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# Designing Active Learning Enriched Biotechnology Instruction Module (BIM) for Middle School Science Course

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**Abstract.** This study aimed at designing instructional material named Biotechnology Instruction Module (BIM) which is enriched with active learning methods to enhance the 8th grade students' learning of the topic. The development of the teaching materials proceeded within the stages of the ADDIE instructional design model. The final form of the instructional module comprised active learning materials of DNA Isolation Experiment, Bulletin Boards, 4x2 Biotechnology Learning Station, Case Studies Text, and "What Would You Do If You Were…?" activities. Instructional module covers the topics such as genetically modified organisms (GMO), gene therapy, cloning and bioremediation. The "Biotechnology Instruction Module" is expected to help students to learn in a meaningful way the rapidly changing and renewed biotechnology issues, to foster knowledge and understanding of key issues, to promote socioscientific discourse in class, and to encourage higher order thinking skills. All the data show that the instructional module applied in the real classroom environment is successful in realizing the learning objectives of the subject of biotechnology.

**Keywords:** Biotechnology education; biotechnology instruction module; bulletin board; case study; learning station.

## 1. Introduction

Overlapping with many disciplines in current conditions, biotechnology is described as the combination of all technologies used to obtain biological systems and living organisms or their variations as a whole or their constituents (Reece et al., 2015, p. 396; Biotechnology & Biosecurity Special Commission [BBSC], 2000, p. viii; Thieman & Palladino, 2013). Biotechnology that fundamentally dates to the period before common era is classified under two categories as the following: traditional biotechnology formed as the product of the use of methods (basic fermentation) recently regarded as traditional; and modern biotechnology that has been established with the advent of technological developments (invention of microscope) and modern techniques (recombinant DNA technology, in vitro nucleic acid techniques, etc.). Whereas traditional biotechnology is a nonprogressive technology with strict borders, modern biotechnology is highly potent technology which is quite responsive to improvement (BBSC 2000). Discovery of double-helix structure of DNA in 1953 has led to the start of modern biotechnology era. Owing to in-vitro condition gene cloning through the Polymerase Chain Reaction (PCR) technique, which was developed by Karl Mullis et al. in 1986 and received the 1993 Nobel Prize for Chemistry, immensely accelerated all the field work (Brown, 2010; Mullis et al., 1986; Öz Aydın, 2004; Thieman & Palladino, 2013). Modern biotechnology can be classified into areas such as agricultural biotechnology, animal biotechnology, forensic biotechnology, aquatic biotechnology, medical biotechnology, and bioremediation (Thieman & Palladino, 2013).

Examples given for biotechnology's field of application have several positive and negative effects. Although genetically modified organisms (GMO) have been devised to be produced for good reasons, it is highly likely that adverse outcomes are generated. Biotechnology practices were used in abusive ways and fabrication of biological agents was initiated (Eroğlu, 2006; Mehta & Gair, 2001; Thieman & Palladino, 2013; Yazıcı, 2009). Upon the spread of research concerning biotechnology field, the Convention on Biological Diversity signed at the UN Earth Summit held in Rio de Janeiro in 1992 legislated certain limitations to the utilization of biotechnology in case of possible negative outcomes (United Nations, 1992). To benefit from the field to the fullest for the sake of humanity, proper biotechnology education and instruction procedures must be organized.

### 1.1. Problem Statement

Education and teaching at early ages are crucial for the reasons that biotechnology is quite widespread in various fields (food, pharmaceuticals, agriculture, livestock, industry, environment and environmental pollution, etc.) and that it is necessary to respond appropriately in case of any biotechnology-related problems. In the education of biotechnology, which develops rapidly and includes a wide range of socio-scientific issues, factors such as teachers, course books, and educational methods play a vital role (Sıcaker & Öz Aydın, 2015; Steele & Aubusson, 2004). If biotechnology is valuable enough to be taught in schools, then a much larger volume of research is required for the effective teaching of the subject (Steele & Aubusson, 2004).

It is necessary for individuals to improve themselves their whole lives due to the rapid development of the information in the 21st century. To help with this, an education network with the name of "European Initiative for Biotechnology Education" was founded in Europe in 1991 under the leadership of Organization for Economic Co-operation and Development. Having 20 centers across seventeen countries, the network aims to develop teaching materials for individuals whose ages range from 16 to 19 and train individuals with capabilities of life-long learning regarding the 21st century knowledge throughout their lives (EIBE, n.d.). In addition, National Centre for Biotechnology Education (www.ncbe.reading.ac.uk/) founded in 1995 is one of the information resources regarding biotechnology. "The Helix" and "Scientriffic" journals launched by "Double Helix Science Club" publish teaching materials and scientific holiday programs which can be used at classrooms. Moreover, "Your World: Biotechnology and You" journal holds practical project contests in the field of applied educational studies (as cited in Sönmez, 2014). Out of teaching models, the most appropriate one must be chosen for students to lead a more efficient biotechnology education (France, 2000). Qualified individuals who are equipped with critical attitudes towards biotechnology and can make educated decisions are required on the grounds that biotechnology would have immense effects on the society. Therefore, one of the most suitable instructional approaches that can be utilized for training individuals of such caliber is active learning.

Upon the review of the literature, certain studies, in which various active learning and teaching approaches were suggested or implemented, are noteworthy. For the teaching of biotechnology, Dunham et al. (2002) recommended the use of multiple teaching strategies approach in which many approaches such as Ausubel's meaningful learning approach and problem-solving skills co-exist. Corn et al. (2004) developed a computer-assisted GAME (Genomics Analogy Model for Educators) to teach genetics and genomic topics through Lego Analogy and Small Town Analogy. Moreover, in teaching biotechnology, Taraban et al. (2007) utilized the active teaching approach that depended on lab experiments within the cycle of guided inquiry-based 5E teaching and reported significant increase in achievement levels for students who participated in lab-based active learning approach. Mueller et al. (2015) used a web-based active learning material named The Apple Genomics Project to teach biotechnology genomic processes by taking the apple plant as a model. In the context of active learning, different methods exist apart from the abovementioned strategies and methods with regards to biotechnology.

Collaborative learning, one of the methods included in this study, is a learning method in which students interact with each other in small groups and learn by cooperation. It aims at increasing interest and curiosity, hence, the academic achievement (Gök et al., 2009; Johnson & Johnson, 1999). Another method used in this research is the case studies. In the case studies activities where the students face with real life problems, they are asked to analyze the presented case, generate ideas and suggest solutions (Herreid, 2004, 2011; Temiz, 2010). The method also contributes to a significant growth in the higher order thinking skills of students with both low and high academic achievement levels (Dori et al., 2003). The learning station technique is another active learning technique included in this research.

In the studies of national literature that focused on implementing active learning, among the most challenging factors with regards to the approach are reported as the following: over-population in Turkish classrooms, excessive amount of learning outcomes in the curriculum, necessity for teachers to prepare beforehand and teachers who are more accustomed to traditional teaching. The main barrier in the way of implementation of active learning approach is the inadequacy of materials developed in Turkish language to take reference (Kalem & Fer, 2003).

### 1.2. Related Research

In order for an individual to keep pursuing life-long learning, introducing them with active learning, starting from the very early ages of their lives, will be impactful over training them with skills of interest in learning and access to knowledge. Ün Açıkgöz (2014) defined active learning as the following:

> Active learning is a learning process during which the learner is burdened with the responsibility of the learning process, given the opportunities for decision-making regarding various aspects of the learning process and self-regulation, and urged to use cognitive abilities during learning through complex instructional endeavors. (p. 17).

The aim of the classrooms where active learning is implemented is to train individuals who are life-long learners, are creative and can solve problems, effectively communicate, and make their own decisions; in that, active learning classrooms suggest using techniques and tactics such as discussions to ease storing the knowledge, experiential learning, teaching others and putting the knowledge into practice (Ün Açıkgöz, 2014). The research in the literature indicated that active learning, in comparison with traditional learning, significantly increases achievement (Biricik, 1999; Kalem & Fer, 2003; Taraban et al., 2007).

