Mixed reality model for learning and teaching in anatomy using peer assisted learning approach

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SUMMARY

The objective of this study was to evaluate the effectiveness of mixed reality models in anatomy teaching and learning at Kirkpatrick's level I, using Peer Assisted Learning approach. This study was based on a single group, post-test study design and was carried out at three affiliated medical schools of Khyber Medical University, Peshawar, over four months. A total of 97 first- and second-year medical students from three medical schools were enrolled. All students received a basic introduction to the use of Hololens (Microsoft), the mixed-reality simulator-based course on the anatomy of the heart and liver via peer-assisted learning (PAL) method. Student satisfaction was evaluated at Kirkpatrick Level I of program evaluation using a validated and structured PAL questionnaire.

Most students agreed or strongly agreed to the effectiveness of questions (mean ± SD 4.3±0.2, percentage 86±4.4%). There was no difference between the satisfaction scores of male and female students (p=0.34), whereas a slight difference was seen between 2nd- and 1st-year students' satisfaction scores (88% versus 85%, p=0.03). There was also a statistically significant difference of perceptions between different medical schools' students' scores (p=.000). Students appear to be satisfied with the use of the mixed reality model for learning anatomy. A randomized trial to directly compare the satisfaction levels between traditional methods and mixed-reality model may be conducted and the effects of mixed-reality models on learning should be assessed.

Key words: Anatomy – Kirkpatrick model – Mixed-reality – Peer-assisted learning

INTRODUCTION

Anatomy has long been considered a cornerstone of not only the basic medical sciences but

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also for the surgical and allied specialties (McLachlan and Patten, 2006; Losco et al., 2017). The implications of anatomical education are manifold; therefore, the lack of anatomical knowledge may result in serious clinical complications due to its significant association to clinical practice (Losco et al., 2017). Thus, strong anatomy knowledge underpins good clinical practice (Collins, 2008; Losco et al., 2017). Anatomy teaching in undergraduate medical schools has traditionally relied upon didactic teaching, cadaver dissection, tutorials, plastic models, and 2-dimensional photographs (McLachlan and Patten, 2006). The complexity of the human body requires powerful tools to know the relationship of organs (Ali and Evans, 2013; Birbara et al., 2020; Shazad et al., 2021). Many alternative tools and approaches such as dissection versus prosection and the use of radiographic material instead of human specimens are being questioned for their effectiveness in anatomy education (McLachlan and Patten, 2006; Lochner et al., 2016).

The popularity of anatomy e-learning tools is on the rise, with the traditional methods being side-lined (Singh and Kharb, 2013). This rise may be attributed to increasing interest of the students in the electronic learning tools (Van Nuland and Rogers, 2016; Losco et al., 2017). Nowadays, more emphasis is given to the applied sciences, as a result of which less time is allocated to basic sciences education including anatomy in a medical curriculum (Vasan, 2003). This change calls for those teaching tools that are more informative, appealing, and less time-consuming, such as computer-assisted learning tools (Collins, 2008). Similarly, simulation tools and imaging techniques such as radiography and computed-assisted teaching methods have also been used (Sugand et al., 2010; Griksaitis et al., 2012; Knobe et al., 2012). Lately, a mixture of advanced 3-dimensional digitalized models and virtual reality is emerging as a novel substitute to conventional anatomy teaching. These models merge the real world with the virtual one, thus connecting the two in the best possible authentic way (Dutta, 2016; Vasilevski and Birt, 2020; Young et al., 2020). One such form of virtual reality is the mixed reality that combines the real world with virtual reality in 3-D models, and is visualized on hologram using specialized lenses (Dutta, 2016). Mixed reality encompasses a continuum of virtuality, ranging from augmented reality to a completely virtual environment (Milgram and Kishino, 1994; Farshid et al., 2018).

With these advancements, it is critical to determine their impact on educational standards, as the cognitive effort required during the e-learning process may differ significantly from the one needed using the conventional tools (Dutta, 2016). The efficacy of any anatomy teaching tool can be gauged by assessing the extent to which the recall and retention of knowledge are acquired (Losco et al., 2017). For such assessments, Hammick et al. (2010) recommended the program evaluation tools such as Kirkpatrick's levels to gauge their degree of effectiveness hierarchically (Kirkpatrick, 1998; Rajeev , 2009; Losco et al., 2017). Hence, it would be interesting to evaluate the immediate impact of the mixed reality model on anatomy education.

