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

Running title: Phase I of "stem cells: hope or hype?" project

Abstract

Aims: To evaluate the effectiveness of an interactive teaching intervention on medical students' knowledge and attitudes about stem cell research and therapy.

Methods: A quasi-experimental, one group pre-posttest study design was employed. A six-session interactive teaching course (intervention) was conducted for a duration of 6 weeks. Pre and post intervention surveys were used. Differences in students' knowledge and attitude mean scores were examined using paired t-test, while gender differences were examined using independent t-test.

Results: Seventy one sixth year medical students were invited to participate in this study. A pre-intervention survey was distributed to 58 students who agreed to participate (81.6%). Out of 58 students, only 48 (82.7%) completed the entire course. Total knowledge scores and attitude score significantly increased post intervention. Significant gender differences in knowledge and attitude scores were not detected post intervention.

Conclusions: Integrating stem cell science into medical curricula coupled with interactive learning approach were effective in increasing students' knowledge about recent advances in stem cell research and therapy, and in improving attitudes toward stem cells research and applications.

Keywords: Quasi experimental, stem cells, medical education, interactive teaching, Jordan

What's known?

Traditional medical educational model is challenged by an evident gap between the rapidly changing disciplines, such as stem cell science, and clinical practice. New curricula and innovative teaching techniques are fundamental for bridging this gap and achieving optimum patients' care.

What's new?

Our study provides an evidence that interactive learning approach in stem cells 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.

Introduction

The emerging discipline of stem cells (SC) biology and the rapid revolution in SC research have radically transformed our thinking of cells, evolution, and disease. Using SC for clinical applications is the future of translational medicine, since SC can potentially be used to treat many kinds of difficult diseases that cannot currently be treated [1, 2]. Advances in SC research in combination with tissue engineering techniques promise therapies to restore or replace damaged tissues [3]. This raises the need of medical education to introduce basic SC knowledge and the concept of translational medicine in the life sciences field. At the same time, SC research and applications still raise complex social, legal, ethical and religious issues [4-6], especially on conservative societies [7].

The paradigm-shifting concept in SC applications transformed the priorities of both undergraduate and graduate medical educational programs [8]. Today, the traditional academic model for medical education is challenged by an evident gap between the rapidly changing disciplines in basic biomedical sciences and the clinical practice. Although medical students (MS) have access to theoretical advancements in SC research [9], traditional teaching approaches still fail to bridge this gap in practice. Updated teaching techniques that facilitate integration of advancements in SC research with clinical practice are, therefore, critical for MS to achieve optimum patients' care [10]. Restructuring of medical education to meet current and future health care needs of SC-based interventions, including new curricula featuring the ethical, legal and social implications of SC research are thus a priority [11, 12].

Since the early 1990s, many medical curricula have transitioned from the traditional subject-based teaching toward the integrated system-based teaching [13]. Traditional didactic lecture for one hour becomes monotonous after 15-20 minutes as students' participation in the learning process is minimal, if any [14]. Interactive teaching approach, on the other hand, actively engages learners, and interchanges ideas between learners and facilitators [15]. The effectiveness of educational interventions in increasing knowledge and attitudes towards SC applications were reported [16-18].

Although it is currently a hot research topic, SC education for undergraduate students is still very rare [11]. The present study was conducted to evaluate the effectiveness of interactive teaching intervention on medical students' knowledge and attitudes toward SC, their therapeutic uses and potential research applications. The interactive teaching modality was designed to introduce MS to the groundbreaking area of SC biology and to shed light on current advances in SC research. MS as future physicians are expected to be able to answer patients' questions regarding SC, and to help them differentiate between what is realistic and unrealistic regarding SC-based therapies. Knowledge generated from this study has the potential to enhance curriculum development and teaching approaches, and to bridge the gap between basic sciences and clinical practice.

Methods

Study design, participants and setting:

A quasi-experimental, one group, pre-posttest design was employed for a sample of 71 sixth year MS, at the University of Science and Technology Yemen-Jordan branch (USTY-Jo), during the first semester of the academic year 2018-2019. USTY-Jo academic director facilitated the conduct of the study by granting an orientation lecture where study details were discussed and an informed consent form was distributed. Study participation was voluntary and a pre-intervention survey was distributed to all MS who agreed to participate (N=58 students).

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 "Stem Cells: Hope or Hype?" project. Each interactive session lasted between two and three hours and included brain storming, learning by teaching, role playing, class debate, panel discussions, reflections on stories, real life situations, case-based scenarios, and videos. Details about the intervention are summarized in Table 1.