Considering the research conducted on biotechnology education, it is evident that the level of knowledge of biotechnology and genetic engineering among high school students is not sufficient (Dawson & Schibeci, 2003; Lock & Miles, 1993; Sıcaker & Öz Aydın, 2015). Individuals' familiarity with Genetically Modified Organisms (GMO), one of the most prominent topics of biotechnology, seems similarly inadequate (Demir & Pala, 2007). Based on the survey research conducted on students who had decent knowledge background regarding biotechnology, it was revealed that individuals were anxious about the use of biotechnology. Moreover, students remarked that society was not potentially informed about the effects of biotechnology on human health and that more actions concerning this issue were needed (Cavanagh et al., 2005). Failure in allocating enough time for the subject and students' unfamiliarity with biotechnology affect student achievement scores. In connection, the increase in student achievement scores has a direct effect on their positive opinions (Doğru, 2010). In a study by Chen and Raffan (1999), conducted in England and Taiwan, it was found that students with adequate knowledge of the subject showed more affirmative attitudes towards biotechnology. In accordance with investigations conducted on different age groups, it was found out that the elevation in educational level and background knowledge led students to develop more positive attitudes towards biotechnology (Dawson, 2007). Furthermore, it was observed in studies exploring students' attitudes towards biotechnology, the higher the education and knowledge levels got, the more positive attitudes they developed (Çamur, 2016). Additionally, gender factor had an impact over pre-service teachers' attitudes towards socio-scientific subject areas such as genetically modified organisms, genetic tests, and genetic therapy (Cebesoy & Dönmez Şahin, 2013). Based on the studies conducted on pre-service teachers (Akçay, 2016) and students of ages between 12 and 17 (Dawson, 2007) indicated that students had positive attitudes regarding practices such as stem cell therapy whereas they showed negative attitudes towards the issue of GMO. Moreover, it was observed that older students tended to respond more positively (Dawson, 2007). In the research conducted by Klop and Severiens (2007), a survey study was carried out to investigate the attitudes of students concerning biotechnology. A vast majority (42%) of students stated indecisiveness over the effects of biotechnology. Lastly, Simon (2009) exhibited biotechnology knowledge and attitudes in terms of gender through Eurobarometer 52.1. It was deducted that a high level of knowledge always led to development of more positive attitudes.

Nordqvist and Aronsson (2019) reviewed the research on biotechnology education conducted over the last 20 years and deduced that only nine out of the collection of sixty-four studies were directly related to biotechnology teaching. Therefore, this indicates that further studies must gain distance from research designs that provide basic data such as frequency, measures of central tendency, correlations, etc. Instead, research that would help with the development of practices with regards to biotechnology education to enable its teaching and learning are much more valuable (Nordqvist & Aronsson, 2019).

### 1.3. Research Objectives

The main purpose of the research is to design, apply and evaluate an instructional material based on active learning approach to effectively teach 8th grade students "Biotechnology" topic in Middle Schools Science Course Curriculum (MoNE, 2018) planned to last four lesson periods.

## 2. Theoretical Framework

In active learning approach, various methods and techniques are used that enable students to actively participate in the learning process, give opportunities for decision-making and self-regulation, encourage them to use their cognitive skills and simplify knowledge storing (Ün Açıkgöz, 2014). Due to the large number of methods and techniques available in active learning approach, it is quite appropriate for teaching such complex subjects as biotechnology (Corn et al., 2004; Erdağı & Önel, 2015; Güccük, 2013; Güneş, 2009; Saral, 2008).

Teachers who teach the topics of biotechnology, genomic or genetics in their lessons regard them as the most challenging subjects in the science curriculum (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004). According to Radford and Bird-Stewart (1982), the main reason for this understanding is the requisition of such topics for a more analytical approach as opposed to other approaches of biology. Apart from proving to be a difficult topic for students, teachers consider the use of practical activities in biotechnology lessons to be troublesome as well as spending time for a unit related to biotechnology subject in the curriculum (Steele & Aubusson, 2004). In some studies, a series of factors hindering educators from teaching biotechnology were reported. The pioneering obstacles among them were cited as the difficulty of the subject and teachers' lack of practical skills to teach the topic. In their research, Borgerding et al. (2013) proposed that teachers struggled from anxiety because they lacked knowledge about the topic, experience regarding the techniques of the topic, time and teaching materials. Moreland et al. (2006) suggested that the issue of enabling learning experiences in the field of biotechnology was the biggest problem awaiting a solution from the perspectives of many teachers and science educators of the time. Moreover, the research conducted by Chen and Raffan (1999), Dawson and Schibeci (2003) and Lock and Miles (1993) indicated that students did not harbour sufficient amount of knowledge in the fields of biotechnology and genetic engineering. Teachers must believe that the way, approach and materials used to ensure teaching biotechnology subject are valuable for students and they are likely to attract their attention (Steele & Aubusson, 2004). To overcome this deficiency, actions to increase the efficiency of science lessons are needed to be taken.

The number of materials design research that include recommendations for biotechnology lesson plans and different methods to be used in these lesson plans is quite low (Berry et al., 2013; Fernandez-Novell et al., 2013; Hohenshell et al., 2004; Krageskov Eriksen, 2015; Nordqvist & Aronsson, 2019; Paolella, 1991; Toth & Janstova, 2013). Considering the biotechnology education studies in Turkey, it can be seen that a vast majority of those studies are scale development and misconception research associated with measuring attitudes, knowledge, values and self-regulation (Kaya, 2009; Özdemir, 2005; Sıcaker et al., 2020; Sönmez & Kılınç, 2012). If biotechnology subject is deemed worthy for teaching at schools, then sufficient amount of research to devise methods, approaches and materials to allow the effective teaching of the topic must be conducted.

## 3. Method

### 3.1. Research Design

Concept of research and development is a research method used to produce a particular commodity and test its effectiveness (Gall et al., 2003). This study aims to create interactional product-based materials regarding the subject of biotechnology. Thus, the research at hand is an Educational R n D study.

#### *3.1.1. Instructional Design Model*

The instructional material to be used in teaching the topic of Biotechnology has been developed in accordance with ADDIE instructional design model. The phases of the ADDIE model are described below (Gagne et al., 2005).

(1) Analysis phase: In this phase, the instructional developer analyses performance requirements, students' prior knowledge, skills, and abilities of the incoming students. In this stage specifying learning objectives is very important because they serve as a guide for the planning, development, implementation, and evaluation of activities to be included in the instructional material. The formative evaluation activities begin.

(2) Design phase: In the design phase, a plan of instruction that includes selecting the instructional methods and media and determining the instructional strategies is developed. At this stage, instructional developer outlines the learning objectives and the topic content covered by these objectives; decide the resources and measurement tools. In this phase formative evaluation activities continue.

(3) Development phase: In this phase, lesson materials are developed. If the activities selected in the previous phase comprised items such as experiments, animations, worksheets, etc. these are developed. During this phase, instructional developer validates each unit of instruction and its associated instructional materials as they are developed. Validation process includes internal review, trials (individual, small-group, operational, and whole system), and revisions grounded on feedback from formative and summative assessment activities.

(4) Implementation phase: The instructional system, whose design and development is finalized in the development phase, becomes ready for use in the implementation phase. The operational evaluation activities provide feedback from the classroom practices on the students' performance.

(5) Evaluation phase: Evaluation is such a process that it starts at the analysis stage and continues until the evaluation stage. There are three forms of evaluation, formative, summative and operational evaluation. Formative evaluation consists of evaluations and validations of processes and products and includes individual and/or small group trials. In the development phase operational trials that constitute the summative evaluation were performed as the final step of validation. Operational evaluation consists of evaluation of the instructional system during the implementation phase. Where possible and appropriate, it is recommended that each form of evaluation be used when developing, updating, and revising instruction (Gagne et al., 2005).

### 3.2. Participants

The participants were eighth-grade students with ages of 13-14, in a private school affiliated with the Turkish Ministry of National Education, enrolled in Science course in the 2020-2021 academic year. Implementations were carried out in a real classroom environment during the development process of the instructional module for the subject of biotechnology with two different groups of participants. The first group of students was used in the pilot study carried out during the development phase of the design and the second group of students was used in real classroom implementation phase of the design.

There were eight 8th grade classes in the school and one of them was randomly selected by a draw of lot. There were 22 students in this randomly selected class. From the remaining seven classes, 10 students were chosen randomly among the students who wanted to participate in the pilot study with their own consent. All students both in the pilot group and in the selected class were informed about the purpose of the study and their roles in this research. The students were also informed that their confidentiality and anonymity would be respected, and that they were free to choose to participate or not, and to discontinue the participation at any time. All of the students agreed to participate in the research. In line with ethical issues; the students who participated in the implementation study were chosen on the basis of voluntary participation, and students were not asked to write information (such as name, gender) that would reveal their identity on the products they created during the instructional process. Thus, the implementation of the instructional module developed for the Biotechnology topic was carried out.