A recent paradigm shift has been observed in educational philosophies, with more emphasis being given to student-centered learning rather than a teacher-centered approach (Harve and Yip, 2013; Lochner et al., 2016). Furthermore, novel learning approaches such as Problem Peer Assisted Learning (PAL) have also been introduced into medical didactic practices (Yiou and Goodenough, 2006; Ali and Evans, 2013). PAL involves students assisting the learning and teaching process with a small group of peers (Fuchs et al., 1997; Nnodim, 1997). It not only develops pedagogic literacy among the students but has proven to be more satisfying and rewarding (Ali and Evans, 2013). Although PAL has long been practiced informally (Dent and Harden, 2009), its inclusion into formal medical education is still anticipated (Ali and Evans, 2013). Since the question of which teaching and learning method fits best to the novel tools remains to be answered, this study aims at determining the immediate impact of this novel mixed reality model on anatomy education using the PAL approach. This evaluation will correspond to level I (satisfaction) of the Kirkpatrick model of program evaluation, with an anticipation that in future such tools may be utilized in acquiring as well as enhancing the knowledge, understanding, and application of anatomical knowledge to common medical problems.

METHODS

It was a multi-center, post-test design study conducted at Khyber Medical University (KMU), Peshawar, Pakistan, as a joint venture with MCORPUS-SPRL (Belgium). The study was conducted in collaboration with three affiliated medical schools of KMU (hereafter: medical school A, B, and C). Ethical approval was taken from the ethics board of KMU's and the medical colleges involved.

For sampling, all 150 1st and 2nd year students belonging to three medical schools were invited to participate in the study, of which 64.66% (97/150) students participated. First- and second-year MBBS students from medical school A and B (n=44/50 and 34/50, respectively) and only first-year MBBS students from medical school C (n=19/25) participated in the study. Of the 44 students from medical school A, 20 were from the first year while 24 were from the second year. While out of 34 students of medical school B, 17 each from first and second year took part in the study. The second-year students of medical school C were on the preparatory leave for final term exam. These students had undergone the same medical entrance exam before getting enrolled into their respective medical schools. Written consent was acquired from the participating students. Students were ensured that their inclusion or exclusion in this study would have no bearing on their academic score.

Before the start of the study, all the students and trainers were provided with personal logins into the mixed-reality platforms. The study comprised of two phases. Phase I and Phase II. Each of these phases further consisted of three sessions.

Phase I: During the **first session of phase 1**, five KMU faculty members (facilitators) were introduced to the mixed-reality gadget "Hololens" MCORPUS-SPRL (Brussels Area Belgium) and its components**.** Hololens is an advanced mixed-reality gear used to contextually visualize the augmented human body organs in 360^{o} view for more advanced learning. The Hololens was operated by the hand and finger movements controlled in a navigation-pane-like fashion. With Hololens goggles the human body organs could be visualized in a three-dimensional interface, which could then be displayed on screen for other learners, thus allowing a shared learning experience. **Second session** was a hands-on session, in which the facilitators individually manipulated Hololens and its software to get familiarized with 3D anatomy of liver, heart, brain, and eye. During the **third session**, the facilitators developed comprehensive lesson plans for the anatomy of heart and liver. This was meant to avoid inconsistencies in the PAL sessions that were to be carried out in small groups of medical students.

