Effectiveness of interactive teaching intervention on medical students' knowledge and attitudes toward stem cells, their therapeutic uses, and potential research applications

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Background: Stem cells science is rapidly developing with potential use to treat many non-treatable diseases. The medical students, as future physicians, should be equipped with the proper knowledge and attitude regarding this promising field. Interactive teaching whereby the teachers actively involve the students in the learning process is an encouraging approach to improve their interest, knowledge, and team spirit. This study aims to evaluate the effectiveness of interactive teaching intervention on medical students' knowledge and attitudes about stem cells research and therapy.

Methods: A pre-post test study design was employed. A six-session interactive teaching course was conducted for a duration of six weeks as an intervention. Pre- and post-intervention surveys were used. The differences in the mean scores of students' knowledge and attitudes were examined using paired t-test, while gender differences were examined using an independent t-test.

Results: Out of 71 sixth-year medical students from different nationalities invited to participate in this study, the interactive teaching course was initiated by 58 students resulting in a participation rate of 81.7%. Out of 58 students, 48 (82.8%) completed the entire course. The mean age (standard deviation) of students was 24 (1.2) years, and 32 (66.7%) were males. The results showed poor knowledge about stem cells among the medical students in the pre-intervention phase. Total scores of stem cell-related knowledge and attitudes significantly improved post-intervention. Gender differences in knowledge and attitudes scores were not significant post-intervention.

Conclusions: Integrating stem cells science into medical curricula coupled with interactive learning approaches effectively increased students' knowledge about recent advances in stem cells research and therapy and improved attitudes toward stem cells research and applications.

Title Page

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Running title: **Stem cell-related education intervention**

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Abstract

Background: Stem cells science is rapidly developing with potential use to treat many non-treatable diseases. The medical students, as future physicians, should be equipped with the proper knowledge and attitude regarding this hopeful field. Interactive teaching whereby the teachers actively involve the students in the learning process is a promising approach to improve their interest, knowledge, and team spirit. This study aims to evaluate the effectiveness of interactive teaching intervention on medical students' knowledge and attitudes about stem cells research and therapy.

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Keywords: Stem cells; knowledge; Education; Medical curriculum; Students; Interactive teaching; Arab

Introduction

The emerging stem cells (SCs) biology discipline and the rapid revolution in SCs research have radically transformed our thinking of cells, evolution, and disease. Using SCs for clinical applications represents the future of translational medicine since SCs can potentially be used to treat many kinds of difficult diseases that cannot currently be treated (Chang et al. 2018; Protze et al. 2019). Advances in SCs research combined with tissue engineering techniques promise therapies to restore or replace damaged tissues (Kwon et al. 2018). This raises the need for medical education to introduce basic SCs knowledge and the concept of translational medicine into the life sciences field. At the same time, SCs research and applications still raise complex social, legal, ethical, and religious issues (Al-Aqeel 2005; Curley & Sharples 2006; Pourebrahim et al. 2020), especially in conservative societies (Bouzenita 2017).

The emerging developments in SCs applications are transforming the priorities of undergraduate and postgraduate medical educational programs (Scott 2015). Today, the traditional academic model for medical education is challenged by an evident gap between the rapidly changing disciplines in basic biomedical sciences and clinical practice. Although medical students have access to SCs research theoretical advancements, traditional teaching approaches still fail to bridge this practice gap (Brass 2009). Thus, updated teaching techniques that facilitate the integration of SCs research advancements with clinical practice are critical for medical students to achieve optimum patient care (Knoepfler 2013). Restructuring medical education to meet the current and future health care needs of SCs-based interventions, including new curricula featuring the ethical, legal, and social implications of SCs research, are thus a priority (Pershing & Fuchs 2013; Pierret & Friedrichsen 2009).

Since the early 1990s, many medical curricula have transitioned from traditional subject-based teaching toward integrated system-based teaching (Ling et al. 2008). Traditional didactic lectures for one hour become monotonous after 15-20 minutes as students' participation in the learning process is minimal (Gupta et al. 2015). On the other hand, the interactive teaching approach actively engages learners and interchanges ideas between learners and facilitators (Kaur et al. 2011). The effectiveness of educational interventions in increasing knowledge and attitudes towards SCs applications was reported previously by a few studies (Azzazy & Mohamed 2016; Jin et al. 2018; Kaya et al. 2015).

Although it is currently a hot research topic, SCs education for students is uncommon (Pierret & Friedrichsen 2009). The interactive teaching modality was designed to introduce medical students to the groundbreaking area of SCs biology and shed light on current advances in SCs research. Medical students, as future physicians, are expected to answer patients' questions regarding SCs and help them differentiate between what is realistic and unrealistic regarding SCs-based therapies. Also, they should be able to use evolving discoveries in stem cells research and apply them in the care of patients. Thus, we aimed in this study to assess the medical students' knowledge and attitudes toward SCs, their therapeutic uses, and potential research applications and then evaluate the effectiveness of interactive teaching intervention on their knowledge and attitudes.