### 3.3. Data Collection

Several data collection tools were prepared by the researchers. An evaluation checklist was prepared to assess whether the deigned instructional materials contain active learning features. Other data collection tools were a word association test (WAT) and a questionnaire including four open-ended questions, which were used to collect data that could be evidence of the effectiveness of instructional materials.

### 3.4. Data Analysis

Data collected through WAT and questionnaire were analyzed using content analysis and descriptive statistical analysis methods. Content analysis was conducted by reading the texts (students' answers) for a specific purpose, by analyzing the texts within a context and deriving inferences to find evidence about the effectiveness of the developed teaching materials. Content analysis was carried out to analyze the students' answers to the four-open ended questions included in the questionnaire. Frequency tables were prepared to classify the answers given by the students to the WAT and to write down the number of repetitions of these answers.

### 3.5. Validity and Reliability

To confirm that the developed teaching materials are valid materials that provide active learning an evaluation checklist was prepared by the researchers. The face validity of the checklist was established by five experts, verifying that the checklist include statements that reflect the features of active learning approach.

Inter-rater reliability coefficient was calculated to prove the consistency of coding among researchers. Inter-rater reliability coefficient was calculated as percentage agreement and was found to be 96.4 %. Any discrepancies in the coding were discussed by the coders and resolved through consensus, and thus the themes were finalized.

## 4. Findings

### 4.1. Designing Biotechnology Instruction Module (BIM)

Module is the organized complement of the presented content. A teaching module can support a lesson's purpose, learning outcomes, topics, one of its concepts, or a theme. In this section, the design process of Biotechnology Instruction Module (BIM) is explained step by step in accordance with the phases of the ADDIE instructional design model.

#### *4.1.1. Analysis Phase*

In 2017, Bilgican (2017) designed a material for teaching the Biotechnology topic taking into account the learning objectives related to the subject included in the Middle Schools Science Course Curriculum (Turkish Ministry of National Education [MoNE], 2013), which was published by the Turkish Ministry of National Education and entered into force in 2013. However, the curriculum was revised in 2018 (Turkish Ministry of National Education [MoNE], 2018) and the subject's learning objectives changed. Thus, the need for biotechnology subject teaching material with content that covers the new learning objectives has arisen. The learning objectives of the 8th grade Biotechnology topic in the Middle Schools Science Course Curriculum (MoNE, 2018), which was revised in 2018, are as follows:

- Relates genetic engineering and biotechnology. Examples of bioremediation, vaccination, gene transfer, cloning, and gene therapy are emphasized.
- Discusses the dilemmas created within the scope of biotechnological applications and the beneficial and harmful aspects of these applications for humanity.
- Predicts what future applications of genetic engineering and biotechnology may be.

The new learning objectives and new concepts (such as bioremediation, vaccination) announced in the curriculum (MoNE, 2018) have caused the content of the subject to be taught to be redefined. The necessity of making arrangements has also emerged in order to integrate the STEM approach, which was added to the main philosophy of the new curriculum, with the instructional material. The time allocated for teaching the topic of Biotechnology in the curriculum is 4 lesson hours.

#### *4.1.2. Design Phase*

Inquiry-based learning approach is recommended as core instructional strategy in the curriculum (MoNE, 2018). Since this approach is student-centered, it requires the active participation of the student in the learning process. Active learning methods are the most successful methods in this regard. In this phase, the active learning methods, techniques and tactics to be used in the instructional material were decided. Learning activities, which are suitable for realizing each learning objective, have been planned considering how the STEM approach can be incorporated into the content of the activities. At this stage, the initial outline has been completed as illustrated in Table 1.

**Table 1.** Planned Activities Covering Learning Objectives in the Curriculum

| Learning Objectives (MoNE, 2018) | Activities that could facilitate the acquisition of the knowledge/skills specified in the objectives |
|---|---|
| F.8.2.5.1. Relates genetic engineering and biotechnology. Examples of bioremediation, vaccination, gene transfer, cloning, and gene therapy are emphasized. | 4x2 Biotechnology Learning Station<br>Case Studies Text |
| F.8.2.5.2. Discusses the dilemmas created within the scope of biotechnological applications and the beneficial and harmful aspects of these applications for humanity. | Bulletin Boards<br>4x2 Biotechnology Learning Station<br>What Would You Do If You Were…? |
| F.8.2.5.3. Predicts what future genetic engineering and biotechnology applications may be. | DNA Isolation Experiment<br>Case Studies Text<br>What Would You Do If You Were…? |

With these determined activities, it is also aimed to provide students with field-specific skills defined in the curriculum. Table 2 shows the activities and which skills they cover.

**Table 2.** Field-Specific Skills in the Curriculum Covered by the Planned Activities

| Field-Specific Skills in the Curriculum | Activities |
|---|---|
| a. Scientific Process Skills | DNA Isolation |
| b. Life Skills | |
| Analytical thinking | Station, Case study,<br>What Would You Do If You Were…? |

| | |
|---|---|
| Decision making | Case study, What Would You Do If You Were…? |
| Creative thinking | Case study, What Would You Do If You Were…? |
| Entrepreneurship | Case study, What Would You Do If You Were…? |
| Communication | Station |
| Teamwork | Station |

The instructional module devised in the study is planned to include five activities in accordance with learning outcomes and objectives demanded by Middle Schools Science Course Curriculum (MoNE, 2018) and materials to address these activities.

#### *4.1.3. Development Phase*

The development of the module took place in three main stages. These stages include development of the instructional materials, validation studies, trial and revisions made in the light of feedback from evaluations. At the end of this phase, all teaching materials have been finalized.

At the first stage of the *Development Phase*, it was decided in which order the content of the subject will be applied through which activities. Below is a brief description of how the activities decided in the design phase (see Table 1) were developed.

- DNA Isolation Experiment: Since the new curriculum (MoNe, 2018) emphasizes the development of scientific process skills in students, the DNA Isolation Experiment, which is suitable for the learning objectives of the subject, was chosen. It is thought that this experiment will play an important role in realizing the learning objectives "Relates genetic engineering and biotechnology" and "Predicts what future genetic engineering and biotechnology applications may be".
- Bulletin Boards: Due to the intense content of the subject, it was planned to give some of the subject text in the form of bulletin boards containing visuals. In line with the learning objectives, six bulletin boards were prepared: (1) Biotechnology bulletin board 1, (2) Biotechnology bulletin board 2, (3) Genetically modified organisms bulletin board, (4) Gene therapy bulletin board, (5) Cloning bulletin board, and (6) Bioremediation bulletin board. Considering the explanations of the learning objectives related to the Biotechnology subject in the 2018 curriculum, information about the concepts of bioremediation and vaccination has been added to the bulletin boards' content. While preparing the content of bulletin boards, course textbooks were used. In this way, heaps of information-filled pages in the book have become bulletin boards that students can read without getting bored.
- 4x2 Biotechnology Learning Station: The learning station technique was chosen because it offers an environment where students can find solutions to problems collaboratively. Bilgican (2017) designed the 4x3 Biotechnology Learning Station in her study. However, with the revision of the curriculum, the content of the subject has also changed and this technique has been transformed into the 4x2 Biotechnology Learning Station. Four stations classified as GMO, gene therapy, cloning and bioremediation were constructed for the learning station technique; each station was equipped with two stops. These stops were designated as controversial issues and applications. Also, worksheets have been developed to be used in the "4x2 Biotechnology Learning Station" activity.
- Case studies: Case studies were prepared and questions were added at the end. In this way, it was aimed to give students opportunities to bravely express their opinions concerning the scientific, societal and ethical issues proposed in the case studies text. To Kelly (1990), ethics is a compound product constituted with knowledge, morals and emotions, therefore requires empathy and must be taught as a constituent of science education. Accordingly, in teaching biotechnology subject, moral issues and dilemmas caused by biotechnological innovations must be included.
- "What Would You Do If You Were…?" activity: With this activity, it is aimed to improve the decision-making skills of the students by enabling them to put themselves in

someone else's shoes and use their scientific creativity. The activity developed by Bilgican (2017) was designed to include four questions in total, one for each of the main concepts of the topic (GMO, gene therapy, bioremediation, cloning). The monkey cloning example has been added to this activity as the 5th question to cover the learning objective of "Predicts what future genetic engineering and biotechnology applications may be" in the new curriculum (MoNE, 2018). This is a different and more up-to-date example of cloning than Dolly the Sheep given in textbooks and can lay the groundwork for an ethical discussion in class.