Study tools:

A structured, self-administered questionnaire was developed by the researchers after reviewing the literature regarding SC. The questionnaire was not based on a particular study but on information from various studies, and on recent guidelines from international organizations such as; the International Society for Stem Cell Research (ISSCR) and the New York Stem Cell Foundation (NYSCF) [19, 20]. The questionnaire was reviewed by a panel of experts, pilot-tested on 20 participants, and the necessary modifications were done.

The questionnaire was divided into three major sections: demographics, SC knowledge, and SC attitudes. SC knowledge section was designed to identify sources of knowledge and to measure knowledge regarding SC utilizing a total of 27 statements (α =0.61 and 0.78 in pre and post intervention, respectively) that are classified into 4 domains: basic knowledge with a total of 13 statements (α =0.42 and 0.61), potential applications with a total of 4 statements (α =0.69 and 0.66), therapeutic uses with a total of 4 statements (α =0.44 and 0.32), and research with a total of 6 statements (α =0.86 and 0.75). Section three was designed to measure attitudes toward SC utilizing a total of 10 statements (α = 0.76 and 0.68). Higher scores indicated accurate knowledge statements and positive attitude statements. Responses to statements were summed to create a score for total knowledge, total attitude, and each of the four knowledge domains. Originally, knowledge scores ranged from 0 to 108 for "total SC knowledge", 0 to 52 for "SC basic knowledge", 0 to 16 for "SC potential applications", 0 to 16 for "SC therapeutic uses", and 0 to 24 for "SC research". Total attitude score ranged from 0 to 40. All scales were converted into mean scores (range 0 to 4). Mean scores greater than, or equal to, 2 indicated good knowledge and positive attitude, while scores less than 2 indicated poor knowledge and negative attitude.

Data analysis:

Data was analyzed using IBM Statistical Package for Social Sciences (SPSS) Version 21.0 (IBM Corp., Armonk, NY, USA). Internal consistency (α) for overall scales and sub scales were tested using Cronbach's alpha. Descriptive statistics were presented as means and standard deviations (SD) for continuous variables, while categorical variables were presented as proportions and frequencies. Paired-samples *t*-test was used to examine mean differences in students' knowledge and attitude scores pre and post educational intervention, and 95% confidence interval of the difference in means (MD) was presented. Independent-samples *t*-test was used to examine mean gender differences in students' knowledge and attitude scores. Alpha level was set at 0.05.

Ethical considerations:

The study protocol was approved by the research committee at USTY-Jo. Purpose of the study was dully explained to the study participants and signed consents were obtained. The study was undertaken with full confidentiality and information provided by study participants was not disclosed to others.

Results

Out of the 71 sixth year MS at USTY-Jo who were invited to participate in the study, 58 (81.6%) were enrolled in the interactive teaching course. The final sample consisted of 48 (82.7%) students who were initially enrolled and completed the entire six week course sessions (completion rate = 67.6%). Out of 48 students, 32 (66.7%) were males and more than one half (56.3%) were of Jordanian (29.2%) or Yemeni (27.1%) nationalities. 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 SC 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 scores are summarized in Table 3. The mean (SD) total knowledge score significantly increased from 2.09 (0.30), pre intervention, to 3.09 (0.41) (P= 0.000), post intervention. Similarly, all knowledge domain scores significantly increased following the intervention.

The mean SC basic knowledge domain score significantly increased from 2.14 (0.30) to 3.09 (0.47), (P = 0.000). Post intervention, participants reported improved familiarity with types of SC (3.77 (0.43) vs. 1.88 (0.94), P = 0.000), sources of SC (3.67 (0.52) vs. 2.17 (0.78), P= 0.000), therapeutic uses of SC (3.69 (0.51) vs. 2.15 (1.05), P= 0.000) and three germ layers from which tissues and organs are generated (3.69 (0.59) vs. 2.67 (1.02), P= 0.000). Students' knowledge of sources of embryonic SC significantly improved for statements related to leftover blastocysts after in vitro fertilization (2.96 (1.34) vs. 2.06 (0.76), P = 0.000), 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 SC potential applications domain, the mean score significantly increased from 2.66 (0.77) to 3.46 (0.59), (P= 0.000). Post intervention, students reported significantly higher knowledge scores regarding potential applications of SC such as replacing or restoring damaged tissues (3.58 (0.85) vs. 2.85 (1.09), P= 0.000), screening new drugs and toxins (3.48 (0.83) vs. 2.21 (1.09), P= 0.000), modeling disease in a culture dish (3.48 (0.83) vs. 2.56 (1.09), P= 0.000) and studying early human development (3.42 (0.71) vs. 3.02 (0.84), P= 0.004).

