in a study by Martins and G. Signori *et al.* [16] and Li and Zhan [35] which aimed to design the curriculum of a "Creativity & Innovation" subject in an informational systems course for undergraduate students at a private Brazilian university in accordance with the design-thinking model. The findings confirmed the important role of the design-thinking-based teaching method in encouraging scientific research within projects conducted by groups of students. It also enhanced student integration, and with an added value. In the same context, a semi-experimental study conducted by Zubaidi and Khalaf [1] aimed to investigate the effect of teaching an educational unit in science (specifically electricity concepts) based on design thinking in light of their formal thinking. The results revealed a statistically significant difference in the degree of acquisition of electricity concepts attributed to both the teaching strategy based on design thinking and the difference in formal thinking. Furthermore, the results showed a statistically significant difference in the interaction between teaching strategy and formal thinking.

On the other hand, Sawruk [36] conducted a study to examine the mechanisms of developing design-thinking skills through teaching one science unit under project-based teaching considering the principles of the integrative approach. The study found that the skills of design-thinking developed when using this instructional approach, showing that design-thinking skills can be learned and mastered using various practical methods. Furthermore, a study by Painter [13] investigated the degree to which employing design-thinking in teaching mathematics enabled students to acquire math concepts. The study adopted the qualitative approach of research, and data were collected through systematic interviews; the findings showed that the design-thinking-based teaching method helped students master mathematics concepts. Sawruk [36] found that design thinking is an essential way to enhance 21st century skills, and that there has been a concomitant rise of needs and interest in involving students into design thinking. Design-thinking studies tend to pay more attention to STEM domains, and the core concepts of design thinking in K-12 education have been frequently valued and pursued, including empathy, defining, ideation, prototypes, exploration, testing, evaluation, and optimization. Overall, the 43 articles consulted suggest that design thinking shows outstanding potential in optimizing teaching and learning, these results supported by [37, 38].

In the workplace, when team members can visualize customer impact, they gain a better understanding of their company's vision. As a result, it makes their job meaningful; this is a genuine motivation for employees, as 76% of employees rated the meaningfulness of their job as important to their motivation [36]. Creating teams of people with different backgrounds (i.e., "interdisciplinary" teams) is an important prerequisite for design thinking [39]. This is underlined by the basic principle of collaboration [25], which means that in addition to having people with different educations, experiences, and perspectives on a team, it is also important to ensure that the whole team work together through the steps of the process. In other words, tasks should not be divided up based on what is most suitable for the individual members of the team. Interdisciplinary and radical collaboration in practice leads to varying levels of experience and expertise with the process within the team. This supports and motivates the team to maximize their performance.

After reviewing the previous studies, we notice that some of them addressed topics related to the importance of design-thinking in the teaching-learning process, whereas others addressed instructional strategies, programs, and developed units, and their impact on the acquisition of scientific concepts, like those in biology and mathematics. Some studies examined the mechanisms of developing the skills of design-thinking. Based on our review, we can conclude that educational approaches based on design thinking play effective roles in enhancing students' learning and motivation. Like many other studies, this study uses a semi-experimental approach; it is distinguished by its dependent variable, which is related to the achievement of BA students enrolled in a cell biology course, and their motivation toward learning, in addition to the study environment in the KSA.

IV. Method and Procedures

The population of this study comprised all female students enrolled in the biology department of the College of Science at IAU, KSA during the 2020/2021 academic year; the college is exclusively attended by female students. To implement this study in a natural setting, existing intact classes were used [39]. The students come from diverse towns within the eastern region of Saudi Arabia. The population of this study was demographically homogenous, including for age, nationality mother tongue (Arabic), educational system, and cultural background, and held almost equivalent socioeconomic status.