At the second stage of the *Development Phase*, a study was conducted to confirm that the developed materials are valid materials that provide active learning. At this stage, an evaluation checklist, which was prepared by the researchers, was used by experts to evaluate the designed instructional materials before implementation. Demographic information about the experts was given in Table 3.

**Table 3.** Information Regarding the Experts Evaluating the Instructional Materials

| | Person A | Person B | Person C | Person D | Person E |
|---|---|---|---|---|---|
| Area of Expertise | Learning-teaching, survey development | Science educator | Biotechnology, biotechnology education | Learning-teaching, survey development | Science education |
| Experience | 7 years | 3 years | 13 years | 13 years | 8 years |
| Age | 38 | 33 | 45 | 42 | 34 |
| Gender | Female | Female | Female | Female | Female |

The collective results of the evaluation of the five field experts with respect to the strong and weak sides of the materials are given in Table 4. The blank version of Table 4 is the prepared checklist by the researchers.

**Table 4.** Collected Results of Experts' Evaluation of Instructional Materials

| Criterion No | Criteria | *DNA Isolation Experiment* | | *Bulletin Boards* | | *4x2 Biotechnology Learning Station* | | *Case Studies Text* | | *What Would You Do If You Were…?* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Strong | Weak | Strong | Weak | Strong | Weak | Strong | Weak | Strong | Weak |
| 1 | Can ensure permanent learning. | √ | | √ | | √ | | √ | | √ | |
| 2 | Can ease learning of topics. | √ | | √ | | √ | | √ | | √ | |
| 3 | Can make learning enjoyable. | √ | | √ | | √ | | √ | | √ | |
| 4 | Can help make topics tangible. | √ | | √ | | √ | | √ | | √ | |
| 5 | Can enable practice. | √ | | | √ | √ | | | √ | | √ |
| 6 | Can draw away from rote learning. | √ | | √ | | √ | | √ | | √ | |
| 7 | Can present rich knowledge content. | √ | | √ | | √ | | √ | | √ | |
| 8 | Can provide opportunity for experiential learning. | √ | | | √ | √ | | | √ | √ | |
| 9 | Can increase meaningful learning. | √ | | √ | | √ | | √ | | √ | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Can make group work enjoyable. | √ | | | √ | √ | | √ | | √ | |
| 11 | Can provide an active classroom environment. | √ | | | √ | √ | | √ | | √ | |
| 12 | Can increase classroom interaction. | √ | | √ | | √ | | √ | | √ | |
| 13 | Can improve creativity. | | √ | | √ | √ | | √ | | √ | |
| 14 | Can ensure presentation of obtained knowledge in various ways. | √ | | √ | | √ | | | √ | √ | |
| 15 | Can request respect for different opinions. | √ | | √ | | √ | | √ | | √ | |
| 16 | Can provide learning through real life cases. | √ | | √ | | √ | | √ | | √ | |
| 17 | Can provide skills to access knowledge. | √ | | | √ | √ | | √ | | √ | |
| 18 | Can increase interest in lessons. | √ | | √ | | √ | | √ | | √ | |
| 19 | Can provide opportunity for scientific debates. | √ | | √ | | √ | | √ | | √ | |
| 20 | Can be implemented within time period allocated in the curriculum. | √ | | √ | | | √ | | √ | | √ |

The DNA isolation experiment revealed 19 strong features out of 20 criteria. In this respect, experiment emerges as the strongest part of this instructional module. Regarding the results of the checklist pointing to the characteristics of the active learning approach, bulletin boards devised for introductory knowledge for the students revealed 14 strong features out of 20 criteria. The 4x2 Biotechnology Learning Station technique enabling students to practice their prior knowledge revealed 19 strong items out of the 20 criteria. Visually enhanced case studies text activity that would last one lesson period had 16 strong properties out of the 20 criteria. "What Would You Do If You Were…?" activity planned to be used in the fourth lesson matched 18 of the strength criteria in the scale. However, experts have flagged the time criterion as the weak point of the last three techniques (learning station, case studies text, and "What Would You Do If You Were…?"). The time duration prescribed by the curriculum is four lesson hours for the Biotechnology topic and according to the experts it does not appear to be adequate for the implementation of all planned activities. All the finalized teaching materials and the order in which they will be applied within four lesson hours are given in Table 5.

**Table 5.** Activities Planned for Lesson Periods

| Lesson Periods | Activities |
|---|---|
| 1stLesson | a. DNA Isolation Experiment<br>b. Bulletin Boards |
| 2nd and 3rdLessons | 4x2 Biotechnology Learning Station |
| 4thLesson | Case Studies Text, What Would You Do If You Were…? |

At the third stage of the *Development Phase*, a trial was conducted with a small group of student (n=10). Over the course of pilot study, not only the development and improvement of materials were focused on, but also the amount of time allocated for learning outcomes by the curriculum was evaluated. Feedback from the trial can be summarized as follows:

- The DNA isolation experiment is short and interesting.
- The bulletin boards contain easy-to-understand summaries and pictures, it is enjoyable to talk about and discuss.
- Working at the learning station is fun, it increases communication between students and encourages cooperation; the tasks in the worksheets used in the station are understandable, but there are many tasks in a worksheet and it takes a lot of time to complete them.
- The information contained in the case study texts was found interesting by the students; the questions at the end of the text were thought-provoking and prompted discussion.
- The "What Would You Do If You Were…?" activity could not be applied in the classroom within the time allotted in the curriculum. A fifth lesson period was needed to complete the activity. Extra time was given to students to work on the activity in class to assess whether the activity was working towards achieving the learning objectives. However, in order to complete this activity, students need to compile information and news from different sources, create tables, and enrich their reports with photographs; this has led to the need for an internet connection and computers that are not present in the classroom.

Two important results regarding the activities were obtained from the evaluation of both the experts (formative evaluation) and the trial with students (summative evaluation). The first, the time allocated in the curriculum is insufficient to complete the activities prepared for the subject content. So the "What Would You Do If You Were…?" activity was decided to be assigned to the students as homework. Secondly, the necessity of reducing the number of tasks in the worksheets prepared for the learning station technique and writing instructions on the worksheets has emerged. After these minor revisions, the instructional materials became ready for use in a real classroom implementation.

#### *4.1.4. Implementation Phase*

The final form of the instructional module was applied with the students in a real classroom setting. At this stage, operational evaluation of the designed instructional material was done. Operational evaluation addresses the question of whether the instructional material will actually serve its purpose in the context of its operational use. To test this question, the implementation of the instructional module was conducted in form of a pre-test post test one group quasi-experimental design research. The implementation process is summarized in Table 6.

**Table 6.** Research Design of the Study

| Group | Pre-test | Treatment | Post-test |
|---|---|---|---|
| Randomly selected an intact 8th grade class | Word association test (pre-WAT), open ended questions (evaluation of prior knowledge) | Implementation of the instructional module | Word association test (post-WAT), open ended questions (evaluation of the effectiveness of the instructional module on student knowledge of biotechnology topic) |

In the implementation phase, the WAT and a questionnaire including open-ended questions are administered to the students as a pre-test and post-test. The WAT contains the phrases "Biotechnology" and "Genetic Engineering". Students are asked to write what comes to mind about these words in 45 seconds. The four open-ended questions asked are as follows:

(1) Can you give examples of the beneficial applications of genetic engineering for humanity?

(2) Can you give examples of the harmful applications of genetic engineering for humanity?
(3) Could you give examples of beneficial applications of biotechnology for humanity?
(4) Can you give examples of harmful applications of biotechnology for humanity?

By comparing the pre-test and post-test results, it was aimed to determine the changes in the cognitive schema of the students related to the concepts of biotechnology subject, which the teaching created. When the pre-WAT results are examined, it is seen that a total of 54 concepts related to the concept of Biotechnology and a total of 68 concepts related to the concept of Genetic Engineering were expressed by the students. When the post-WAT results are examined, it is seen that a total of 51 concepts related to the concept of Biotechnology and a total of 37 concepts related to the concept of Genetic Engineering were expressed by the students. Table 7 demonstrates the concepts with the highest frequency (f) (at least 20% of the sample) obtained from the pre-WAT and post-WAT.