For SC therapeutic uses domain, the mean total score significantly increased from 1.84 (0.63) to 2.45 (0.80), (P= 0.000). Post intervention, students became significantly more aware about side effects of trying unproven SC therapies, especially tumor formation potential if the balance is skewed between cell differentiation and self-renewing properties of SC (2.88 (1.04) vs. 2.25 (0.79), P= 0.001).

In the SC research domain, the mean total score significantly increased from 1.76 (0.89) to 3.27 (0.56) (P= 0.000). Post intervention, students became more comfortable in giving an explanation of induced pluripotent SC (3.40 (0.71) vs. 1.65 (1.16), P= 0.000), transcription factors (3.13 (0.89) vs. 1.85 (1.19), P= 0.000), and differences between therapeutic cloning and reproductive cloning (3.21 (0.82) vs. 1.81 (1.20), P = 0.000). Moreover, participants became more knowledgeable that adult cells can be "reprogrammed" genetically to assume SC-like state (3.31 (0.83) vs. 1.85 (1.05), P= 0.000). Students were also more comfortable having a discussion about mitochondrial replacement therapy (3.52 (0.74) vs. 1.83 (1.19), P= 0.000) and somatic cell nuclear transfer (3.06 (0.10) vs. 1.58 (1.07), P= 0.000).

Attitude 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, students became more interested in expanding their knowledge regarding SC (3.77 (0.43) vs. 3.29 (0.92), P= 0.001), and considered a well-structured program or training focusing on SC science (3.48 (0.68) vs. 2.83 (0.91), P= 0.000). Students reported improved positive attitudes regarding integration of SC education in undergraduate 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 SC 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 SC 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 SC (1.13 (1.20) vs. 1.29 (1.09), P= 0.420) and preserving umbilical cord blood in a private bank (2.35 (1.52) vs. 2.63 (1.20), P= 0.322) 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 SC potential applications (2.85 (0.66) vs. 2.28 (0.85), P= 0.014) and SC research (1.95 (0.81) vs. 1.39 (0.95), P= 0.036). Accordingly, total knowledge score of males was higher than females (2.16 (0.27) vs. 1.95 (0.30), P= 0.017). However, after the intervention, gender differences were not statistically significant.

Discussion

The current study assessed the effectiveness of an interactive educational intervention on levels of knowledge and attitudes toward SC, their therapeutic uses and potential research applications among sixth year MS at USTY-Jo. Overall, SC knowledge and attitude scores improved following the intervention. Post intervention, participants were more interested in expanding their knowledge regarding SC and considered well-structured programs or training course focusing on SC science as an approach to improve their understanding of SC. Positive attitudes regarding the integration of SC education in undergraduate curricula were also reported. This is the first evidence from the Middle East that interactive learning approach in SC may be of great benefits not only to MS 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. As future health care leaders, MS represent a source of information, or misinformation, which may influence patients' behaviors and serve as a valuable source of information [21]. This makes medical schools an ideal place to address information misconceptions and emphasize positive attitudes of SC applications. Improvements in the medical curriculum in the region should, therefore, 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 scientific topics rapidly advancing in the field of medicine where relying merely on available evidence from textbooks may introduce delays in transforming knowledge to MS.

Previous educational interventions were successful in increasing knowledge about SC transplantation and banking, not only among MS but also among nursing and law students, and in showing more positive attitudes toward SC donation following certain intervention [16, 17]. Innovative SC education using practical experiment to master the technique for SC culture and differentiation were also reported to deepen medical students' understanding of regenerative and translational medicine [18]. In comparison with other studies, our educational intervention was more comprehensive, detailed and more engaging for students as it utilized different interactive teaching techniques It also covered more topics that were not covered in the previous research such as SC research and potential applications, unproven SC therapies and SC tourism, cord blood banking and donation, and bioethics. As well, 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 spread for a total of 6-week duration.

In the current study, the most common sources of knowledge regarding SC were lectures followed by media. Mass media is the primary source of science communication to the public, and can significantly influence public attitudes toward controversial emerging technologies in regenerative medicine, such as the use of leftover blastocysts as a source for embryonic SC and genome editing [22]. In addition, media portrayal of translational SC research is highly optimistic and may result in fostering of unrealistic expectations regarding the speed of clinical translation [23]. MS should consider other sources for knowledge that are based on scientific evidence, such as medical journals and conferences. Unfortunately, none of the MS in our study chose panel discussions as a source for knowledge regarding SC, despite being considered as a valuable way to trigger an exchange of viewpoints regarding ethical controversies surrounding SC. Medical schools should, therefore, invest in furthering students' knowledge about SC by enhancing exposure to updated medical literature and medical conferences.