Materials and Methods

Study design, participants, and setting:

A pre-post test design was employed for a sample of 71 sixth-year medical students, at the University of Science and Technology Yemen-Jordan branch (USTY-Jo), during the first semester of the academic year 2018-2019. An orientation lecture was held to explain the study aims, design, and details for the students, and the students were invited to participate. Study participation was voluntary, and a pre-intervention survey was distributed to all medical students who agreed to participate. Participants were then invited to attend a six-session interactive teaching course, the intervention, for a duration of six weeks. This intervention was a part of phase Ⅰ of the "Stem Cells: Hope or Hype?" project. Each interactive session lasted two to three hours and included brainstorming, learning by teaching, role-playing, class debate, panel discussions, reflections on stories, real-life situations, case-based scenarios, or videos. Details about the intervention are summarized in **Table 1**. After finishing the intervention, the same survey was distributed among the participants.

Study tools:

The researchers developed a structured, self-administered questionnaire after detailed reviewing the literature regarding SCs knowledge and attitudes. The questionnaire was not based on a particular study but preferably on information from various studies and recent guidelines from international organizations such as the International Society for Stem Cell Research (ISSCR) and the New York Stem Cell Foundation (NYSCF) (Azzazy & Mohamed 2016; Lovell-Badge et al. 2021; NYSCF 2017). The questionnaire was reviewed by a panel of experts in SCs clinical practice and teaching, pilot-tested on 20 participants, and the necessary modifications were done. The questionnaire was designed and distributed in the English language as it is the official teaching language of the Jordanian medical schools. A soft copy of the distributed questionnaire is provided in **supplementary file 1**.

The questionnaire was divided into three major sections: demographic characteristics, SCs knowledge, and SCs attitudes. The demographics section included questions about age, gender, nationality of participants, name of the registered medical school, and student year level. The names of participants were recruited to avoid duplicated data with preserving complete confidentiality. The SCs knowledge section began with a rating question about the participant perception of knowledge regarding stem cells in general with a ten-point Likert scale, ranging from "zero = low knowledge" to "10 = high knowledge". Then, a question about the participants' preferred sources to obtain knowledge about SCs with multiple choices included books, medical journals, workshops, social media, lectures, medical conferences, panel discussions, colleagues, and other sources.

After that, the SCs knowledge section included 27 statements to measure the participants' knowledge regarding SCs (Cronbach's Alpha =0.61 and 0.78 in pre-and post-intervention, respectively). These statements were grouped into four domains: basic knowledge about SCs with a total of 13 statements (Cronbach's Alpha =0.42 and 0.61), potential applications of SCs with a total of four statements (Cronbach's Alpha =0.69 and 0.66), therapeutic uses of SCs with a total of four statements (Cronbach's Alpha =0.44 and 0.32), and lastly the participant knowledge about SC research with a total of six statements (Cronbach's Alpha =0.86 and 0.75). The third section was designed to assess the medical students' attitudes toward SCs via a total of ten statements (Cronbach's Alpha = 0.76 and 0.68).

Participants responded to each statement of the SCs knowledge and attitude scales described above, using a 5-point Likert scale ranging between "strongly disagree" and "strongly agree", and scored from zero to four for each scale statement. Higher scores indicated good knowledge and positive attitude, while lower scores indicated poor knowledge and negative attitude. Responses to statements were summed to create scores for total knowledge, total attitude, and each of the four knowledge domains. Knowledge scores ranged from zero to 108 for "total SCs knowledge", zero to 52 for "SCs basic knowledge", zero to 16 for "SCs potential applications", zero to 16 for "SCs therapeutic uses", and zero to 24 for "SCs research". The total attitude score ranged from zero to 40. After that, the scores of scales were converted into mean scores ranging from zero to four by dividing the scale score on the number of scale statements.

Statistical analysis:

Data were analyzed using IBM Statistical Package for Social Sciences (SPSS) Version 21.0 (IBM Corp., Armonk, NY, USA). Internal consistency for overall scales and subscales were tested using Cronbach's alpha. Descriptive statistics were presented as means and standard deviations (SD) for continuous variables after verifying the normality of the dataset. Categorical variables were presented as proportions and frequencies. A Paired-samples *t*-test was used to examine mean differences in students' knowledge and attitude scores pre- and post-educational intervention, and 95% confidence intervals of the difference in means (MD) were reported. Independent-samples *t*-test was used to examine mean gender differences in students' knowledge and attitude scores. *P*-value was set at or less than 0.05 to be significant.

Ethical considerations:

The study protocol was reviewed and ethically approved by the Institutional Review Board (IRB) of the research and ethics committee at USTY-Jo (IRB number, 9/120/2019). This study was conducted following the 1975 Helsinki declaration, as revised in 2008 and later amendments or comparable ethical standards. The study objectives and design were dully explained to the study participants, and written signed informed consent was obtained from each participant. Participants could terminate the survey and intervention at any time desired. The study was undertaken with complete confidentiality, and information provided by study participants was not disclosed to others. Participants did not receive any compensation or rewards for their participation in the study.