Phase II: In second phase, the facilitators had hands-on interactive sessions with the students. These sessions were carried out separately within the setting of the respective medical schools. All the participating students had already learnt the gross anatomy of the liver and heart during a single problem-based learning (PBL) session of two hours for each topic. This phase also consisted of three sessions. During the **first session**, the facilitators introduced Hololens and the fundamentals of mixed reality to the participants. This was followed by a practical session on Hololens, where students were briefed about its handling. The goggles were worn by facilitator and the 3D-anatomy of eye and brain were visually displayed on the projector screen. The **second session** was carried out in a peer-assisted learning setting. Although these students were already aware of the small group teaching methods such as PBL, PAL was relatively new to them. Students were briefed about the norms of the PAL and were split randomly into 4-5 groups of 5-6 students each. Students belonging to year 1 and 2 were grouped separately. For year one, the PAL sessions were based on heart anatomy while for year 2 the students learned liver anatomy. The first student from each group was taught by the facilitator. Later, each student was asked to wear the Hololens gear, operate it independently, guide and discuss the topic with their subsequent group member as peer tutor in a same way as they had learned from their preceding group member as peer tutee. So, basically, all the students had both experiences of being a tutor initially followed by a tutee later in the session. This peer tutor-tutee interaction was intended to provide step-by-step instructions to the tutee to learn anatomy using Hololens. The rest of the PAL sessions continued in such a fashion.

During the **third session**, each participant filled the PAL questionnaire to evaluate the effectiveness of the intervention using level 1 of the Kirkpatrick model and gauge the productivity of PAL approach. The PAL questionnaire was a five-point Likert scale questionnaire with a total of 28 items (Ali and Evans, 2013). The questionnaire was contextualized to inquire about the use of a mixed reality model for learning anatomy using PAL approach. It was divided into four parts with four questions as a peer group, six as peer tutor and tutee each, while 12 questions were on evaluation and feedback on PAL sessions. Students were not only unaware of this division; they had not taken part in any similar type of evaluation or responded to a questionnaire of similar sort in the past. The questionnaire also contained two open-ended questions inquiring about the strengths and the weaknesses of the whole learning experience. The students responded to all the questions mentioned in the PAL questionnaire.

Data analysis

The data analysis was carried out using Microsoft Excel version 16.16.27 and IBMS SPSS version 22 (USA). The questionnaire data were analyzed for each item using frequency distribution. The variables which were presented in terms of mean values proportions and percentages included (1) the number of students in total and from each medical school, (2) the gender-wise distribution and (3) the satisfaction level of students as per the PAL questionnaire. These stats also contained mean values with standard deviation. The pair-wise comparison between the responses of three medical schools was carried out using analysis of variance (ANOVA) followed by Post-Hoc Tukey test. Moreover, a heat-mapping concept was used to analyze the responses of the participants. On a heat map, red indicated the lowest while the green shade indicated the highest level of responses. The item-wise analysis of participants' responses was carried out using an approach suggested by Zamalia (2009). On a scale of 1 to 5, a score of 2.5 or less was defined as a negative response while a score of 3.5 and above was defined as a positive response. Scores between 2.5 and 3.5 were considered neutral. For item-wise analysis, since the data was continuous in nature therefore, mean values with standard deviations were used. Since the degree of agreement on the items of Likert questionnaire was categorized into five categories ranging from totally disagree to totally agree, median and IQR values were computed. $p \leq 0.05$ was considered significant.

RESULTS

In this study, 97 medical students participated of which 64.9% were first-year medical students while 35.1% belonged to second year. The great majority of students were female (71.1%).

Frequency statistics of satisfaction level (Kirkpatrick Level 1)

The perceptions of the students regarding the mixed-reality model and PAL sessions were evaluated at four different states, i.e., as a peer group, as a tutor, as a tutee, and a final section of evaluation and feedback. The mean percentage satisfaction level for all the responses was 86.42%±4.46. Overall, the highest level of agreement was observed for item D11 (I enjoyed the session), with all the participants rating it in agreement (N=97, 100%). It was followed by item B6 (Every undergraduate student should be given the opportunity to use this model for learning) and item D5 (Topics selected were relevant to medical education) (97.94% for each item). Interestingly, item A4 (It is more informative than the traditional lecture system) earned the lowest proportion of affirmative response with 70% of the participants rating in its favor, while 21.65% gave neutral response (Fig. 1).

The item-wise analysis of participants' responses was also carried out. For all the items, a positive trend was observed with the great majority of them getting rated above 3.5. The most positive trend was observed for item D11 and B6, with mean values of 4.65±0.48 and 4.65±0.56 respectively. The lowest positive trend was witnessed for the item which asked whether this session improved students' analytical abilities through discussion in peers (4.04±0.75). This was followed by the item "It is more informative than traditional lecture system" (4.05±1.03) (Table 1).