Interactive learning approach was effective in significantly improving the levels of knowledge and positive attitudes towards SC. Improvements also spread out to all knowledge domains and were sufficient to reduce gender gaps related to SC knowledge score. While positive attitudes towards SC were improved following the intervention, negative attitudes related to religious controversies surrounding SC actually worsened. When emerging biotechnology involves human subjects complex social, legal, ethical and religious issues arise [(4)], especially in conservative societies like that under investigation. However Islamic teachings carry a great deal for disease prevention and health promotion, it is important to focus more on increasing our understandings about how could SC applications play a role in advancing the health of human beings to facilitate adoption of these technologies [(7)]. Within this context, future SC-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 [(5)]. However negative attitudes toward ethical controversies surrounding SC 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 that are in line with religious beliefs. Notably, our findings regarding religious and ethical controversies call for incorporating bioethics into the medical curriculum when addressing SC related topics as ethical concerns were reported to be the obstacle that have obscured the true potential that SC holds for revolutionizing medicine and treatment options in the future [(24)]. Medical curricula need to be restructured not only to include SC or other emerging technologies in biomedicine, but also to include research and healthcare ethics [(9, 25, 26)]. Adoption of new technologies for patient care is a challenging process, since there are many ethical dilemmas surround it, and the future doctors should be prepared to deal with such dilemmas when they arise [(6)].

Limitations

The sample selected was from a single medical school, which may limit the generalizability of the results. While response and enrolment rates were not optimal, they are considered sufficient among MS. A parallel group, with no intervention, was not utilized which may introduce testing effects and may exacerbate the results.

Conclusions

Advances in SC research promise SC-based therapies to replace lost or dying cells. MSs are the next generation of physicians, and they should be able to use new discoveries in SC research and apply them in the care of patients. That is why this study was conducted, to evaluate the effect of interactive teaching on medical students' knowledge and attitudes 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. After the intervention course, higher levels of knowledge and more positive attitudes were detected by MS. Differences in knowledge between males and females were vanished after the intervention course. General experience was interesting for both students and researchers, and many of the students were enthusiastic for more courses designed with this approach. Finally, Knowledge generated from this study has the potential to enhance curriculum development and teaching approaches.

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Author Contributions:

FA and KK conceived of the study, designed survey tools, drafted portions of the manuscript; FA, KK and AAM designed and supervised the interactive teaching course. FA analyzed data. AAZ, MA, JA, MAZ and AAM assisted in data analysis, interpreted the results, and drafted portions of the manuscript. All authors read and approved the final version of the manuscript.

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Table 1: Detailed Study Intervention.

Week one: stem cell basic biology	**Week three:** unproven stem cell therapies and stem cell tourism	**Week five:** cord blood banking and donation
Objectives:		
- Reviewing history of SC research. - Understanding basic biology of SCs and identifying characteristics that distinguish SCs from other types of cells. - Classifying SCs according to source and potency.	- 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 SC tourism and serious risks from trying unproven SC therapies.	- 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.
Interactive teaching methods:		
Brain storming: 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**: Lecturer presented a short video about discovery of the microscope by Robert Hooke, then he presented a diagram illustrating major historical events in SC research.	**Case-based scenarios:** for patients who tried unproven SC therapies. **Group activity:** students were divided into eight groups which were assigned to search for websites that promote for unproven SC therapies.	**Role playing:** Students played different roles were assigned to them, parents who are interested in cord blood banking and healthcare providers who should answer parents' question. **Guest lecturer:** to take about cord blood banking. **Real life situations:** students provided health education for pregnant women about cord blood banking.
Week two: stem cell potential applications	**Week four:** stem cell research	**Week six:** bioethics of stem cell research
Objectives:		
- Recognizing potential applications of SCs in studying early human development, modeling diseases in a culture dish, testing new drugs and restoring lost tissues.	**-** Understanding induced pluripotent stem cells (iPSCs) and role of transcription factors. - Giving an explanation of SC-assisted technologies such as: MRT, SCNT and human/animal chimeras.	- Discussing ethical controversies surrounding SC research and SC-assisted technologies.
Interactive teaching methods:		
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 to do seminar for other students.	**Story:** reflection on Shinya Yamanaka story who won Nobel Prize for discovering induced pluripotent SCs.	**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: 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%)

Note: *M* = Mean and *SD* = Standard Deviation.