A. Sample

Four female classes of the IAU cell biology course participated in the experiment for 50 days during the 2020/2021 academic year. These classes were intentionally selected by using the purposive sample technique, because one of our colleagues, an instructor of cell biology, eagerly volunteered to carry out the experiment and observe the outcomes of the design-thinking teaching method on her students. Therefore, she was the instructor of the two experimental groups. Another colleague enthusiastically joined the experiment, and she oversaw dispensing the same contents of the course to the two control groups following the conventional method. With support from the authors, the experimental instructor explained the design-thinking teaching method procedures to the students and subsequently received a positive response on their part, expressing an intense interest in cooperating and exploring this new method. The actual total samples consisted of 92 students including 50 (54.3%) students in the experimental groups and 42 (45.7%) students in the control groups. As regards GPA, they represented 27 students (29.3%) at an "excellent" level, 39 (42.4%) at a "very good" level, and 26 (28.3%) at a "good" level. Table I shows the participants' distribution according to the teaching methods.

TABLE I: PARTICIPANTS' DISTRIBUTION BY TEACHING METHODS

Variables		Frequency	Percent	Valid Percent	Cumulative Percent
Teaching Method	Exp	50	54.3	54.3	54.3
	Traditional	42	45.7	45.7	100.0
	Total	92	100.0	100.0	
GPA	Excellent	27	29.3	29.3	29.3
	V. Good	39	42.4	42.4	71.7
	Good	26	28.3	28.3	100.0
	Total	92	100.0	100.0	

B. *Study Design*

A quasi-experiment is an empirical interventional study used to estimate the causal impact of an intervention on a target population without random assignment. Quasi-experimental research shares similarities with the traditional experimental design or randomized controlled trial, but it specifically lacks the element of random assignment to a treatment or control. Instead, quasi-experimental designs typically allow the researcher to control the assignment to the treatment condition but use some criterion other than random assignment (e.g., an eligibility cutoff mark) [40, 41].

In the current study, the researchers used the quasi-experimental design due to the difficulty of assigning individual students randomly, as required by experimental design [40, 41].

C. *Study Instrumentation*

This study used three research instruments for investigation:

1) *The instructor's guide to the design-thinking teaching method*

The researchers reformulated the content of the cell biology course from a textbook approved by the college of science to make it compatible with the design-thinking model and with the lesson implementation procedure. The instructor in the experimental group used her manual after being validated by a panel of five experts comprising university lecturers: two holding a PhD in science/biology education, two holding a PhD in biology, and one holding a PhD in gifted education. The comments and recommendations approved by the arbitration board were taken into consideration.

Validation was conducted in two stages: The researcher first designed the entire instructional material (The Scenario) considering one design-thinking-based teaching method. The researcher sent the booklet versions to individual experts, requesting their opinions in terms of the clarity of the objectives, and how best the booklets represented cell biology instructional content as contained in the textbook approved by the department and College of Science at the university during the 2020/2021 academic year. Each expert was provided with the biology textbook, and their opinions were sought regarding how the proposed lesson preparation complied with procedures corresponding to each of the design-thinking phases. The experts were also sent a statement listing characteristics within each phase of design thinking. The researcher received feedback from all the experts and adopted their notes, and suggestions that were agreed upon by at least half of respondents. In the second validation stage, the modified instructional material was resent to the experts, and their opinions were requested, similarly to the first validation stage. Upon receiving the experts' opinions and notes, the researcher made the necessary changes that were agreed upon by most respondents.

Prior to the practical implementation of the study, the selected teachers were exposed to a three-day training workshop, carried out for three hours per day, with a total of nine training hours. At the end of the second training day, a researchers asked the two volunteer teachers to present any lesson chosen from the booklets provided by the researchers for the actual study on the third day of the training workshop. A group discussion for both teacher-teacher and researchers-teacher was carried out in order to gain feedback on the design-thinking-based teaching method. The training was held in coordination with the biology department and the College of Science at IAU. The purpose of this training was for the teacher to master the treatment teaching method. The teachers were informed that they would be part of an experiment in which new instructional methods would be tested. They worked with the new methods and learned how to use them with their students. In the present study, the focus was on cell biology content. Regular classroom visits were scheduled by the researcher in coordination with the biology department and the teacher to follow-up on the actual implementation of the study in the classroom. Finally, the researcher met the teachers for feedback and assessment regarding the application of the teaching method.