Results

Out of 71 sixth-year medical students invited to participate in this study, 58 initiated the interactive teaching course resulting in a participation rate of 81.7%. The final sample consisted of 48 medical students who initially enrolled and completed the entire six-week course sessions with a completion rate of 82.8%. Out of 48 medical students, 32 (66.7%) were males, and more than half (56.3%) were of Jordanian or Yemeni nationalities. The mean age (SD) of students was 24 (1.2) years. Demographic characteristics of study participants are summarized in **Table 2**.

Knowledge regarding stem cells

The three most common sources of knowledge regarding SCs before the intervention course were lectures (56.3%), media (45.8%), and books (41.7%), while panel discussions were the least common source (Data not presented). Detailed information about pre-and post-educational intervention knowledge scores is summarized in **Table 3**. Pre-intervention, the lowest mean score among knowledge domains was observed with stem cells research section (1.76

(0.89)), and therapeutic uses (1.84 (0.63)), followed by stem cells basic knowledge (2.14 (0.30)) and their potential applications (2.66 (0.77)). The mean scores of all knowledge domains were lower than three in the pre-intervention phase of the study. The mean (SD) total knowledge score was 2.09 (0.30) pre-intervention, which is significantly improved to 3.09 (0.41) post-intervention (p<0.001). Similarly, all knowledge domains' scores significantly increased following the intervention.

The mean SCs basic knowledge domain score significantly increased from 2.14 (0.30) pre-intervention to 3.09 (0.47) post-intervention (p<0.001). Post-intervention vs. pre-intervention, participants reported improved the knowledge with different types of SCs (3.77 (0.43) vs. 1.88 (0.94), p<0.001), sources of SCs (3.67 (0.52) vs. 2.17 (0.78), p<0.001), therapeutic uses of SCs (3.69 (0.51) vs. 2.15 (1.05), p<0.001) and three germ layers from which tissues and organs are generated (3.69 (0.59) vs. 2.67 (1.02), p<0.001). Students' knowledge of sources of embryonic SCs significantly improved for statements related to leftover blastocysts after in vitro fertilization (2.96 (1.34) post-intervention vs. 2.06 (0.76) pre-intervention, p<0.001), but not for statements related to umbilical cord (1.73 (1.65) vs. 1.35 (0.91), p=0.165) or trophoblast of blastocyst (1.79 (1.64) vs. 1.54 (0.65), p=0.316).

For potential applications of SCs domain, the mean score significantly increased from 2.66 (0.77) pre-intervention to 3.46 (0.59) post-intervention (p<0.001). Post-intervention vs. pre-intervention, students reported significantly higher knowledge scores regarding potential applications of SCs such as replacing or restoring damaged tissues (3.58 (0.85) vs. 2.85 (1.09), p<0.001), screening new drugs and toxins (3.48 (0.83) vs. 2.21 (1.09), p<0.001), modeling disease in a culture dish (3.48 (0.83) vs. 2.56 (1.09), p<0.001) and studying early human development (3.42 (0.71) vs. 3.02 (0.84), p=0.004).

For SCs therapeutic uses domain, the mean total score significantly increased from 1.84 (0.63) to 2.45 (0.80) (p<0.001). Post-intervention vs. pre-intervention, students became significantly more aware regarding the side effects of trying unproven SCs therapies, especially tumor formation potential if the balance is skewed between cell differentiation and self-renewing properties of SCs (2.88 (1.04) vs. 2.25 (0.79), p=0.001).

In the SCs research domain, the mean total score significantly increased from 1.76 (0.89) to 3.27 (0.56) (p<0.001). Post-intervention vs. pre-intervention, students became more comfortable in giving an explanation of induced pluripotent SCs (3.40 (0.71) vs. 1.65 (1.16), p<0.001), transcription factors (3.13 (0.89) vs. 1.85 (1.19), p<0.001), and differences between therapeutic cloning and reproductive cloning (3.21 (0.82) vs. 1.81 (1.20), p<0.001). Moreover, participants became more knowledgeable that adult cells can be "reprogrammed" genetically to assume an SCs-like state (3.31 (0.83) vs. 1.85 (1.05), p<0.001). Students were also more comfortable discussing mitochondrial replacement therapy (3.52 (0.74) vs. 1.83 (1.19), p<0.001) and somatic cell nuclear transfer (3.06 (0.10) vs. 1.58 (1.07), p<0.001).

Attitudes toward stem cells

As described in **Table 4**, the total attitude score significantly increased from 2.66 (0.56) to 2.85 (0.53) (p=0.048). Post-intervention vs. pre-intervention, students became more interested in expanding their knowledge regarding SCs (3.77 (0.43) vs. 3.29 (0.92), p=0.001), and considered a well-structured program or training focusing on SCs science (3.48 (0.68) vs. 2.83 (0.91), p<0.001). Students reported improved positive attitudes regarding integration of SCs education in medical college curricula (3.35 (0.93) vs. 2.83 (0.10), p=0.010), translational research (3.27 (0.84) vs. 2.83 (0.93), p=0.009), and spending more money by government to support SCs research (3.69 (0.72) vs. 3.38 (0.82), p=0.046). In addition, participants' improvements in attitude were statistically significant towards umbilical cord blood donation (3.27 (1.13) vs. 2.85 (0.10), *p*=0.049), but not for bone marrow donation (3.10 (1.23) vs. 2.81 (0.94), *p*=0.212). Participants' negative attitudes regarding religious controversies surrounding SCs did not improve as the pre-intervention mean significantly decreased from 1.88 (1.10) to 1.13 (1.30), (*p*=0.003). However, similar reductions reported in attitude mean scores related to ethical controversies surrounding SCs (1.13 (1.20) post-intervention vs. 1.29 (1.09) pre-intervention, *p*=0.420) and preserving umbilical cord blood in a private bank (2.35 (1.52) post-intervention vs. 2.63 (1.20) pre-intervention, *p*=0.322) but they were not statistically significant.