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 am familiar with 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	0.000*
	Post	3.77 (0.43)	3-4				
2- I am familiar with sources of stem cells.	Pre	2.17 (0.78)	0-4	1.50	1.22	1.78	0.000*
	Post	3.67 (0.52)	2-4				
3- I am familiar with therapeutic uses of stem cells.	Pre	2.15 (1.05)	0-4	1.54	1.22	1.86	0.000*
	Post	3.69 (0.51)	2-4				
4- I am familiar with the three germ layers (i.e. 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	0.000*
	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	0.000*
	Post	3.50 (0.72)	1-4				
6- As a stem cell differentiates it gradually loosing potency and it 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	0.000*
	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	0.000*
	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	0.000*
	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	0.000*
	Post	2.96 (1.34)	0-4				
12- Embryonic stem cells are derived from 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 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				
Total score of stem cell basic knowledge.	**Pre**	**2.14 (0.30)**		**0.95**	**0.83**	**1.09**	**0.000***
	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*	*95% CI 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 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	0.000*
	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	0.000*
	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 disease, skin burns, or spinal cord injury (true).	Pre	2.85 (1.09)	0-4	0.73	0.38	1.08	0.000*
	Post	3.58 (0.85)	0-4				
Total score of stem cell potential applications.	**Pre**	**2.66 (0.77)**		**0.80**	**0.53**	**1.09**	**0.000***
	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 an 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				
Total score of stem cell therapeutic uses.	**Pre**	**1.84 (0.63)**		**0.61**	**0.36**	**0.85**	**0.000***
	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 comfortable giving an explanation of induced pluripotent stem cells (iPSCs).	Pre	1.65 (1.16)	0-4	1.75	1.38	2.12	0.000*
	Post	3.40 (0.71)	2-4				
23- I would be comfortable giving an explanation of transcription factors.	Pre	1.85 (1.19)	0-4	1.28	0.87	1.67	0.000*
	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	0.000*
	Post	3.31 (0.83)	1-4				
25- I would be comfortable having a discussion about somatic cell nuclear transfer (SCNT).	Pre	1.58 (1.07)	0-4	1.48	1.07	1.89	0.000*
	Post	3.06 (0.10)	0-4				
26- I would be comfortable giving an explanation of differences between therapeutic cloning and reproductive cloning.	Pre	1.81 (1.20)	0-4	1.40	0.96	1.83	0.000*
	Post	3.21 (0.82)	0-4				
27- I would be comfortable having a discussion mitochondrial replacement therapy.	Pre	1.83 (1.19)	0-4	1.69	1.28	2.10	0.000*
	Post	3.52 (0.74)	1-4				
Total score of stem cell research.	**Pre**	**1.76 (0.89)**		**1.51**	**1.20**	**1.82**	**0.000***
	Post	**3.27 (0.56)**					
Total knowledge score.	**Pre**	**2.09 (0.30)**		**1.00**	**0.86**	**1.15**	**0.000***
	Post	**3.09 (0.41)**					

Note: *M* = Mean, *SD* = Standard Deviation, *Min* = Minimum score, *Max* = Maximum score, *CI* = Confidence Interval, *MD* = Mean Difference, *Pre* = Pre educational intervention and *Post* = Post educational intervention.
* Significant at $p < 0.05$ based on paired-samples t-test.
Note: total score of knowledge is the sum of total scores of 4 major domains (stem cell basic knowledge, potential applications, therapeutic uses and research).
Note: knowledge scores > 2 indicate good knowledge, while < 2 indicate poor knowledge.

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 in undergraduate 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	0.000*
	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 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 donation of umbilical cord blood of their babies 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'm 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				
Total attitude score.	**Pre**	**2.66 (0.56)**		**0.19**	**0.02**	**0.38**	**0.048***
	Post	**2.85 (0.53)**					

Note: *M* = Mean, *SD* = Standard Deviation, *Min* = Minimum score, *Max* = Maximum score, *CI* = Confidence Interval, *MD* = Mean Difference, *Pre* = Pre educational intervention and *Post* = Post educational intervention.

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

Note: total attitude score is the sum of total scores of 10 statements which were designed to assess attitudes.

Note: attitude scores > 2 indicate positive attitudes, while < 2 indicate negative attitudes.

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**

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