**Table 7.** The results of pre- and post-WAT analysis

| Biotechnology | | | |
|---|---|---|---|
| Pre-WAT Concepts | f | Post-WAT Concepts | f |
| Science | 14 | Cloning | 14 |
| Technology | 11 | Animals | 12 |
| Animal | 9 | Technology, Dolly, Gene Therapy | 8 |
| Cloning | 8 | Gene transfer, Genetic materials, GMO | 7 |
| Biology, Gene | 7 | Herb | 6 |
| Technological tools | 6 | Vaccine, Genetic Engineering, Living being, Biology | 5 |
| Genetics, Living being | 5 | | |
| **Genetic Engineering** | | | |
| Pre-WAT Concepts | f | Post-WAT Concepts | f |
| Gene | 19 | Genetic materials | 28 |
| DNA chain | 12 | Occupations | 15 |
| Engineer | 11 | Gene therapy | 12 |
| Biotechnology | 8 | Cloning | 8 |
| Heredity | 6 | Gene transfer | 7 |
| Genetics/ genetic code, Science, Nucleotide | 5 | Vaccine | 6 |
| | | Animals | 5 |

When the two results are compared, although it seems that there is a decrease in the total number of concepts written by the students, it has been noticed that there is a significant change in the conceptual structures of the students related to the subject of biotechnology. The post-WAT results showed that the students wrote more relevant concepts and that the frequencies of the concepts increased.

The answers given by the students to the open-ended questions were also analyzed and summarized as themes. Table 8 gives a summary of the students' answers about the benefits of biotechnology and genetic engineering.

**Table 8.** Summary of the Students' Answers about the Benefits of Biotechnology and Genetic Engineering

| Benefits of Biotechnology and Genetic Engineering | | | |
|---|---|---|---|
| Pre-test Themes | f | Post-test Themes | f |
| Gene transfer/exchange | 11 | Productive food | 21 |
| Treatment of diseases | 7 | Gene Transfer/exchange | 18 |
| Extending shelf life | 5 | Treatment of diseases | 18 |
| Cloning endangered organisms | 4 | Cloning endangered organisms | 14 |
| Genetic disorder detection | 4 | Fermentation | 9 |
| Fixing mutations | 4 | Job | 8 |
| Job | 3 | Vaccine | 6 |
| Artificial insemination | 2 | Environmental cleaning | 4 |
| Economic gains | 2 | Fruit yogurt | 3 |
| Order baby | 2 | Insulin | 3 |
| Insulin | 1 | Bioremediation | 2 |
| Vaccine | 1 | Gene map | 1 |
| Artificial organ | 1 | Artificial organ | 1 |
| Paternity test | 1 | Pharmaceutical production | 1 |
| New products | 1 | Vitamin pills | 1 |
| Renewable energy | 1 | | |

It was determined that the students used the concepts and information they learned about the subject while answering the open-ended questions administered after the instruction. Some statements that show that students improved their understanding of the subject are given below.

- "Replacing defective genes with healthy genes…"
- "Foods (GMO) resistant to heat and cold are produced."
- "Hereditary diseases can be treated."
- "To produce vaccines against diseases."
- "Cloning of endangered creatures…"
- "Foods such as vinegar, yogurt, cheese, wine, kefir, etc. are produced with traditional biotechnology."
- "Reproducing oil-eating bacteria and plants that clean up pollution and placing them in contaminated area helps to clean up environments (land or marine)."

Analysis results of students' answers about the harms of biotechnology and genetic engineering are as in Table 9.

**Table 9.** Summary of the Students' Answers about the Harms of Biotechnology and Genetic Engineering

| Harms of Biotechnology and Genetic Engineering | | | |
|---|---|---|---|
| Pre-test Themes | f | Post-test Themes | f |
| Genetic disorder | 11 | Cloning | 13 |
| Environmental hazards | 6 | GMO crops | 9 |

| | | | |
|---|---|---|---|
| Mutation | 5 | Allergy | 9 |
| Radiation | 5 | Environmental hazards | 8 |
| GMO products | 5 | Mutation | 8 |
| Cloning | 4 | Bio weapon | 4 |
| Abuse | 3 | Genetic disorder | 3 |
| Animal experiments | 2 | Health problems | 3 |
| Order baby | 2 | Epidemic diseases | 3 |
| | | Pollination | 2 |
| | | Radiation | 1 |

As can be seen in the Table 9, there is a considerable increase in the frequency of the concepts related to the subject. The statements expressed by the students about the harms of biotechnology and genetic engineering clearly show the contribution of the teaching. Examples of the students' statements are given below.

- "As a result of biotechnology and genetic engineering's studies, the food chain may be disrupted."
- "Biological weapon"
- "Allergic reactions"
- "Having an allergic reaction when someone who is allergic to hazelnut consumes a different food with the hazelnut gene transferred."
- "May cause mutation."
- "Hundreds of embryos died before Dolly was cloned."
- "The short lifespan of the cloned creature."

In order to understand whether learning objectives have been achieved at the end of this instruction, the products (poetry, painting, poster, drawing…) produced by the students during the instruction process or their willingness to participate in the activities and the ways of participation (sharing opinions, participating in a discussion personally, relating ideas or events, predicting…) were evaluated. While the evaluation of a product was about whether it has been produced as required by the task, the evaluation of an active participation was about whether each student participated and the quality of the participation. Table 10 depicts what was evaluated in relation to each activity to decide whether the learning objectives were met or not.

**Table 10.** Evaluated Products, Processes and Ways of Participation

| Learning Objectives (MoNE, 2018) | Activities to Achieve the Objective | Product or Way of Participation | Objective Achieved or Not |
|---|---|---|---|
| F.8.2.5.1. Relates genetic engineering and biotechnology. Examples of bioremediation, vaccination, gene transfer, cloning, and gene therapy are emphasized. | 4x2 Biotechnology Learning Station | Completed worksheet tasks (poetry, painting, poster, drawing…), communication, teamwork | + |
| | Case Studies Text | Sharing opinions, participating in a discussion, analytical thinking, creative thinking | + |
| F.8.2.5.2. Discusses the dilemmas created within the scope of | Bulletin Boards | Reading, participating in a discussion, sharing opinions | + |

| | | | |
|---|---|---|---|
| biotechnological applications and the beneficial and harmful aspects of these applications for humanity. | 4x2 Biotechnology Learning Station | Completed worksheet tasks (poetry, painting, poster, drawing…), analytical thinking, participating in a discussion on ethical issues, communication, teamwork | + |
| | What Would You Do If You Were…? | Analytical thinking, Decision making, Creative thinking, sharing opinions | + |
| F.8.2.5.3. Predicts what future genetic engineering and biotechnology applications may be. | DNA Isolation Experiment | Using scientific process skills | + |
| | Case Studies Text<br>What Would You Do If You Were…? | Analytical thinking, Decision making, Creative thinking, relating ideas or events, predicting | + |

All these qualitative data show that the instructional module applied in the real classroom environment is successful in realizing the learning objectives of the subject of biotechnology. Also, it can be concluded that the final forms of the teaching materials are obtained and they are ready to be used in the next teachings.

#### *4.1.5. Evaluation Phase*

In fact, the evaluation was done at every stage. The formative evaluation consisted of evaluations of the process and products emerging at the phases, and validations conducted during the development phase. Expert opinions and changes made in line with these opinions are also formative evaluation. Summative evaluation consisted of evaluation of the operational trial carried out as the final step of validation in the development phase. Operational evaluation consisted of evaluation of the instructional module during the implementation stage. This evaluation included the qualitative analysis of students' pre-tests and post-tests to decide whether the instructional materials actually served their purpose (teaching the biotechnology topic). The results of WAT analysis and open ended questions' answers analysis have shown that instruction is effective and the instructional material actually serves its purpose in the context of its operational use.

The issues regarding the validity and reliability of the research determined as a result of the evaluations are given below.

- The instructional materials prepared by the researchers were evaluated by five experts and in line with the suggestions the contents of the materials were improved. Having a detailed plan of the instructional module that allows other researchers to implement the same instruction also contributes to internal validity.
- The facts that the learning objectives related to the Biotechnology topic were proposed for eight-grade level in the Middle Schools Science Course Curriculum (MoNE, 2018) and that the eight-grade participants provided positive feedback with respect to the instructional materials at the end of the study strengthens the external validity of the instructional module.

At the end of the ADDIE design process, BIM emerged, to teach Biotechnology topic to the 8th grade students in Science course. The final version of developed BIM was presented in the next section.