Gender Differences

As shown in **Table 5**, male students at baseline scored higher knowledge levels in comparison with female students with regard to SCs potential applications (2.85 (0.66) vs. 2.28 (0.85) respectively, *p*=0.014) and SCs research (1.95 (0.81) vs. 1.39 (0.95) respectively, *p*=0.036). Accordingly, the total knowledge score of males was higher than females (2.16 (0.27) vs. 1.95 (0.30) respectively, *p*=0.017). However, after the intervention, gender differences were not statistically significant.

Discussion

The current study sheds light on the effectiveness of an interactive educational intervention in improving the knowledge and attitudes of medical students toward SCs, their therapeutic uses, and potential research applications. The intervention course was carried out for six weeks, and different interactive teaching methods were used. The study results have proven that participants' knowledge was not sufficient in the pre-intervention phase. Overall, SCs knowledge and attitude scores improved following the intervention. Post-intervention, participants were more interested in expanding their knowledge about SCs and considered well-structured programs or training courses as a successful approach to improve their understanding of SCs. The participants reported positive attitudes regarding the integration of SCs education in medical college curricula after the intervention. This is the first evidence from the Middle East and North Africa that the interactive learning approach in SCs may be of great benefits not only to medical students but also to the overall health system as it will reflect on future doctors being more informed and better guided to serve their patients with up-to-date information. This study could enhance medical curriculum development and teaching approaches and bridge the gap between basic sciences and clinical practice.

As future health care leaders, medical students represent a source of information, or misinformation, which may influence patients' behaviors and serve as a valuable source of information (Davies et al. 2002). This makes medical schools an ideal place to address information misconceptions and emphasize positive attitudes toward SCs applications. Therefore, improvements in the region's medical curriculum should seriously consider interactive session models and introduce broader and more scientific resources for students in the healthcare field. This is especially true to follow-up on rapidly advancing scientific topics in the medical fields, where relying merely on available evidence from textbooks may introduce delays in transferring knowledge to medical students.

Previous educational interventions successfully increased the knowledge about SCs transplantation and banking among medical, nursing, and law students and showed more positive attitudes toward SCs donation following a particular intervention (Azzazy & Mohamed 2016; Kaya et al. 2015). Innovative SCs education using practical experiments to master SCs culture and differentiation techniques were also reported to deepen medical students' understanding of regenerative and translational medicine (Jin et al. 2018). Compared with other studies, our educational intervention was more comprehensive, detailed, and engaging for students as it utilized different interactive teaching techniques. It also covered more topics missed in the previous research, such as SCs research and potential applications, unproven SCs therapies and tourism, and bioethics (Azzazy & Mohamed 2016; Jin et al. 2018; Kaya et al. 2015). Besides, study material developed by our research team could be adopted by other medical schools interested in establishing similar courses, and our interactive teaching course could be integrated within medical curricula as a spread for a total of six-week duration.

In the current study, the most common sources of knowledge regarding SCs were lectures followed by media. Mass media is the primary source of scientific communication to the public as it can significantly influence public attitudes toward controversial emerging technologies in regenerative medicine, such as the use of leftover blastocysts as a source for embryonic SCs and genome editing (Sharpe et al. 2016). Also, the media portrayal of translational SCs research is highly optimistic and may foster unrealistic expectations regarding clinical translation speed (Kamenova & Caulfield 2015). Medical students should consider other sources for knowledge based on scientific evidence, such as medical journals and conferences. Unfortunately, none of the medical students in our study chose panel discussions as a source for SCs knowledge, despite being considered a valuable way to trigger an exchange of viewpoints regarding ethical controversies surrounding SCs. Therefore, medical schools should further invest in students' knowledge about SCs by enhancing exposure to updated medical literature and medical conferences.