2) *The achievement test*

The researchers elaborated on an achievement test according to a blueprint for the target content in cell biology approved by the College of Science at IAU. The test consisted of MCQs addressing students' understanding of cell biology content. A panel of five experts (the same expert manual referee team) validated the test. Some items were only readjusted, while two items were deleted based on the experts' opinions. The final version of the achievement test included 30 MCQ items (Appendix 1). To ensure the readability of the test items, and time needed for completion, we first administered a pilot test on one class (N = 36), who were randomly selected from the same college but who did not take part in the main study. It was confirmed that none of these students were enrolled in the targeted cell biology course. Considering the feedback received, some items were rewritten, and the required response time was recognized by finding out the mean time span required for the pilot sample to complete the test. The mean periods (31 minutes) taken by the first students and the last students were computed. It is a common practice in achievement tests to delete one or more items depending on the difficulty and discrimination coefficient values. Results from the pilot sample test were scored, and then difficulty and discrimination coefficients were computed for individual items. Results showed that all the difficulty coefficients were between 0.33–0.76, and discrimination coefficients were more than 0.35. These statistical findings were acceptable for the study's purposes [40, 41].

To calculate the reliability coefficient of the test the researchers used the Cronbach Alpha equation in the SPSS program, which measures the internal consistency of the items. The reliability coefficient was 0.78. This result is considered "good" and acceptable for educational research purposes [40, 42].

3) The questionnaire on students' motivation toward learning biology

Based on the literature reviewed and the questionnaires on students' motivation toward learning, the instrument used in this study was adopted from [22] and [23]. This research instrument is commonly used by researchers to measure overall student motivation because of its validity and reliability. The previous items were designed using a 5-point Likert scale (with 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree), while the researchers in the current study added one more level to obtain a 6-point scale (1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Slightly Agree, 5 = Agree, and 6 = Strongly Agree).

To test the validity of the instrument, it was submitted to a board consisting of five experts holding a PhD degree in biology, educational psychology, and science/biology teaching methods. The experts were invited to give their feedback regarding the clarity and suitability of individual items and their appropriateness for gauging the goals designed to measure. In light of their comments and opinions, necessary adjustments were made to three items, and the final version of the instrument included 10 items. The researchers also calculated the reliability factor through the Cronbach Alpha equation, obtaining 0.77. This result is considered "good" and acceptable for scientific research purposes [42, 43].

D. Statistical Standard

The following equation was adopted for paragraphs classification into three categories denoting weak (W), medium (M), and strong (S) [4, 44–46].

$$P = \frac{U-L}{N},$$

where U and L represent the upper and lower limits of the scale, respectively, and N represents the number of required categories.

$$P = \frac{6-1}{3} = 1.67$$

Using the numerical value of P, namely P = 1.67, the three category intervals are determined along with the range between 1.00 and 6.00. They were found to take the following values: $W \in (1.00, 2.67)$, $M \in (2.68, 4.35)$, and $S \in (4.36, 6.00)$, representing weak, medium, and strong, respectively. (See the last column on the right in Table II, and Table V).

V. Implementation of the Study

After ensuring the validity and reliability of the study instruments, identifying a study population and a study sample was the next step. The present researchers considered the following aspects:

