Biotechnology: knowledge, perception and future in Saudi Arabia

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ABSTRACT
The use of different biotechnological applications has grown immensely over the previous years to almost double the industry’s size. There has been significant attention directed to the potential of the biotechnology industry and its imminent role in ensuring a country’s development. The Kingdom of Saudi Arabia (KSA) is one of many countries planning to employ biotechnologies as a means of reaching a high-income economy. This study investigated the knowledge and perceptions of a cohort of 178 university students from around the KSA on biotechnology applications. The study showed that the majority, 50%, agreed that they had information about biotechnology and its application. Many respondents (43.8%) agreed with the biotechnology practices and activities. There was a significant positive correlation between the knowledge and perception of the students ($\chi^2 = 34.54, \rho = 0.0001$). The majority of the respondents acknowledged that biotechnology was essential for enhancing the students’ perception and improving biotechnology activities. The responses demonstrated the attitudes and beliefs (which have a great influence on the personal decisions of individuals) of current students, who eventually will be policy-makers, leaders and consumers, and will generally represent the future society of the country. Consequently, the study allowed to suggest creating awareness and increasing the influence of this topic to all stakeholders. There is a need for educators and curriculum developers to emphasize the significance of biotechnology. In addition to the importance of positioning the applications of this field in the public sphere, due to its supporting role in the country’s scientific progress and economic growth.

Introduction
Biotechnology is an essential scientific field due to its involvement in almost all aspects of life. Therefore, it is difficult to give a clear-cut definition of biotechnology, since it includes various fields of science and production. However, a simplified definition states that biotechnology is a set of powerful tools that use some or the whole part of the living organism to obtain or modify products, improve plant and animal species, or develop microorganisms to benefit mankind [1]. The field of biotechnology has experienced enormous growth in the past two decades, resulting in a global doubling in the industry’s size [2–4]. This field involves the application of numerous biotechnologies in various disciplines, e.g. medicine, agriculture, pharmaceutical industries, etc. In recent years, biotechnology has developed cutting-edge innovations that have had a great impact on clinical advancement that would otherwise be impracticable. This has been made possible by the evolution and advancement of biotechnological techniques in medicine. Modern biotechnological applications play a critical role in explaining the sub-atomic comprehension for diseases, advancing new strategies and targeting drugs [5–7]. Analysis and treatment along these lines are progressively entwined. Also, agricultural biotechnology is considered as the next phase of green revolution, where it uses molecular technologies for plant’s DNA fingerprinting and molecular engineering for efficiently producing environmentally friendly plants of desirable traits. This shows how biotechnology is an essential field worldwide and could take on an increasingly significant role as the industry develops [8, 9]. Moreover, there has been significant attention directed to the budding nature of the biotechnological industry with progress emanating from the development of drugs and eco-friendly products. These goods have the potential of generating incredible opportunities for society by improving the quality of health care and producing a
cleaner environment, along with improving the economic state of the country. However, all these would raise various concerns to many individuals and stakeholders regarding ethics, acceptable risk levels, effectiveness of the new techniques and products [5, 10, 11]. Biotechnology’s economic impact as a large field of industry seems to be promising. In fact, the biotechnologies are ones of the advanced technologies that countries are investing in, in order to achieve sustainable development in the current century. Thus, biotechnology education becomes largely important since today’s public often have to make decisions about the applications and products of biotechnology. The capabilities of this knowledge are the creation of fundamental and gradual innovations, in addition to the several applications that generate wealth for countries [12].

Present-day biotechnology’s function in a nation’s prosperity has generated unique scholarly requests and public policy discussions. There are expanding debates about the potential commitments that biotechnology education and biotechnological activities developments can make worldwide [13, 14]. Today this discussion has remained two-fold: one that sees biotechnology as the wellspring of answers for a considerable number of stakeholders, and social and ecological issues that non-industrial nations have embraced, and the other side considering innovation with significant doubt—an outrageous indignation about generating more ills for nations. However, a knowledge-intensive biotechnology education plays a key role in the provision of all the scientific and required information to the public individuals who happen to control eventually (directly and/or indirectly) this field and its applications [10, 15, 16].

Regarding these views, the present study seeks to determine the perspectives of biotechnology learning and knowledge in regard to the country’s development.