### 4.2. The Final Biotechnology Instruction Module (BIM)

Out of four lesson periods designated for the topic of Biotechnology in the science curriculum, the first lesson included DNA isolation experiment and bulletin boards. In the second and third lesson periods learning station technique was employed, while the fourth period included the case studies text. To allow students to revise their knowledge and gain life-long learning skills, activity of "What Would You Do If You Were…?" was assigned as homework. The activities in the BIM integrated with the science course curriculum were presented in Table 11.

**Table 11.** The Final Version of Activities Implemented in Lesson Periods

| Lesson Periods | Activities |
|---|---|
| 1st Lesson | a. DNA Isolation Experiment<br>b. Bulletin Boards |
| 2nd and 3rd Lessons | 4x2 Biotechnology Learning Station |
| 4th Lesson | Case Studies Text, |
| Homework assignment | What Would You Do If You Were…? |

#### *4.2.1. 1st Lesson Activities*

*DNA Isolation Experiment*

Through the experiment students would realize that DNA as a fundamental structure of organisms could easily be seen and doing the experiment (Genetic Science Learning Center, 2018), as an introduction to the lessons would ignite their curiosities to cause motivation. Moreover, an introduction to biotechnology would be made with the question "What can we do with the obtained DNAs?".

*Bulletin Boards*

Through the bulletin boards to be used in the first lesson period, a discussion environment is created and students are directed to ponder over these questions. These bulletin boards, on which visually enriched biotechnology topics were presented, were classified into six headings:

(1) *Biotechnology bulletin board 1:* Divides the subject into two historical periods as traditional and modern, and mentions positive and negative effects.

(2) *Biotechnology bulletin board 2:* Divides the subject into four topic areas in a broad sense and enables to see the entirety of the matter for the following bulletin boards.

(3) *Genetically modified organisms bulletin board:* Mentions examples of genetically modified living organisms and their adverse effects on other organisms.

(4) *Gene therapy bulletin board:* Includes some gene therapy examples administered until recent times and types of gene therapy.

(5) *Cloning bulletin board:* Includes the description of cloning and some sample practices administered in the field.

(6) *Bioremediation bulletin board:* Mentions the types of environmental problems it addresses and the nature of its applications.

An exemplary bulletin board was given in Figure 1.

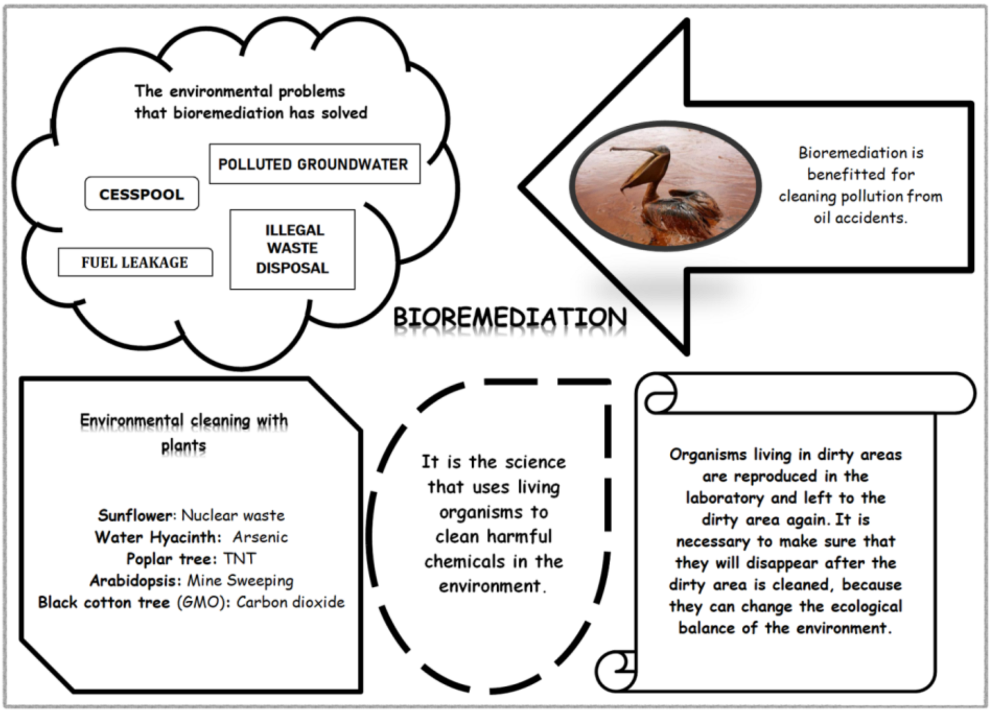



**Figure 1.** An Exemplary Bulletin Board

#### *4.2.2. 2nd and 3rd Lessons Activities*

*4x2 Biotechnology Learning Station*

To teach biotechnology subject, one of the active learning activities was learning station. In the present study a modified version of the learning station named "4x2 Biotechnology Learning Station" was developed (see Figure 2). The GMO, gene therapy, cloning and bioremediation are the four stations each involving two stops (controversial issues and applications) each in accordance with the learning outcomes of the curriculum. In the final version of the worksheets, a wide variety of active learning tactics were used such as collecting news articles from newspapers and magazines, prioritizing the news, creating visual images, writing texts, drawing, writing letters, making mind maps, poetry and story writing, making Venn diagrams, etc.

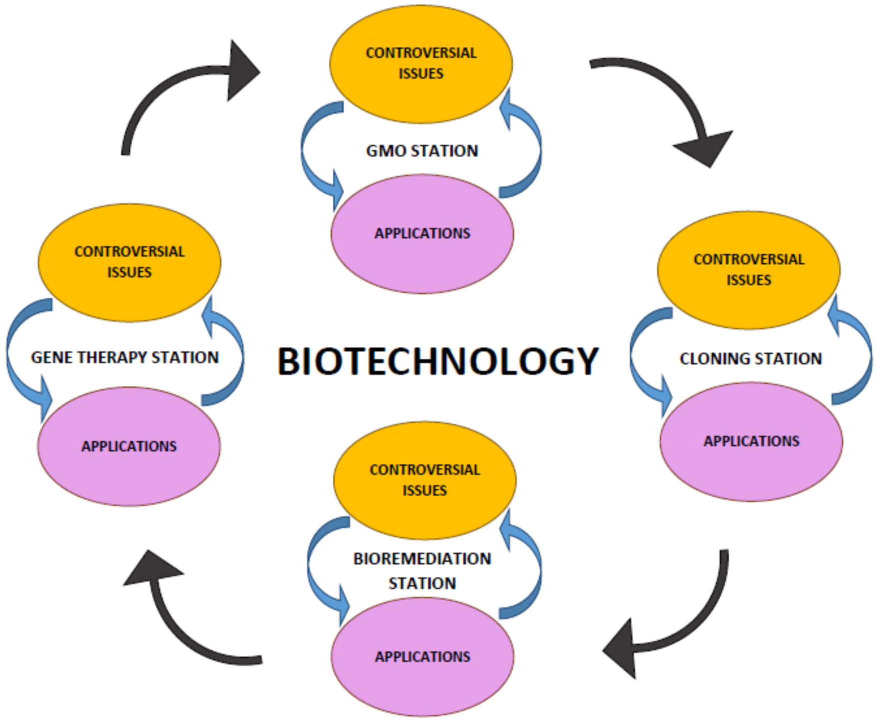



**Figure 2.** 4x2 Biotechnology Station

To manage the stations in an orderly manner, student road maps were devised (see Figure 3).