The interactive learning approach was effective in significantly improving the levels of knowledge and positive attitudes towards SCs. Improvements also spread to all knowledge domains and were sufficient to reduce gender gaps in SCs' knowledge scores. While positive attitudes towards SCs were improved following the intervention, negative attitudes related to SCs' religious controversies actually worsened. Complex social, legal, ethical, and religious issues arise when emerging biotechnology involves human subjects (Al-Aqeel 2005), especially in conservative societies. However, Islamic teachings carry an excellent deal for disease prevention and health promotion, and it is crucial to focus more on increasing our understanding of how SCs applications could advance the health of human beings to facilitate the adoption of these technologies (Bouzenita 2017). Within this context, future SCs-related interventions should focus on incorporating religious leaders from within the medical community to present their points of view related to scientific facts from a religious perspective (Pourebrahim et al. 2020). However, negative attitudes toward ethical controversies surrounding SCs therapies worsened following the intervention; this change in mean attitude scores was not statistically significant. Ethical concerns may be tightly connected to religious concerns and can only be mitigated by openly discussing the lack of religious restrictions related to medical improvements. Notably, our findings regarding religious and ethical controversies call for incorporating bioethics into the medical curriculum when addressing SCs-related topics as ethical concerns were reported to be the obstacle that have obscured the proper potential use of SCs for revolutionizing medicine and treatment options in the future (Hug 2005). Medical curricula need to be restructured to include SCs or other emerging technologies in biomedicine and include research and healthcare ethics (Abdulrazeq et al. 2019; Brass 2009; Sarkadi & Schatten 2012). Adopting new technologies for patient care is challenging since many ethical dilemmas surround it, and future physicians should be prepared to deal with such dilemmas when they arise (Curley & Sharples 2006).

A few limitations should be mentioned. The sample size was relatively small, and the participants were selected from a single medical school, limiting our results' generalizability. While response and enrolment rates were not optimal, they are considered sufficient among medical students. Data collection in this study was also limited to quantitative methods; utilizing a qualitative approach supported by quantitative methods would be recommended to provide a richer analysis of the phenomena. A parallel group with no intervention was not utilized which may introduce testing effects and exacerbate the results. The same survey was utilized pre-and post-intervention that was self-reported by the participants, which might explain that the improvements in knowledge and attitudes scores could be by chance and not due to intervention effects.

Conclusions

This study demonstrates the crucial role of interactive teaching on medical students' knowledge and attitudes toward stem cells, their therapeutic uses, and potential research applications. This study results have proven poor knowledge about stem cells in the pre-intervention phase with a remarkable improvement and statistical significance post-intervention. After the intervention course, significantly more positive attitudes were reported by the medical students. Differences in knowledge between males and females have vanished after the intervention course. The experience of interactive teaching technique was interesting for both students and researchers, and many of the students were enthusiastic about more courses designed with this approach. Educators and medical schools are thus calling for integrating new interactive teaching approaches to address the life sciences instead of traditional teaching methods. The stem cells concept should be incorporated into the medical school curriculum to update future physicians with evidence-based medical practice. Further studies with a larger sample are recommended to evaluate the needed curriculum content development, practical teaching approaches, and the most effective practice matters. In addition, developing educational programs considering social, ethical, legal, religious, and cultural issues is recommended.

Footnote page

Compliance with Ethical Standards:

All procedures performed in this study involving human participants were reviewed and ethically approved by the Institutional Review Board (IRB) of the research and ethics committee at the University of Science and Technology Yemen-Jordan branch (USTY-Jo) (IRB number, 9/120/2019). This study was conducted following the 1975 Helsinki declaration, as revised in 2008 and later amendments or comparable ethical standards.

Informed consent:

Written informed consent was obtained from all individual participants included in the study.

Availability of data and materials:

The datasets generated and analyzed during the current study are provided in **supplementary file 2**. The data demonstrate the participants' responses pre- and post-intervention.

Declaration of interests:

The authors declare that they have no competing interests. No financial or other relationship could lead to a conflict of interest. No writing assistance was aided in the preparation of the manuscript.

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Table 1(on next page)

Detailed Study Intervention

1 **Table 1.** Detailed Study Intervention

Number and title of intervention week	**Objectives of the intervention**	**Interactive teaching methods**
Week one: Stem cells basic biology	✓ Reviewing the history of stem cells (SCs) research. ✓ Understanding the basic biology of SCs and identifying characteristics that distinguish SCs from other types of cells. ✓ Classifying SCs according to source and potency.	**Brainstorming:** The lecturer asked students an opening question: what do you know about SCs? , then he used the whiteboard to list all the ideas generated by the students and grouped them into few headlines. **Visual aids:** The lecturer presented a short video about the discovery of the microscope by Robert Hooke, and then he presented a diagram illustrating major historical events in SCs research.
Week two: Stem cells potential applications	Recognizing potential applications of SCs in studying early human development, modeling diseases in a culture dish, testing new drugs, and restoring lost tissues.	**Group activity and learning by teaching:** Students were divided into eight groups and were given one of four topics that cover potential applications of SCs. Each group had to read five articles about the topic and do a seminar for other students.
Week three: Unproven stem cells therapies and stem cell tourism	✓ Listing current therapeutic uses of SCs such as bone marrow transplantation for leukemia. ✓ Shedding light on potential therapeutic uses of SCs such as limbal SCs for degenerative eye diseases. ✓ Increasing awareness about SCs tourism and severe risks due to trying unproven SCs therapies.	**Case-based scenarios:** for patients who tried unproven SCs therapies. **Group activity:** students were divided into eight groups assigned to search for websites that promote unproven SCs therapies.