As a **peer group**, the participants rated item A2 (I found it an interactive way of learning and understanding) the highest (4.49±0.56) while item A4 (It is more informative than traditional lecture system) was rated the lowest (4.05±1.03). Item B6 (Every undergraduate student should be given the opportunity to use this model for learning) received the most positive rating not only as a **peer tutor**, while item B3 (It increased my presentation skills) received the least positive rating (4.08±0.89). As a **tutee** item C1 (I was clear about the topic we discussed) got the maximum grading (4.42±0.64), while item C4 (My analytical ability was improved through discussion in peers) had the lowest (4.04±0.75). Among the items belonging to **the evaluation and feedback section**, item D11 (I enjoyed the session) was rated highest (4.65±0.48), while item D3 (I learned more than I would have done on a conventional course) showed the least positive trend (4.08±0.94). Collectively, the students showed the lowest degree of satisfaction as tutees (83.78%, mean 4.19±0.39) while their experience as Peer group received the highest degree of satisfaction (87%) and a most positive rating (4.35 ±0.45) (Table 1).

Degree of agreement on the items of Likert questionnaire

For frequency distribution across all medical colleges, the data were pooled together and heat maps were generated (Fig. 2). Red indicates the lowest and green indicate the highest level of responses. Very few participants responded in the "strongly disagree" and "disagree" category (Fig.