In addition to the various applications of biotechnology that can be introduced to foster the development of diverse fields in a country, there are other different biotechnological processes that can help substitute traditionally applied methods (e.g. healthcare, food preservation, etc.). Of the apparent multitude of contentions to be viewed while considering a biotechnical cycle, improving the engagement of the stakeholders in a country to increase biotechnological applications becomes the sole purpose. Various industries that apply biotechnology have been analyzed, and extraordinary measures (biotechnological versus regular cycles) are considered from a monetary perspective [9, 17, 18]. However, to understand the extent of biotechnology education and the future of biotechnological applications in the KSA, this study sought students’ responses about these issues.

The KSA has given special care to biotechnology in many fields, especially the medical field for diagnosis and treatment of diseases, through biotechnology foundations and companies to manufacture pharmaceutical products and support biotechnical research. In addition, different biotechnology centres have been established such as the National Biotechnology Centre (NBC). It is a joint effort between King Abdulaziz City for Science and Technology KACST and King Faisal Specialist Hospital & Research Centre [19, 20]. The NBC’s main activity is to enhance and develop scientific and medical research and biotechnology. In addition, one of its most major interests is to translate research discoveries into viable industries through bio-incubators and spinoffs. The current status of biotechnology has seen the KACST to be responsible of supervising the implementation of the National Policy for Science and Technology. Moreover, developing and implementing the strategic plan for biotechnology has been tasked to the Natural Resources and Environment Research Institute. This plan was created after studying the status of biotechnology research and development in the KSA carefully [21]. The government through strategic planning has moved to encourage the development of different biotechnological institutes and companies in the KSA. Through the development of research activities, KSA can provide solutions to several challenges in the country by improving biotechnological applications involvement [22, 23]. KSA is confident that biotechnology program strategic plans like this will pave the way for an effective growth in the biotechnology field [24]. The kingdom’s biotechnology market is still in its infancy but is a growing and challenging one. KACST is one of the facilities working with all other biotechnologically related facilities to promote the importance of biotechnology and how this field can contribute to scientific and economic progress. Their program seeks to transfer and localize global biotechnologies and direct its applications to achieve health and food security. Additionally, the program aims at using biotechnology to preserve, develop and sustain genetic assets, along with supporting environmental resources. These goals are concerned with the research and development of biotechnology. The economy of Saudi Arabia is primarily based on oil, and there are multiple environmental debates to switch to low carbon fuels. If significant numbers of oil buyers switch to alternate fuels, the KSA might suffer a massive setback to its economy [24]. Alternatively, a key
focus of KSA’s 2030 vision goals is to increase the share of non-oil exports in non-oil GDP from 16% to 50% through creating an environment which broadens the economic base [25]. In that case, intense biotechnology research and industrial growth can provide support to the economy through attracting the best local and international biotechnological talents and increasing global investments. This will be made possible through the involvement and engagement of the country’s decision-makers, as well as research and educational institutions.

The rapid growth of biotechnology knowledge has made it necessary to rethink the schools and colleges’ curriculum contents during the past decades. It has provoked consideration of the ethical and social issues related to biotechnological education and knowledge inspiring the present study.

Subjects and methods

Study design

The study applied a cross-sectional design. The data were collected from February 2020 to March 2020 via a questionnaire. The questionnaire was built upon information collected from various articles related to the subject using Google survey forms and distributed by electronic copy from February 19th, to March 17th, 2020. The questionnaire garnered 178 responses from students from different universities in Saudi Arabia. This included 88.2% (n = 157) female and 11.8% (n = 21) male respondents. The majority 42.1% (n = 75) of the respondents were from Taif University, 35.4% (n = 63) from King Abdulaziz University, and 14.0% (n = 25) from King Saud Bin Abdulaziz University for Health Sciences. Effat University and King Saud University each had the least respondents, with 0.6% (n = 1). Regarding the student’s specializations, 86.5% (n = 154) were studying in science-related bachelor programs with a high likelihood of biotechnology, while 13.5% (24) were studying bachelor programs in the humanities. The questionnaire’s critical constructs consisted of the respondents’ knowledge of biotechnology education and its eventual impact related to its potential growth and impact in the KSA. Reliability analysis conducted using the Cronbach alpha showed that the five items of knowledge had a Cronbach’s alpha (α = 0.781), the five items about perception had a Cronbach’s alpha of α = 0.900, and the rest measures of reflection on country development had a Cronbach’s alpha of α = 0.723 (Table 1). Any attempts to increase the alpha would not come through deleting any items since the alpha had reached the threshold.

| Items          | Cronbach’s alpha based on standardized items | Number of items |
|----------------|---------------------------------------------|-----------------|
| Knowledge      | .781                                        | 5               |
| Perception     | .900                                        | 5               |
| Reflection     | .723                                        | 4               |

The target population included students from various Saudi universities. The inclusion criteria sampled universities who offer biotechnology related courses alongside other courses. The collected data were cleaned and exported to SPSS v. 25 for analysis. The software was used to classify the respondents’ social demographics. Descriptive responses were also analyzed, and correlations were conducted using a chi-square test.