A. Instructor Training

To enable the instructor to master the design-thinking-based treatment teaching method, the selected instructor for the experimental group was exposed to a three-day training workshop carried out for three hours per day, with a total number of nine training hours. At the end of the second training day, the researchers asked the instructors in the experimental groups to present any lesson from the provided booklets by the researchers with her assistant for the actual study during the last day of the training workshop. A group discussion was carried out to obtain comments and feedback about the design-thinking teaching method. The instructor was informed that she would be a part of an experiment in which new instructional methods would be tested. She worked with the new method and learned how to practice it with her cell biology students. The application of the design-thinking approach in this study was confirmed through consistent classroom visits scheduled by the researchers in the organization with the College of Science and the instructor to track the real implementation of the study in the classroom and working continuously to develop and update the teaching mechanism used according to the design thinking steps. For the control group instructor, the researchers asked her to run the classes as usual without any change in the teaching method and any guide. She only used the same achievement test before starting the target cell biology content and delivered the students' pre-test instrument at the beginning and post-test at the end of the experiment to assess students' motivation toward learning biology.

B. The Instructional Method Based on the Design-Thinking Model

It is worth mentioning that the teaching method based on design thinking in the current study was used for dispensing the cell biology course for the experimental group for four months (a whole semester). The cell biology textbook, oriented toward the second year, and adopted by the Biology Department at the College of Science at IAU for the 2020/2021 academic year, includes the following content: structures and purposes of basic components of prokaryotic and eukaryotic cells (animal and plant), especially macromolecules (proteins, carbohydrates, and nucleic acids), and membrane and organelle structure. Furthermore, how these cellular components are used to generate and utilize energy in the cells. Also, it involves understanding the cellular components underlying mitotic cell division (the cell cycle). The course involves examples of changes in cell functions in response to the environmental or physical changes that cause mutations (apoptosis, necrosis, and cancer).

To achieve the study aims of examining the impact of a design-thinking-based instructional method on enhancing students' motivation and performance in a cell biology course, the researchers followed these steps:

1) Designed the content of this curriculum according to the design-thinking model, based on their expertise in this field and other science curricula and teaching methods, as well as their work as trainers for the design-thinking program in the leadership center at the university they work for.
2) Attended lectures with students—as students, not as teachers. Two of the new teaching assistants were invited to attend to experience the experiment and sympathize with real students.
3) Students were asked about their interests, aspirations, and expectations for the course. This was conducted during each lecture by one of the researchers, after agreement with the course teacher and his exit from the classroom so that the students could speak freely and without embarrassment. The aim of this step was to develop and improve teaching and learning practices for upcoming lectures.
4) After each lecture, the researchers held a meeting with the teaching assistants and the real teacher of the experimental group to explain the practices conducted during the lesson and identify the challenges that students suffered from, and that had reduced their motivation toward learning.
5) A concerted effort was made to generate as many ideas and suggestions as possible to overcome the previous problems and challenges.
6) Based on that, the previously suggested plan was reconsidered to deliver content and modified in light of the best suggestions and ideas, such as using new digital applications like Kahoot and Slido, designing educational games, and conducting a case study related to the lesson, after which they were directly implemented inside the classroom.
7) Ideas were generated as to how to solve new problems and improve the mechanisms of delivering the content in accordance with the students' interests and needs.
8) Video clips were designed, and students were directed to many websites that addressed the course topics.
9) Students were assigned parts of the content to be explained and delivered in the coming lectures.
10) Students were asked to do homework in groups (4–6 students), in addition to advising students to contact local and international experts in the field of cell biology to benefit from the experts' experience.
11) The experimentation and development processes were carried on after each lecture by adding a practical or activity.
12) At the end of the course, the students conducted a pilot project in the College of Science Hall, entitled Science Bakery for Plant & Animal Cell Pizza, where pizza was baked in two different shapes using ingredients that simulated the plant and animal cells and their components.
13) The students explained the project theme and its relationship to the content.

The project was successful due to students' cooperation, based on recorded student responses and reflections, which asserted the importance of working in groups to conduct different projects related to the course. Appendix 2 includes some relevant photos.