Week four: Stem cells research	✓ Understanding the induced pluripotent stem cells (iPSCs) and the role of transcription factors. ✓ Explaining SCs-assisted technologies such as MRT, SCNT, and human/animal chimeras.	**Story:** a reflection on Shinya Yamanaka's story, who won Nobel Prize for discovering induced pluripotent SCs.
Week five: Cord blood banking and donation	✓ Explaining techniques and procedures of cord blood collection, banking, and donation. ✓ Summarizing advantages and disadvantages of cord blood transplantation in comparison with bone marrow transplantation. ✓ Comparing between different types of Cord blood banks.	**Role-playing:** Students played different roles assigned to them: parents who are interested in cord blood banking and healthcare providers who should answer parents' questions. **Guest lecturer:** to take about cord blood banking. **Real-life situations:** students provided health education for pregnant women about cord blood banking.
Week six: bioethics of stem cells research	Discussing ethical controversies surrounding SCs research and their-assisted technologies.	**Panel discussion:** with bioethics expert. **Class debate:** Class was divided into eight groups; four groups argued for another four groups against research involving embryonic SCs.

Table 2(on next page)

Respondents' Characteristics (n = 48)

Table 2. Respondents' Characteristics (n = 48)

Characteristics	Value
Gender, *N (%)*	
Male	32 (66.7%)
Female	16 (33.3%)
Age, *M (SD)*	**24 (1.21)**
Nationality, *N (%)*	
Jordanian	14 (29.2%)
Palestinian	3 (6.3%)
Syrian	8 (16.7%)
Iraqi	6 (12.5%)
Yemeni	13 (27.1%)
Others	4 (8.3%)

Abbreviations: *M* = Mean**;** *SD* = Standard Deviation.

Table 3(on next page)

Pre- and post-educational intervention mean knowledge scores and differences (n = 48)

Table 3. Pre- and post-educational intervention mean knowledge scores and differences (n = 48)

Pre- and post-educational intervention mean scores of students' knowledge regarding stem cells, their potential applications, therapeutic uses, and research involving them				Differences between pre-and post-educational interventions			
Stem cells: basic knowledge	*Score*	*M (SD)*	*Min-Max*	*MD*	*95% CI Lower*	*Upper*	*p-value*
1- I have sufficient knowledge of different types of stem cells, such as adult and embryonic stem cells.	Pre	1.88 (0.94)	0-4	1.89	1.57	2.23	*<0.001**
	Post	3.77 (0.43)	3-4				
2- I have sufficient knowledge of the sources of stem cells.	Pre	2.17 (0.78)	0-4	1.50	1.22	1.78	*<0.001**
	Post	3.67 (0.52)	2-4				
3- I have sufficient knowledge of the therapeutic uses of stem cells.	Pre	2.15 (1.05)	0-4	1.54	1.22	1.86	*<0.001**
	Post	3.69 (0.51)	2-4				
4- I have sufficient knowledge of the three germ layers (endoderm, mesoderm and ectoderm), and organs and tissues generated from each layer.	Pre	2.67 (1.02)	0-4	1.02	0.70	1.34	*<0.001**
	Post	3.69 (0.59)	2-4				
5- Cell differentiation is the process by which stem cells become more specialized cell types (true).	Pre	2.85 (0.97)	1-4	0.65	0.38	0.92	*<0.001**
	Post	3.50 (0.72)	1-4				
6- As a stem cell differentiates, it gradually loses potency and becomes unipotent (true).	Pre	2.23 (1.06)	0-4	0.48	0.13	0.83	*0.009**
	Post	2.71 (1.32)	0-4				
7- Self-renewing is the ability of a stem cell to produce more stem cells with identical characteristics as the "parent" cell (true).	Pre	2.46 (0.82)	0-4	0.89	0.60	1.20	*<0.001**
	Post	3.35 (0.84)	1-4				
8- Adult stem cells are pluripotent cells that have the potential to make all cell types of the body (false).	Pre	1.58 (1.16)	0-4	1.34	0.75	1.92	*<0.001**
	Post	2.92 (1.49)	0-4				
9- Bone marrow is the only source for adult stem cells (false).	Pre	2.17 (1.24)	0-4	1.10	0.67	1.54	*<0.001**
	Post	3.27 (1.25)	0-4				
10- Stem cells can differentiate into many cell types within a germ layer (true).	Pre	2.73 (0.94)	0-4	0.52	0.12	0.93	*0.013**
	Post	3.25 (1.02)	0-4				
11- Embryonic stem cells are derived from leftover blastocysts after in vitro fertilization (true).	Pre	2.06 (0.76)	0-4	0.90	0.48	1.31	*<0.001**
	Post	2.96 (1.34)	0-4				
12- Embryonic stem cells are derived from the umbilical cord after childbirth (false).	Pre	1.35 (0.91)	0-3	0.38	-0.16	0.91	*0.165*
	Post	1.73 (1.65)	0-4				
13- Embryonic stem cells are derived from the trophoblast of blastocysts (false).	Pre	1.54 (0.65)	0-4	0.25	-0.25	0.75	*0.316*
	Post	1.79 (1.64)	0-4				

The total score of stem cells basic knowledge	**Pre**	**2.14 (0.30)**		**0.95**	**0.83**	**1.09**	***<0.001****
	Post	**3.09 (0.47)**					

Table 3. (Continued).