Ethics statement

The study sought permission from the Clinical Laboratory Science Committee of Taif University. The respondents had the option to withdraw from the study at any time and offered their responses without being coerced.

Results and discussion

First, the survey included several questions targeted to determine the respondent’s knowledge of biotechnology. The study outcomes showed that the majority 50% (89) agreed on having information about biotechnology and its applications. However, 22.5% (40) were neutral, and 14% (25) believed they did not know any information on the application of biotechnology. When asked whether they knew that biotechnology is based on genetic engineering (genetic modification), a majority 51.7% (92) of the respondents agreed, 20.2% (36) neutral, and 14% (26) strongly agreed and 4.5% (8) strongly disagreed that they knew biotechnology was based on genetic engineering. Of the respondents, 45.5% (81) agreed, 22.5% (40) strongly agreed and 21.3% (38) were neutral when asked whether they knew gene therapy for genetic and cancer diseases is based on the application of different biotechnological techniques. When the respondents were asked whether they knew that insulin hormone injections used by patients with diabetes are one of the essential products of biotechnology, a majority 39.3% (70) agreed, 22.5% (40) were neutral, and 19.7% (35) strongly agreed they were equipped with that information. Finally, the respondents were asked whether they knew that genetic modification of crops contributes to improving their characteristics and productivity;
Table 2. Respondents outcomes on biotechnology knowledge.

| Questions                                                                 | Strongly agree | I agree | Neutral | Disagree | Strongly disagree |
|---------------------------------------------------------------------------|----------------|---------|---------|----------|------------------|
| 1. I have previous knowledge about biotechnology and its fields of application | 19 (10.7%)     | 89 (50%) | 40 (22.5%) | 25 (14%) | 10 (5.6%)        |
| 2. I know that biotechnology is based on genetic engineering (genetic modification) | 26 (14.6%)     | 92 (51.7%) | 36 (20.2%) | 16 (9.0%) | 8 (4.5%)         |
| 3. I know that gene therapy for genetic and cancer diseases is based on the application of different biotechnological techniques | 40 (22.5%)     | 81 (45.5%) | 38 (21.3%) | 9 (5.1%)  | 7 (3.9%)         |
| 4. I know that insulin hormone injections used by people with diabetes are one of the most critical products of biotechnology | 35 (19.7%)     | 70 (39.3%) | 40 (22.5%) | 28 (15.7%) | 5 (2.8%)         |
| 5. I know that genetic modification of agricultural crops contributes to improving their characteristics and productivity. | 39 (21.9%)     | 86 (48.3%) | 28 (15.7%) | 15 (8.4%) | 7 (3.9%)         |

Table 3. Respondents outcomes on perception of biotechnology.

| Questions                                                                 | Strongly agree | I agree | Neutral | Disagree | Strongly disagree |
|---------------------------------------------------------------------------|----------------|---------|---------|----------|------------------|
| 1. I agree to use gene therapy that allows genetic modification of defective human cell | 47 (26.4%)     | 78 (43.8%) | 40 (22.5%) | 10 (5.6%) | 7 (3.9%)         |
| 2. I agree to use genetically modified foods                              | 17 (9.6%)      | 46 (25.8%) | 58 (32.6%) | 39 (21.9%) | 24 (13.5%)       |
| 3. I agree to use genetically modified cotton to produce highly efficient fabrics | 47 (26.4%)     | 90 (50.6%) | 31 (17.4%) | 10 (5.6%) | 4 (2.2%)         |
| 4. I will contribute to work on genetic modification to develop consumable products (such as textiles, cosmetics and petrochemicals) | 33 (18.5%)     | 67 (37.6%) | 59 (33.1%) | 16 (9%)   | 5 (2.8%)         |
| 5. I will contribute to work on genetic modification of living creatures (non-humans) for divergent purposes (such as glowing animals) | 6 (3.4%)       | 18 (10.1%) | 33 (18.5%) | 42 (23.6%) | 85 (47.8%)       |

Most 48.3% (86) agreed while 21.9% (39) strongly agreed that they were informed. The values of knowledge yielded a higher mean of 63.45±.546 and showed a significant positive correlation ($\chi^2$ =32.406, df (10) $p = 0.0001$). The above information is summarized in Table 2.