C. *Conventional Teaching Method*

The conventional teaching method was used for the control group to deliver the same content as the experimental group for four months (a whole semester). The instructor followed the traditional style of presentation and practice. In the presentation phases, the lecturer presented the cell biology textbook content in the form of lectures. She explained all the elements and concepts of the lesson and wrote the main information on the whiteboard. Students were required to follow and write down notes. The instructor usually asked students some questions to check their understanding. At the practice stage, students were presented with some team exercises to complete in the classroom. The amount of time allocated to traditional instruction was the same as that devoted to the design-thinking teaching method. However, the roles were reversed: In the conventional teaching method (a teacher-centered approach) the instructor was the principal manager and controller of the learning environment in the classroom [3, 45, 46].

Before ANCOVA was conducted, several analyses were conducted in order to check the assumptions associated with normality, linearity, and homogeneity of regression. In designing the study, it is essential that the covariant (the pretest of cell biology) is measured prior to the treatment (the teaching method) [46]. This is to avoid scores on the covariate being influenced by the treatment. Based on the range of the value suggested by George and Mallery (2000), it was found that the skewness and the kurtosis values were approaching zero, which led to the conclusion that the distribution of the pretest and posttest cell biology scores was close to the normal shape. The findings of this study did not violate the assumption of a linear relationship between the dependent variable and covariate. The final assumption of ANCOVA is related to the homogeneity of regression slopes [45]; this involves checking to see whether there is a statistically significant interaction between the types of teaching methods and the pretest scores of the cell biology. The result of the test showed non-significant interaction effects between the teaching methods and the pretest scores of the cell biology, $p = 0.083$. Therefore, the findings of this study do not violate the assumption of homogeneity of regression slopes.

VI. RESULTS

The purpose of this study was to investigate the impact of the design thinking teaching method on students' achievement of cell biology and motivation towards learning biology for female students in Science College at IAU. Data were collected through the analysis of information gathered from the questionnaire created for the study purpose. To answer the first question: "Is the use of the design thinking teaching method more effective than the conventional teaching method in heightening students' achievement of cell biology?", the descriptive statistics (M, SD) were conducted, and the results are presented in Table II.

TABLE II: MEANS AND STANDARD DEVIATIONS OF STUDENTS' ACHIEVEMENT OF CELL BIOLOGY

Variable	Group	N	Mean	SD
Teaching Method	Design Thinking Teaching Method	50	25.08	3.12
	Conventionnel Classroom	42	20.67	2.38
	Total	92	23.07	3.56
Surdents' GPA	Excellent	27	24.52	4.43
	V. Good	39	22.59	3.35
	Good	26	22.27	2.31
	Total	92	23.07	3.56

Table II shows the means and standard deviations of each post-test score between the groups according to teaching methods. The mean scores of the conventional classroom recorded students' achievement of cell biology (M = 20.67, SD = 2.38) and the design thinking teaching method (M = 25.08, SD = 3.12) with a difference (4.41) in favor of the experimental group.

Regarding students' achievement of cell biology according to their GPA, Table II indicates that the category of students with Excellent level is the highest group with a Mean of 24.52 and a standard deviation of 4.43. Yet, the achievement of a good level was the lowest with a Mean of 22.27 and a standard deviation of 2.31. By understanding the above results, we find that there are apparent differences in the Mean of students' achievement of cell biology according to teaching method, and GPA. Since the researchers have the results of the pretest and posttest of the study exam for students' achievement, and to ascertain the validity of the differences, the researcher performed the ANCOVA analysis, and the results were presented in Table III.

Comparing the scores of the teaching methods (design thinking teaching method and conventional classroom) on students' achievement of cell biology presented that the impact of the innovative teaching method was statistically significant: $F = 52.867$, $\alpha < 0.05$ where eta square statistic (0.373) indicated a large effect size (Cohen, 1988). Table III shows also that there are statistically significant differences for students' GPA on their achievement in cell biology content: $F = 3.255$, $\alpha < 0.05$. It can be understood that the design thinking teaching method had a vital effect on students' understanding of cell biology content.