Pre- and post-educational intervention mean scores of students' knowledge regarding stem cells, their potential applications, therapeutic uses, and research involving them				Differences between pre-and post-educational interventions			
Stem cells: potential applications	*Score*	*M (SD)*	*Min-Max*	*MD*	*95% CI Lower*	*Upper*	*p-value*
14- Stem cells can be used to study early human development (true).	Pre	3.02 (0.84)	1-4	0.40	0.13	0.66	*0.004**
	Post	3.42 (0.71)	1-4				
15- Stem cells can be used to understand the pathophysiology and analyze disease mechanisms by modeling disease in a culture dish outside the human body (true).	Pre	2.56 (1.09)	0-4	0.92	0.48	1.35	*<0.001**
	Post	3.48 (0.83)	0-4				
16- Stem cells can be used to test and screen new drug candidates and toxins to figure out their potential side effects (true).	Pre	2.21 (1.09)	0-4	1.27	0.84	1.70	*<0.001**
	Post	3.48 (0.83)	0-4				
17- Stem cells can be used to replace or restore tissues that have been damaged by disease or injury, such as diabetes, heart attacks, Parkinson's disease, skin burns, or spinal cord injury (true).	Pre	2.85 (1.09)	0-4	0.73	0.38	1.08	*<0.001**
	Post	3.58 (0.85)	0-4				
The total score of stem cells potential applications	**Pre**	**2.66 (0.77)**		**0.80**	**0.53**	**1.09**	***<0.001****
	Post	**3.46 (0.59)**					
Stem cells: therapeutic uses							
18- There is a wide range of conditions or diseases for which stem cell therapies have been proven to be safe and effective such as osteoarthritis and multiple sclerosis (false).	Pre	1.54 (0.97)	0-4	0.69	0.23	1.15	*0.004**
	Post	2.23 (1.53)	0-4				
19- There is nothing to lose from trying unproven stem cell therapies since they can provide hope for hopeful patients (false).	Pre	1.71 (1.07)	0-4	0.67	0.24	1.10	*0.003**
	Post	2.38 (1.39)	0-4				
20- Bone marrow-derived stem cells will spontaneously regenerate into different cell types such as hepatocytes and neural cells without manipulation in the lab (false).	Pre	1.88 (1.00)	0-4	0.45	-0.01	0.93	*0.055*
	Post	2.33 (1.53)	0-4				

21- If the balance is skewed between differentiation and self-renewing properties of stem cells, it may result in tumor formation (true).	Pre	2.25 (0.79)	0-4	0.63	0.26	0.99	*<0.001**
	Post	2.88 (1.04)	1-4				
The total score of stem cells therapeutic uses	**Pre**	**1.84 (0.63)**		**0.61**	**0.36**	**0.85**	***<0.001****
	Post	**2.45 (0.80)**					

Table 3. (Continued).

Pre- and post-educational intervention mean scores of students' knowledge regarding stem cells, their potential applications, therapeutic uses, and research involving them.				Differences between pre-and post-educational interventions.			
Stem cells: research	*Score*	*M (SD)*	*Min-Max*	*MD*	*95% CI Lower Upper*		*p-value*
22- I would be confident to explain the induced-Pluripotent Stem Cells (iPSCs).	Pre	1.65 (1.16)	0-4	1.75	1.38	2.12	*<0.001**
	Post	3.40 (0.71)	2-4				
23- I would be confident to explain the transcription factors.	Pre	1.85 (1.19)	0-4	1.28	0.87	1.67	*<0.001**
	Post	3.13 (0.89)	0-4				
24- Adult cells can be "reprogrammed" genetically to assume stem cell-like state (true).	Pre	1.85 (1.05)	0-4	1.46	1.04	1.88	*<0.001**
	Post	3.31 (0.83)	1-4				
25- I would be confident to discuss the Somatic Cell Nuclear Transfer (SCNT).	Pre	1.58 (1.07)	0-4	1.48	1.07	1.89	*<0.001**
	Post	3.06 (0.10)	0-4				
26- I would be confident to explain the differences between therapeutic cloning and reproductive cloning.	Pre	1.81 (1.20)	0-4	1.40	0.96	1.83	*<0.001**
	Post	3.21 (0.82)	0-4				
27- I would be confident to discuss the mitochondrial replacement therapy.	Pre	1.83 (1.19)	0-4	1.69	1.28	2.10	*<0.001**
	Post	3.52 (0.74)	1-4				
The total score of stem cells research	**Pre**	**1.76 (0.89)**		**1.51**	**1.20**	**1.82**	***<0.001****
	Post	**3.27 (0.56)**					
The total knowledge score	**Pre**	**2.09 (0.30)**		**1.00**	**0.86**	**1.15**	***<0.001****
	Post	**3.09 (0.41)**					

Abbreviations: *M* = Mean; *SD* = Standard Deviation; *Min* = Minimum score; *Max* = Maximum score; *CI* = Confidence Interval; *MD* =

Mean Difference; *Pre* = Pre-educational intervention; *Post* = Post-educational intervention
* Significant at $p < 0.05$ based on paired-samples t-test.
Note: The total score of knowledge is the sum of the total scores of the four major domains (stem cells' basic knowledge, potential applications, therapeutic uses, and research).