To understand students’ perceptions of biotechnology, the respondents were asked to compare several biotechnological practices that influence biotechnological applications. First, the respondents were asked whether they agree that the use of gene therapy allows genetic modification of defective human cells; the majority of the respondents agreed 43.8% (78), 26.4% (47) strongly agreed, while 3.9% (7) strongly disagreed. On respondents’ agreeing to use genetically modified foods, most of the respondents were 32.6% (58) neutral to this; 43.8% (78) agreed, while 9.6% (17) strongly agreed and 13.5% (24) strongly disagreed. When asked whether they can advocate for the use of genetically modified cotton to produce highly efficient fabrics, 50.6% (90) agreed, 26.4% (47) strongly agreed and 17.4% (31) were reserved on the use of genetically modified cotton to produce highly efficient fabrics. Furthermore, when students were asked whether they will contribute to work on genetic modifications to develop consumable products (such as textiles, cosmetics and petrochemicals) which will aid in improving the status of the country through stakeholder’s involvement, 37.6% (67) agreed, 33.1% (59) were neutral and 18.5% (33) strongly agreed they would approve the biotech process. Finally, students were asked whether they can contribute to work on genetic modification of living creatures (non-humans) for divergent purposes (such as glowing animals), the majority 47.8% (85) of the respondents strongly disagreed, and 23.6% (42) disagreed. The above responses are summarized in Table 3.

Moreover, the respondents were asked for their responses about some future perspectives on some related aspects of biotechnology-practices. This was elicited through questions about whether they thought biotechnological applications oppose scientific ethics or whether the applications of biotechnology would positively impact the economy and lifestyle. The majority 51.7% (92) were neutral, 29.2% (52) disagreed, while 2.8% (5) strongly agreed that they think that biotechnological applications oppose the scientific ethics. When asked whether they thought biotechnology would improve the quality of life, the majority 50.6% (90) agreed, 28.1% (50) were neutral, and 2.2% (4) strongly disagreed that biotechnology will improve the quality of life. When asked whether biotechnology will positively affect the stakeholder’s activities and further improve the economy, most 53.6% (95) agreed, and 25.3% (45) strongly agreed that biotechnology would positively affect the biotechnology industry. Finally, the respondents were asked whether they think that people around them have enough knowledge of biotechnology’s different fields and applications. It was evident that the majority, 52.2% (93) disagreed that people around them had enough knowledge to fully understand biotechnology. These results show that university students in Saudi Arabia know how biotechnological applications can influence stakeholder’s activities.
Therefore, more than half of students answered that they knew information about biotechnology. In fact, most of the students demonstrated a mastery of the biotechnology content as seen in Table 2. This suggests that biotechnology education has been well absorbed and utilized by university students in Saudi Arabia. Interestingly, this contrasts with another study conducted in the KSA as well, which flagged up a significantly limited biotechnology knowledge-base among Saudi Arabian high school students and teachers [26]. Our results also contrast with Taiwanese and Slovenian studies, which showed that university students had limited understanding of biotechnology. These studies demonstrated a higher mean value on student's perception and knowledge when compared to the present study [26–29]. The knowledge responses show that the students were highly knowledgeable about biotechnology. According to Sáez et al. [15], most university students are believed to possess high biotechnology education levels [30].

The student's perceptions of biotechnology's role and areas of advancement show that some students were naïve about possibilities. There was no clarity about students' understanding of how to interpret the biotechnology processes and how they affect biotechnological applications. The majority, 47.8% (85) of the respondents, strongly disagreed when they were asked whether they would work on genetic modification of living creatures (non-humans) for divergent purposes (such as glowing animals). This would show that students did not totally appreciate biotechnology processes despite understanding how such a process might impact stakeholders and the biotechnological uses in society. In fact, most students' and biotechnology educators' abilities can be demonstrated by their appreciation and application of biotechnology knowledge in making life better and influencing the use of biotechnology in the country [26, 27]. However, the respondents showed they could apply and relate other biotechnology processes with activities that would improve life. Around 37.6% of the students, agreed to contribute to genetic modification tasks to develop consumable products (such as textiles, cosmetics and petrochemicals). However, most students seemed to comprehend simple biotechnological processes and their relevance to the development of the KSA. Furthermore, there was a high mean score of 44.56±4.56 about the respondent's perception of biotechnology processes and their relevance to the stakeholder's awareness of any biotechnological applications.