TABLE III: RESULTS OF ANCOVA FOR THE STUDENTS' ACHIEVEMENT OF CELL BIOLOGY VIA TEACHING METHODS

Variable	Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Teaching Method	Corrected Model	448.598	2	224.299	28.308	0.000
	Intercept	545.232	1	545.232	68.811	0.000
	Pre_test	4.485	1	4.485	0.566	0.454
	Group	418.904	1	418.904	52.867	0.000
	Error	705.206	89	7.924		
	Total	50102.829	92			
	Corrected Total	1153.805	91			
GPA level	Corrected Model	107.123[a]	3	35.708	3.002	0.035
	Intercept	441.407	1	441.407	37.111	0.000
	Pre_test	24.901	1	24.901	2.094	0.151
	GPA	77.428	2	38.714	3.255	0.043
	Error	1046.682	88	11.894		
	Total	50102.829	92			
	Corrected Total	1153.805	91			

To answer the second question of the study: "Do the undergraduate students' motivation towards learning biology differ according to the teaching method: design thinking and conventional teaching method, and students' GPA?", researchers computed the Mean of the questionnaire prepared for this purpose, and the results are indicated in Table IV.

TABLE IV: MEANS FOR EACH ITEM OF STUDENTS' MOTIVATION TOWARDS LEARNING BIOLOGY(N=50)

No	Item	Mean	SD	Category
1	The use of digital activities and applications make the class more interesting	4.86	1.24	S
2	The applications and games that were used are easy to use and attractive	5.03	1.13	S
3	The teaching and learning practices I used increased my focus in the classroom (I was more interested)	4.97	1.18	S
4	My participation was more due to the use of activities, applications, and games compared to participating in the traditional lecture	4.62	1.29	S
5	I prefer to participate in the class through games, activities, digital applications, and teamwork	4.59	1.30	S
6	I greatly appreciate the teaching practices that have been applied and the mechanisms for that	4.84	1.28	S
7	I would like to continue with the teaching practices that have been applied in other courses	4.66	1.23	S
8	Teaching practices that have been applied make the class more enjoyable	4.97	1.20	S
9	Teaching practices that have been applied create a better learning environment and facilitate learning	4.87	1.25	S
10	Teaching practices that have been implemented encourage me to share my ideas and work seriously with classmates	4.98	1.20	S
Overall		**4.84**		**S**

The results in Table IV show that the Mean of the students' motivation toward learning biology is generally (4.84). This shows that their preferable level of using design thinking teaching methods was strong. And when we look at the categories for all instrument items, we can see that all the items (10 out of 10) are strong. The highest Mean is 5.03 corresponding to the second item indicating that the applications and games that were used are easy to use and attractive which supports, encourages, and helps students to learn better. This was followed directly by item number ten and eight (M=4.98: SD=1.20, 4.97: SD=1.20) respectively, indicating that students prefer teaching practices that allow them to share their ideas and encourage them to work seriously with classmates which make the class more enjoyable. However, item number five (M=4.59: SD=1.30) came in the last order (still strong category) in terms of the calculation Mean. This item addresses those students prefer to participate in the class through games, activities, digital applications, and teamwork. This was followed by item number four with a Mean of 4.62 showing that students participating in a class using activities, applications, and games compared to participating in the traditional lecture enhance their motivation and interest in learning. Then, the researchers calculated the Means and standard deviations associated with the two teaching methods and students GPA, as shown in Table V.

Table V presents the overall means and standard deviations of each post-test score between the groups of teaching methods and students' GPA. The mean scores of the conventional group showed that students' motivation towards learning biology (M=4.24, SD=0.863) and the design thinking teaching method (M=5.34, SD=0.685), with a difference of (1.10) in favor to the experimental group.