| Road Map 1 | | Road Map 2 | |
|---|---|---|---|
| **Station** | **Stop** | **Station** | **Stop** |
| 1. GMO | Applications | 1. GMO | Positive/negative effects |
| 2. GMO | Positive/negative effects | 2. GMO | Applications |
| 3. CLONING | Applications | 3. CLONING | Positive/negative effects |
| 4. CLONING | Positive/negative effects | 4. CLONING | Applications |
| 5. BIOREMEDIATION | Applications | 5. BIOREMEDIATION | Positive/negative effects |
| 6. BIOREMEDIATION | Positive/negative effects | 6. BIOREMEDIATION | Applications |
| 7. GENE THERAPY | Applications | 7. GENE THERAPY | Positive/negative effects |
| 8. GENE THERAPY | Positive/negative effects | 8. GENE THERAPY | Applications |
| **Road Map 3** | | **Road Map 4** | |
| **Station** | **Stop** | **Station** | **Stop** |
| 1. CLONING | Applications | 1. CLONING | Positive/negative effects |
| 2. CLONING | Positive/negative effects | 2. CLONING | Applications |
| 3. BIOREMEDIATION | Applications | 3. BIOREMEDIATION | Positive/negative effects |
| 4. BIOREMEDIATION | Positive/negative effects | 4. BIOREMEDIATION | Applications |
| 5. GENE THERAPY | Applications | 5. GENE THERAPY | Positive/negative effects |
| 6. GENE THERAPY | Positive/negative effects | 6. GENE THERAPY | Applications |
| 7. GMO | Applications | 7. GMO | Positive/negative effects |
| 8. GMO | Positive/negative effects | 8. GMO | Applications |
| **Road Map 5** | | **Road Map 6** | |
| **Station** | **Stop** | **Station** | **Stop** |
| 1. BIOREMEDIATION | Applications | 1. BIOREMEDIATION | Positive/negative effects |
| 2. BIOREMEDIATION | Positive/negative effects | 2. BIOREMEDIATION | Applications |
| 3. GENE THERAPY | Applications | 3. GENE THERAPY | Positive/negative effects |
| 4. GENE THERAPY | Positive/negative effects | 4. GENE THERAPY | Applications |
| 5. GMO | Applications | 5. GMO | Positive/negative effects |
| 6. GMO | Positive/negative effects | 6. GMO | Applications |
| 7. CLONING | Applications | 7. CLONING | Positive/negative effects |
| 8. CLONING | Positive/negative effects | 8. CLONING | Applications |
| **Road Map 7** | | **Road Map 8** | |
| **Station** | **Stop** | **Station** | **Stop** |
| 1. GENE THERAPY | Applications | 1. GENE THERAPY | Positive/negative effects |
| 2. GENE THERAPY | Positive/negative effects | 2. GENE THERAPY | Applications |
| 3. GMO | Applications | 3. GMO | Positive/negative effects |
| 4. GMO | Positive/negative effects | 4. GMO | Applications |
| 5. CLONING | Applications | 5. CLONING | Positive/negative effects |
| 6. CLONING | Positive/negative effects | 6. CLONING | Applications |
| 7. BIOREMEDIATION | Applications | 7. BIOREMEDIATION | Positive/negative effects |
| 8. BIOREMEDIATION | Positive/negative effects | 8. BIOREMEDIATION | Applications |

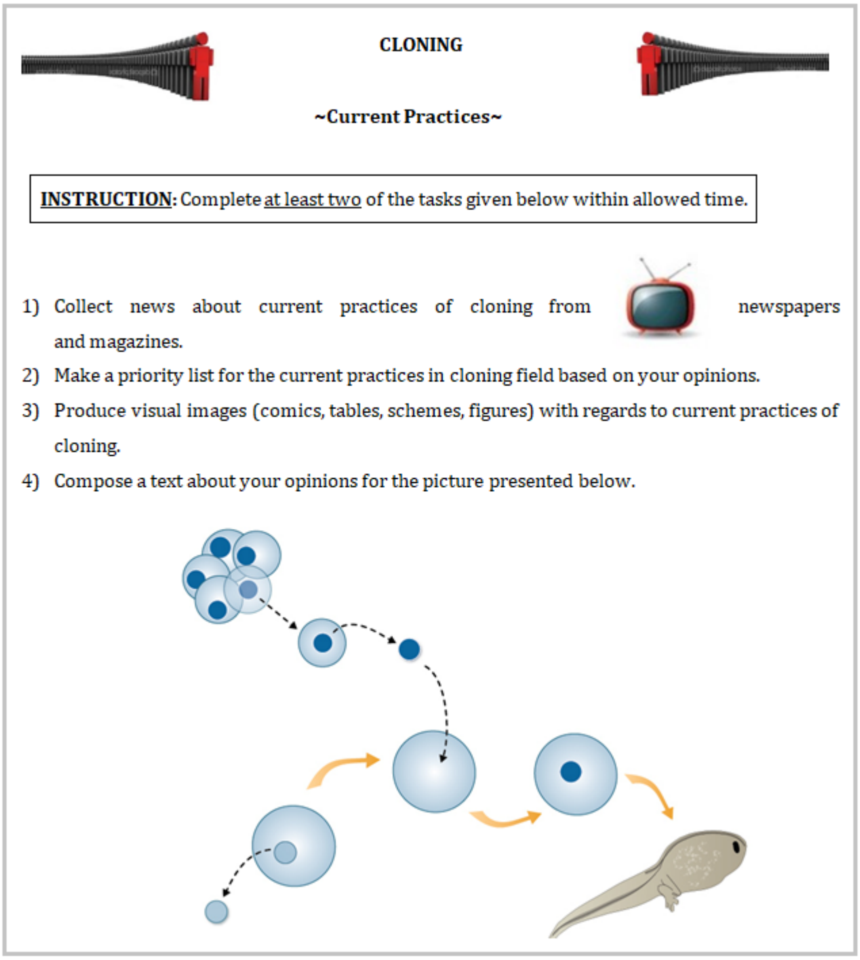
**Figure 3.** Student Road Maps

These road maps were planned to be handed out to the students in a way that, if there were 8 students, each person would get one whereas if the number of students was 16, two students would share one road map. Under the circumstances when the number of students cannot be divided with 8, some stops can be allowed to harbor different numbers of people. In essence, students spend 5 minutes in a stop and head to another stop with teacher's guidance. Thus, each group spends 10 minutes in each station. Table 12 demonstrates the delivery of road maps and order of stations to be followed.

**Table 12.** Road Maps and Stations in Rotation

| Groups | Road Maps | Order of Stations |
|---|---|---|
| Group A | Road Map 1, Road Map 2 | 1. GMO<br>2. CLONING<br>3. BIOREMEDIATION<br>4. GENE THERAPY |
| Group B | Road Map 3, Road Map 4 | 1. CLONING<br>2. BIOREMEDIATION<br>3. GENE THERAPY<br>4. GMO |
| Group C | Road Map 5, Road Map 6 | 1. BIOREMEDIATION<br>2. GENE THERAPY<br>3. GMO<br>4. CLONING |
| Group D | Road Map 7, Road Map 8 | 1. GENE THERAPY<br>2. GMO<br>3. CLONING<br>4. BIOREMEDIATION |

As a result of the tasks assigned in the worksheets, products created with regards to the theme of the station are presented by students. An exemplary worksheet was given in Figure 4.



**CLONING**

**~Current Practices~**

**INSTRUCTION:** Complete at least two of the tasks given below within allowed time.

1) Collect news about current practices of cloning from newspapers and magazines.
2) Make a priority list for the current practices in cloning field based on your opinions.
3) Produce visual images (comics, tables, schemes, figures) with regards to current practices of cloning.
4) Compose a text about your opinions for the picture presented below.

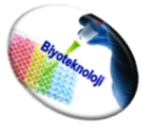
**Figure 4.** An Exemplary Worksheet

#### *4.2.3. 4th Lesson Activities*

*Case Studies Text*

The visually enriched biotechnology case studies text is used in the fourth lesson period. Following the reading of case studies text, small clusters of discussion emerges when the question at the end of the text are addressed. During the discussions, students are expected to employ and develop high-level thinking skills. In this case, high-level thinking skills are categorized under thinking skills such as analyzing the presented information and data, answering the questions or posing new questions, presenting arguments based on science, expressing opinions, making decisions, system-oriented thinking, etc. (Dori et al., 2003). So as to enact all these skills in discussions that are normally under the control of the teacher, students must be given opportunities to bravely express their opinions concerning the scientific, societal and ethical issues proposed in the case studies text. A passage from the case studies text is given in Figure 5.

**BIOTECHNOLOGY AND GENETIC ENGINEERING**




As distinct from biotechnology, genetic engineering is to render the genes of organisms useful for certain purposes. Altering the gene sequencing or adding genes from another organism on occasions, an organism can be equipped with new attributes.

To provide a solution for the famine problem occurring as a result of the rapid increase in world population, more crops were obtained by changing the genetics of fruits and vegetables. The most prominent of the genetically modified products are corn, potato, wheat, tomato, rice and some variations of fish. However, the effects of such products on human health have not been sufficiently studied.

Genes of enzymes and hormones that are not naturally produced or exist in adequate amounts in humans are embedded in the genes of some bacteria and animals by cloning them. These produced materials have the quality to be used by humans. Sick individuals can be treated with gene therapy, and these illnesses can even be prevented from passing on to next generations.