The role of biotechnology knowledge in the development and improvement of biotechnological applications is unrivaled. The results from our study show that the majority of the respondents agreed that biotechnology would improve the quality of life. This was supported by many of the respondents agreeing that biotechnology will positively affect the stakeholder's awareness of the numerous biotechnological applications available. One of the ultimate targets of any government is to ensure that the education provided aids in revamping and improving biotechnological applications in the country [31]. Further correlations were conducted using a chi-square test between the gender of the respondents and their perceptions towards biotechnology education and the role of improving biotechnological application in the KSA, and there was a significant positive correlation (χ²=34.54, df (48) p = 0.0001).

Biosciences and new technology, two independent but closely interacting ‘dancing partners’, are catalysts of industrial and economic change, and most importantly with the emergence of the artificial intelligence and machine learning. In macroeconomic terms, the latest and more advanced knowledge, created and empowered through scientific education and research and further reflected in university outcomes and research publications/output, is likely to provide the country with numerous advantages with regards to its innovation, development and economic growth [32, 33].

From our results, it is worth noting that there is a high level of biotechnology knowledge among the survey participants. The data demonstrated that biotechnology education is embedded in the curriculum, and respondents seemed to understand the course content. However, there was less correlation between the respondents' knowledge and the current practices of biotechnology. This is demonstrated by negative responses toward biotechnology's practices and processes that aim to build biotechnological applications. Nevertheless, this observation is not an excluded case, as this has been observed in other studies that stated that greater knowledge of biotechnology does not always result in greater acceptance [34]. Despite all this, there was a correlation between the respondents' knowledge and their understanding of biotechnology's role in building stakeholder's awareness and improving engagement to biotechnological applications.

Recommendations

The rapid development of biotechnological fields, however, presents a curricular challenge for educators trying to provide students with relevant coursework [35]. Our study recommends that educators and
curriculum developers create a frequently updated bridge between biotechnology education and practice. In addition, further examples and practical approaches should be directed toward biotechnology education to ensure learners grasp their course's curriculum. In fact, one of the SWOT analyses for biotechnology R&D plan in the KSA threats was the lack of sufficient educational programs to produce qualified workers in technical fields to work in both industry and government. Additionally, the biotechnology field offers great economic and social benefits, which on the other hand could be esoteric if poorly understood by the public [24]. Thus, strategic and evidence-informed public engagement by biotechnology stakeholders is an important means of better positioning the sector in the public sphere. Optimistically, this would ensure that the country benefits from the biotechnology education conducted at universities in Saudi Arabia. Further, it would also contribute in producing knowledge-based economy (technology production, investment in technology, establishment of scientific incubators, new industrial, knowledge cities and the biozone). In fact, it is essential for all the relevant individuals to be aware of social acceptance of, and views on, the challenges developing within this field, considering that Saudi Arabia has put itself forward as one of the current and future national economy generators for biotechnology.

Conclusions

The aim of our study was to determine what knowledge and perception are shown by university students studying scientific degrees toward biotechnology and biotechnological applications, since the scarce number of works on biotechnology understandings and awareness developed in our country. Further, we sought to relate their understandings to the future and development of this filed in the KSA. Many students seem to have several concept misunderstandings of biotechnology and its ethics, the awareness plays a crucial role in forming a ‘clear-cut’ opinion about many applications of biotechnology. Since education can shape public (e.g. students) attitudes on biotechnology, priorities on university curricula and teaching approaches should be given. In fact, this would promote the students’ perception in understanding many new biotechnologies. They must have an unbiased attitude toward biotechnology based on understanding of factual issues, given that they will be consumers, producers and policymakers in the future.

Authors’ contribution

Hamsh Banjer conceptualized the study, wrote the manuscript, and supervised the project with support and contribution from Ashjan Shami. Raghad Bin Horaib, Sara Almutiri, Ameera Alnemari, and Rahaf Althumali and collected and analyzed the data.

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Data availability

The data that support the findings of this study are available from the corresponding author, [H.B.], upon reasonable request.

Disclosure statement

The authors would like to specify and declare that the research does not present any conflict of interest.

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