TABLE V: MEANS AND STANDARD DEVIATIONS OF STUDENTS' MOTIVATION TOWARDS LEARNING BIOLOGY

Group	M	SD	N
Teaching Method			
Design Thinking Teaching Method	5.34	0.685	50
Conventional Teaching Method	4.24	0.863	42
Total	4.84	0.946	92
GPA			
Excellent	4.80	0.900	27
V. good	4.86	0.988	39
Good	4.85	0.963	26
Total	4.84	0.946	92

Regarding students' motivation towards learning biology according to their GPA, Table III indicates that the category of students with very good is the highest group with a Mean of 4.86 and a standard deviation of 0.988. Yet, the motivation of the excellent categories was the lowest with a Mean of 4.80 and a standard deviation of 0.900. By interpretation the above results, we find that there are apparent differences in the calculation Mean of the motivation level students in college of science at IAU according to GPA. To ascertain the validity of the differences, the researchers performed the ANCOVA analysis, and the results are presented in Table VI.

Comparing the scores of the teaching methods (design thinking teaching method and conventional classroom) on students' motivation towards learning biology presented that the impact of the innovative teaching method was statistically significant: $F = 46.723$, $\alpha < 0.05$. Table VI shows also there is no statistically significant difference for all the independent variable student GPA on students' motivation towards learning biology. The statistical significance value at ($\alpha = 0.05$) was (0.970, $F = 0.031$).

TABLE VI: THE RESULTS OF ANCOVA FOR THE STUDENT'S MOTIVATION TOWARDS LEARNING BIOLOGY

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Teaching Method						
Intercept	Hypothesis	2094.938	1	2094.938	75.314	.073
	Error	27.816	1	27.816		
Group	Hypothesis	27.816	1	27.816	46.723	.000
	Error	53.581	90	.595		
GPA						
Intercept	Hypothesis	2080.648	1	2080.648	50989.889	.000
	Error	.178	4.359	.041[a]		
GPA	Hypothesis	.056	2	.028	.031	.970
	Error	81.341	89	.914[b]		

VII. DISCUSSION AND CONCLUSIONS

The result of the current study, which is related to the impact of the instructional method based on a design-thinking model for both dependent variables (students' achievement in the Cell Biology course, and their motivation toward learning biology), could be explained by the attractive learning environment this strategy offers, which gives students a chance to practice the scientific knowledge and acquired skills in real-life situations. It also enables students to think, reflect, and exchange feedback at the end of each stage, as well as opening the door for constructive dialogue and discussion, and experiencing exchange. This leads to assessing the scientific knowledge students acquire gradually. It also offers them a deeper understanding of scientific concepts.

The results of this study could also be explained through the empathy researchers built with students while redesigning the content of the course, development, and improvement in the design in each stage. This empathy is considered the base for learning and modern instructional strategies due to its influence on the improved accomplishment of learning outcomes. This also reinforces students' motivation, as mentioned in the study of [8].

In addition, the design-thinking strategy includes "Hands-on, Minds-on" activities, which are represented in the idea-creating stage and the stage of building and examining models. This helps students in understanding and comprehension, consequently improving their learning and enhancing their motivation. This method also offers an interactive environment that is rich in influencing factors. It also enhances higher thinking skills and improves students' performance, as confirmed by [45].

The results of this study agree with and are supported by the results of many studies [8, 26, 30–35] that indicated and confirmed the role and the impact of teaching by adopting design thinking to enhance students' learning, critical thinking, creative thinking, communication, and 21st-century skills, creating an entrepreneurial culture in the minds of students, and making education enjoyable and useful in their daily lives and their professional future, as well as motivating students toward learning, and making their attitudes positive.

VIII. Recommendations

In light of the findings of this study, the researchers recommend serious consideration of the redesigning of university curricula in accordance with the design-thinking model, as well as implementing training courses on how to design and deliver content according to the design-thinking model. Furthermore, they recommend performing many future studies to investigate the efficacy of teaching methods based on design thinking in enhancing higher-order thinking skills and 21st-century skills.

Conflict of Interest

"The authors declare no conflict of interest".

Author Contributions

The researchers cooperated in writing the introduction, problem of the study, literature, and previous studies. The first researcher identified the study questions, its importance and study methodology, and he analyzed and wrote the results and discussed them. While the second researcher designed the achievement test in the cell biology as well as collecting the data.