Table 4 (on next page)

Pre- and post-educational intervention mean attitude scores and differences (n = 48)

Table 4. Pre- and post-educational intervention mean attitude scores and differences (n = 48)

Pre- and post-educational intervention mean scores of students' attitudes regarding stem cells				Differences between pre-and post-educational interventions			
Statements	*Score*	*M (SD)*	*Min-Max*	*MD*	*95% CI Lower*	*Upper*	*p-value*
1- I am interested in expanding my knowledge about stem cells (positive).	Pre	3.29 (0.92)	0-4	0.48	0.22	0.74	*0.001**
	Post	3.77 (0.43)	3-4				
2- Stem cell education should be integrated into medical college curricula (positive).	Pre	2.83 (0.10)	0-4	0.52	0.13	0.91	*0.010**
	Post	3.35 (0.93)	0-4				
3- I would consider a well-structured program or training focusing on stem cell science (positive).	Pre	2.83 (0.91)	0-4	0.65	0.38	0.92	*<0.001**
	Post	3.48 (0.68)	2-4				
4- I think stem cell therapies give rise to ethical controversies (negative).	Pre	1.29 (1.09)	0-4	-0.16	-0.58	0.25	*0.420*
	Post	1.13 (1.20)	0-4				
5- I think stem cell therapies give rise to religious controversies (negative).	Pre	1.88 (1.10)	0-4	-0.75	-1.23	-0.27	*0.003*
	Post	1.13 (1.30)	0-4				
6- Government should spend money to support stem cell research (positive).	Pre	3.38 (0.82)	1-4	0.31	0.01	0.62	*0.046**
	Post	3.69 (0.72)	0-4				
7- Transitional process of taking stem cell therapy from the laboratory through clinical trials should be encouraged (positive).	Pre	2.83 (0.93)	1-4	0.44	0.12	0.76	*0.009**
	Post	3.27 (0.84)	1-4				
8- People should consider the donation of bone marrow for a public bank (positive).	Pre	2.81 (0.94)	1-4	0.29	-0.17	0.76	*0.212*
	Post	3.10 (1.23)	0-4				
9- People should consider the donation of their babies' umbilical cord blood for a public bank (positive).	Pre	2.85 (0.10)	0-4	0.42	0.00	0.83	*0.049**
	Post	3.27 (1.13)	0-4				
10- I am willing to pay money for preserving the umbilical cord blood of my baby in a private bank for later use if a therapeutic need arises (positive).	Pre	2.63 (1.20)	0-4	-0.28	-0.82	0.27	*0.322*
	Post	2.35 (1.52)	0-4				
The total attitude score	**Pre**	**2.66 (0.56)**		**0.19**	**0.02**	**0.38**	***0.048****
	Post	**2.85 (0.53)**					

Abbreviations: *M* = Mean; *SD* = Standard Deviation; *Min* = Minimum score; *Max* = Maximum score; *CI* = Confidence Interval; *MD* = Mean Difference; *Pre* = Pre-educational intervention; *Post* = Post-educational intervention

* Significant at $p<0.05$ based on paired-samples t-test.

Note: The total attitude score is the sum of the total scores of the ten statements, as mentioned earlier.

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Table 5(on next page)

Gender differences in mean knowledge and attitude scores pre-and post- educational intervention

Table 5. Gender differences in mean knowledge and attitude scores pre-and post- educational intervention

Score	Pre-intervention differences between males and females (n = 48)			Post-intervention differences between males and females (n = 48)		
	Males (n = 32) M (SD)	*Females (n = 16) M (SD)*	*p-value*	*Males (n = 32) M (SD)*	*Females (n = 16) M (SD)*	*p-value*
Total score of stem cell basic knowledge	2.15 (0.32)	2.12 (0.24)	*0.734*	3.15 (0.45)	2.99 (0.49)	*0.279*
Total score of stem cell potential applications	2.85 (0.66)	2.28 (0.85)	*0.014**	3.52 (0.58)	3.35 (0.61)	*0.369*
Total score of stem cell therapeutic uses	1.82 (0.65)	1.89 (0.59)	*0.719*	2.50 (0.86)	2.35 (0.68)	*0.571*
Total score of stem cell research	1.95 (0.81)	1.39 (0.95)	*0.036**	3.30 (0.62)	3.20 (0.41)	*0.588*
Total knowledge score	**2.16 (0.27)**	**1.95 (0.30)**	***0.017****	**3.14 (0.42)**	**3.00 (0.39)**	***0.267***
Total Attitude score	**2.66 (0.60)**	**2.66 (0.50)**	***1.000***	**2.81 (0.52)**	**2.92 (0.55)**	***0.517***

Abbreviations: *M* = Mean; *SD* = Standard Deviation
* Significant at $p<0.05$ based on independent-samples t-test.