**Figure 5.** An Illustrative Case Study from the Case Text

Through the questions at the end of the case studies text, the above mentioned skills are also given the opportunity to be exhibited by the students. At the end of this activity, the main purpose is to facilitate students to refer to biotechnology with system-oriented considerations and handle the matter as a whole with its scientific, societal and ethical dimensions.

*What Would You Do If You Were…?*

"What Would You Do If You Were…?" activity can be prepared by using all the knowledge learned during four lesson periods and all research resources. It includes one question for each topic of GMO, gene therapy, and bioremediation and two questions for topic of cloning in the stations. This activity can be designed as an individual work as well as group work depending on the teacher's decision or it can be assigned as homework when there is not enough time for in-class work. Figure 6 shows an excerpt from "What Would You Do If You Were…?" activity.

**What Would You Do If You Were...?**

**INSTRUCTION:** Choose at least two of the tasks given below.
Report your answers regarding the tasks.
Enhance your report with figures, schemes, comics, tables and pictures.

1) Imagine you are a person of high authority. What types of actions would you take with the help of biotechnology remediation to provide solutions for environmental problems in the world?
2) ..........................
3) ..........................
4) You are a genetic engineer and practicing gene cloning. In what areas would you like to implement this method by turning it into an advantage?
5) After Dolly the Sheep, other animals were also cloned. Two clone monkeys named Zhang and Hua Hua were last born in September 2020. Make a projection for the future:
   a) How do you think this method can contribute to research on human health?
   b) Discuss the future of this practice from an ethical point of view.

**Figure 6.** An Excerpt from "What Would You Do If You Were…?" Activity

Owing to the activity, students are able to put themselves inside others' shoes and generate new ideas by developing awareness for global and local problems. It is assumed, therefore, that students will be able to develop their analytical thinking skills, problem-solving skills and scientific creativity.

## 5. Discussion

Results from the biotechnology research conducted to measure knowledge level, attitude, values and self-regulation revealed that material development for teaching the subject is necessary (Chen et al., 2016; Dawson, 2007; Öztürk Akar, 2017; Sıcaker & Öz Aydın, 2015; Simon, 2009). Furthermore, it is required that individuals' gaps in knowledge must be overcome and more effective science teaching must be ensured to develop students' attitudes and behaviors (Chen & Raffan, 1999). That is why; an active learning-based BIM was designed for an effective teaching of the subject.

BIM was devised in a way that it includes socioscientific issues, nature of science, science and technology relationship, societal contributions of science, and awareness for sustainable development sub topics within the learning area of "Science-Technology-Society-Environment" suggested by the Middle Schools Science Course Curriculum (MoNE, 2018). Life skills learning area involves analytical thinking, decision making, creative thinking, communication, and team work sub-areas. The latest version of the BIM comprises DNA Isolation Experiment, Bulletin Boards, 4x2 Biotechnology Learning Station, Case Studies Text, and "What Would You Do If You Were…?" activities.

DNA isolation experiment is an experiment which can be done with easily accessible equipment in any school and do not require high safety precautions. The experiment aims at urging students to notice that DNA is simply a structure which is different from its 2D versions in books and can easily be seen and handled. Similarly, this will help kindle the curiosity of students and motivate them.

Bulletin boards can make learning enjoyable and ensure permanent learning by raising the interest on the condition that rich content knowledge and visual presentation are provided. In the research conducted by Altun et al. (2011) and Keskin (2003), the use of visual materials in teaching biotechnology increased achievement in comparison with lecturing method; thereby, it can be noted that visually enriched bulletin boards used in the current research have the similar potential.

Data from both the pilot study and real classroom implementation showed that the learning station technique increased communication and encouraged collaboration among students. The studies conducted by Albayrak (2016), Erdağı and Önel (2015) and Güneş (2009) depicted that, through station technique, students enjoyed a collaborative learning environment, learned more easily, and their gain scores increased, in turn positively affecting permanence of knowledge.

Development of biotechnology from the past to the current years and various matters with regards to biotechnology were the prominent issues included in the case studies text. As the scholar opinions stated, designed text about a case has the potential to induce an active discussion on scientific subjects with the help of the questions in the end of the text. In studies that implemented teaching based on case scenarios it was reported that the method had an affirmative impact on comprehensible learning and permanence of knowledge, students' motivation level and attitudes towards the lesson (Saral, 2008; Güccük, 2013). The text about the case and the follow-up questions pose as an igniter; that is, it encourages them to generate recommendations for possible solutions and develops their high-level thinking skills (analytical, critical and creative thinking). Educational researchers believe that high-level thinking skills play a vital role in science education (Resnick & Resnick, 1992; Zohar, 1996). Many teachers advocate that it is only possible for high achieving students to use these thinking skills (Raudenbush et al., 1993). On the other hand, it is quite common to believe that when students with low achievement levels graduate from high school, it is quite unlikely for them to develop high-order thinking skills on scientific and technological domains. Regarding the widespread belief about low achievers, the research conducted by Dori et al., (2003) is quite noteworthy in that teaching based on the case developed the high-level thinking skills of low achieving students. This outcome can be thought as a potent evidence for BIM's likely positive impact over elementary school students with different achievement levels.

Teachers tend to avoid giving their students homework that requires high-level thinking skills since they mostly believe that such assignments are difficult and students feel over-challenged and frustrated (Dori et al., 2003). In this context, "What Would You Do If You Were…?" activity included in the BIM undermines such beliefs of teachers and encourages them to trust that their students will likely succeed. In the activity, students were asked to file reports about the subject matters and use visual materials in their reports. Since the time allowed for the activities is limited to 4 lesson periods, student products obtained in this type of activity can be exhibited on wall posters in the classroom environment. It was reported in a wide array of studies that lessons that utilized visual materials (Eroğlu, 2006; Keskin, 2003), conducted experiments (Harms, 2002; Kaya, 2009) or applied virtual laboratories (Altun et al., 2011) maintained permanence of success and increased students' interests and attitudes.

It is natural that management of an environment that requires such intense efforts will be burdened by certain hardships; however, teachers' views can be improved through in-service training and seminars regarding the subjects such as active learning, role of the teacher in active learning and classroom management. France (2007) proclaimed that teachers bear negative perceptions and beliefs about biotechnology and that teachers fail to make time for biotechnology in their lessons for this exact reason (Steele & Aubusson, 2004). Both studies fundamentally reported the lack of biotechnology knowledge as the main outcome. Being teachers' biggest fear in the context of biotechnology, the obstacle constituted by lack of knowledge and materials can be overcome with the BIM developed in the current study which is based on active learning approach.

## 6. Conclusion

Based on the discussion above, it can be concluded that the module which comprises DNA Isolation Experiment, Bulletin Boards, 4x2 Biotechnology Learning Station, Case Studies Text, and "What Would You Do If You Were…?" activities is expected to help students to learn in a meaningful way the rapidly changing and renewed biotechnology issues, and to gain lifelong learning skills that strengthen the desire to learn outside of the school. The tasks included in the BIM developed in the current research encouraged students to form questions, seek and evaluate evidence, express ideas individually and in groups, and discuss issues in groups or in whole classroom with regards to virtually all the biotechnology practices by actively participating in either group activities or individual work. As the educational curricula change, teaching approaches embodied as the basis may go through changes, as well. Moreover, the BIM can be used with all curricula which centralized the student.

### Limitations

The most important limitation of this study is the time duration prescribed by the curriculum. The four lesson hours allocated in the curriculum limits the number of activities that can be developed. The fact that there are just three learning objectives related to the Biotechnology topic in the curriculum also limits the more comprehensive handling of the subject in the activities. Many different materials can also be designed and developed to achieve the same learning objectives. The materials used in this study and the results obtained from the application of these materials may be another limitation of this study.

### Recommendations

In line with the results of the research, suggestions for researchers and practitioners in the field are given below.

- The features of the activities embedded in the BIM, such as being student-centered, enriched with active learning methods and tactics, being interdisciplinary and supporting creativity are also features of the STEM approach. BIM is recommended to be used by science teachers as it can be applied in accordance with STEM approach.
- Since biotechnology and biotechnological applications subject is contemporary and it is a controversial area due to its positive and negative outcomes, increasing the number of lesson periods allocated for biotechnology related topics in the science lesson curriculum will not only decrease the time-based anxiety of teachers, but also lead to an effective teaching.
- This study will also shed light on both teachers' and researchers' efforts to develop teaching materials on other subject matters.

## Conflict of Interest

The Authors declare that there is no conflict of interest.

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