Appendix 1: The Achievement Test

No		Items
1		**The Cell Theory**
	A	Cells are the basic unit of life.
	B	cells come from existing cells.
	C	All living things are made of 1 or more cells.
	D	All of the Above
2		**Biology is the study of......**
	A	Health
	B	Life
	C	Nature
	D	Jazz
3		**Protects plant cell**
	A	cell wall
	B	membrane
	C	nucleus
	D	brain
4		**What does this cell contain**
	A	Has a nucleus
	B	Has one giant vacuole
	C	Has an ER
	D	Has Lysosomes
5		**Which scientist studies biology?**
	A	ecologist ologist
	B	biologist
	C	geneticist
6		**What is the 'pink' section of the prokaryotic cell below**
	A	Cytoplasm
	B	Plasmid
	C	Pilus
	D	Flagellum
7		**What is the brain of the cell?**
	A	Ribosomes
	B	Nucleus
	C	Mitochondrial
	D	Cytoplasm
8		**What kind of cell is this**
	A	Prokaryotic cell
	B	eukaryotic cell
9		What kind of cell is this?
	A	Prokaryotic cell
	B	eukaryotic cell
10		**Which cells have the cell membrane?**
	A	The plant
	B	The animal
	C	Blood cells
	D	Or all three

No		Items
16		**an organism made up of one cell**
	A	unicellular
	B	multicellular
	C	reliable
17		**Apoptosis is programmed cell death.**
	A	True
	B	False
18		**What is a cell (in biology)?**
	A	What prisoners get locked up in.
	B	Hersman
	C	The building blocks of life.
	D	Make you who you are.
19		**What are the two different cell types?**
	A	Eukaryote and Prokaryote
	B	Ekaryote and Pekaryote
	C	Ukaryote and Prekaryote
	D	Eukaryot and Prokaryot
20		**A facilitated diffusion is a form of cell transport that**
	A	moves oxygen & carbon dioxide across membranes
	B	occurs against a concentration gradient
	C	requires specific protein channels
	D	uses energy supplied by ATP
21		**Chromatin allows molecules to move inside the cell**
	A	True
	B	False
22		**During the cell cycle, chromosomes are duplicated in:**
	A	Cytokinesis
	B	S phase
	C	G1 phase
	D	G2 phase
23		**What stage of the cell cycle is this cell in?**
	A	Anaphase
	B	Metaphase
	C	Cytokinesis
	D	Interphase
24		**What stage of the cell cycle is this cell in?**
	A	Prophase
	B	Metaphase
	C	Anaphase
	D	Telophase
25		**Where is the cell membrane? (In this picture)**
	A	4
	B	6
	C	7
	D	11
26		**What is the term for the male reproduction cell?**

11 **The mitochondrion is the powerhouse of the cell.**
A True
B False
12 **These store things in the cell**
A vacuoles
B cytoplasm
C mitochondria
D nucleus
13 **This is the control center of the cell.**
A mitochondria
B nucleolus
C Golgi complex
D nucleus
E 20sec
14 **What type of Cell is this?**
A Chloroplast
B Bacteria Cell
C Animal Cell
D Plant Cell
15 **When a solution has fewer solutes than a cell.**
A Hypotonic
B Hypertonic
C Isotonic
D Ionic

A egg
B Sperm
C chicken
D C
27 **The picture below is showing what process in the cell?**
A exocytosis
B endocytosis
C passive transport
D osmosis
28 **The movement of a cell against a concentration gradient is called what?**
A diffusion
B passive transport
C osmosis
D active transport
29 **The branch of biology that deals with the relations of organisms to one another and their physical surroundings.**
A Ecology
B Science
C Biology
D Biology
30 **What organelle proteins are for the cell?**
A ribosomes
B lysosomes

APPENDIX 2: SOME RELEVANT PHOTOS (SCIENCE BAKERY)

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