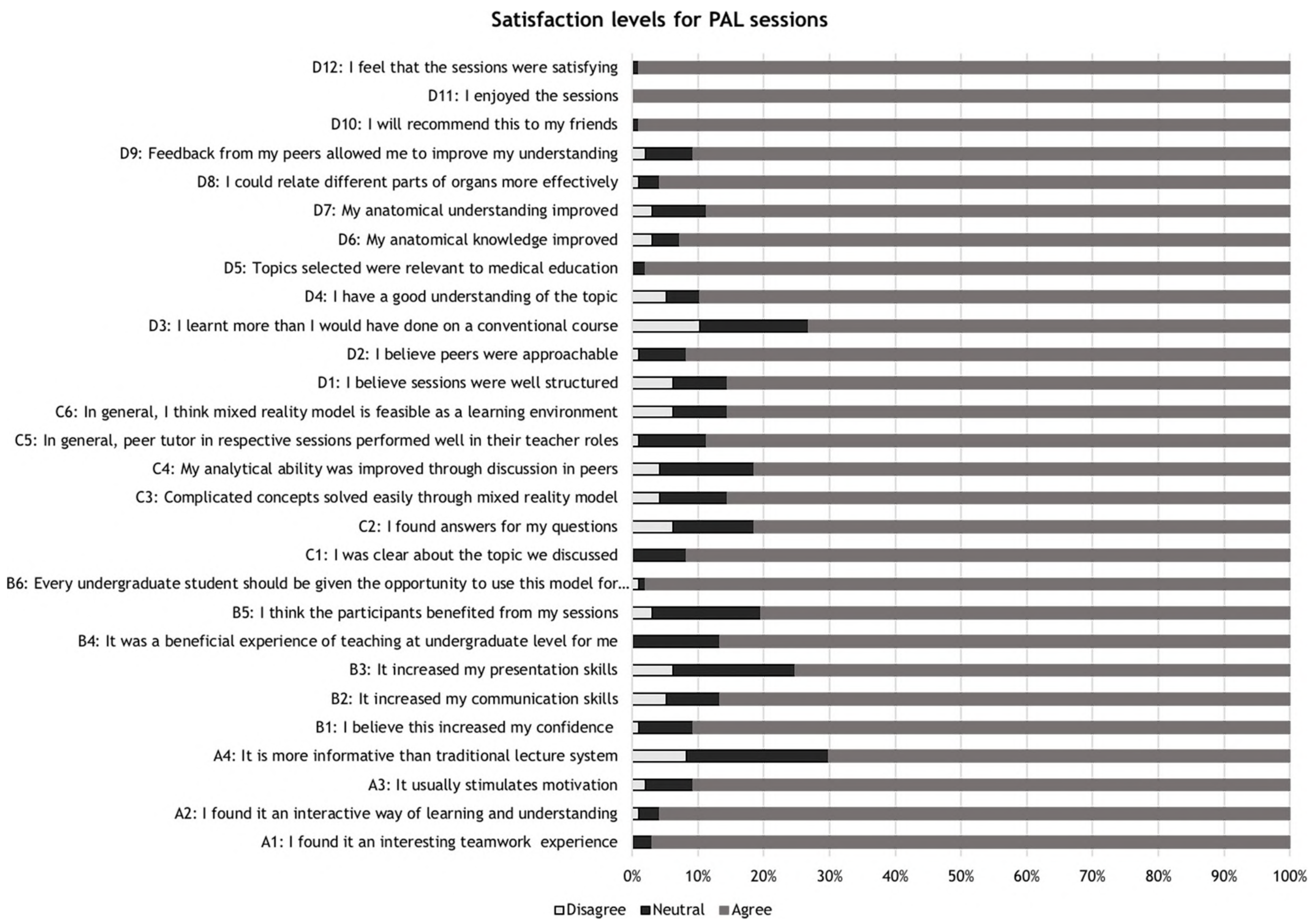

Fig. 1.- Satisfaction level of all the participants in terms of PAL questionnaire.

Table 1. Item wise analysis of PAL questionnaire showing the mean values ± standard deviation for each item.

	As a peer Group	**Mean** ± SD
A1	I found it an interesting teamwork experience	4.49±0.56
A2	I found it an interactive way of learning and understanding	4.56±0.69
A3	It usually stimulates motivation	4.31±0.74
A4	It is more informative than traditional lecture system	4.05±1.03
	As a peer tutor	
B1	I believe this increased my confidence	4.36±0.64
B2	It increased my communication skills	4.24±0.82
B3	It increased my presentation skills	4.08±0.89
B4	It was a beneficial experience of teaching at undergraduate level for me	4.34±0.69
B5	I think the participants benefited from my sessions	4.16±0.81
B6	Every undergraduate student should be given the opportunity to use this model for learning	4.65±0.56
	As a Tutee	
C1	I was clear about the topic we discussed	4.42±0.64
C2	I found answers for my questions	4.10±0.85
C3	Complicated concepts solved easily through mixed reality model	4.16±0.85
C4	My analytical ability was improved through discussion in peers	4.04±0.75
C5	In general, peer tutor in respective sessions performed well in their teacher roles	4.24±0.65
C6	In general, I think mixed reality model is feasible as a learning environment	4.16±0.82
	Evaluation and feedback	
D1	I believe sessions were well structured	4.21±0.82
D2	I believe peers were approachable	4.32±0.64
D3	I learnt more than I would have done on a conventional course	4.08±0.94
D4	I have a good understanding of the topic	4.13±0.78
D5	Topics selected were relevant to medical education	4.52±0.62
D6	My anatomical knowledge improved	4.45±0.66
D7	My anatomical understanding improved	4.34±0.72
D8	I could relate different parts of organs more effectively	4.51±0.63
D9	Feedback from my peers allowed me to improve my understanding	4.32±0.65
D10	I will recommend this to my friends	4.56±0.63
D11	I enjoyed the sessions	4.65±0.48
D12	I feel that the sessions were satisfying	4.53±0.52

2). The median ± IQR of responses to questions in the “strongly agree” category for first-year students in Medical school A was 11±4.75 while for second-year it was 12±3.75. Similarly, for first and second-year students of medical school B, the median and IQR were computed to be 11.50±5.5 and 7.2±3, respectively. Since only first-year students of medical school C took part in the project, their median and IQR values were 5.50±4.75. Interestingly, the median responses were consistently zero across all medical schools for the strongly disagree category. When the data from all medical schools were pooled together, the median and IQR values for the “strongly agree” category were found to be 42±18 while for the “agree” category it was 43±11.

The PAL questionnaire also contained two open-ended questions inquiring about the strength and a suggestion regarding this novel experience. Although the responses were not assessed qualitatively, some of the students made interesting comments and recommendations.

Question	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
A1	0	0	3	41	53
A2	0	1	3	33	60
A3	1	1	7	46	42
A4	2	6	21	26	42
B1	0	1	8	43	45
B2	0	5	8	43	41
B3	0	6	18	39	38
B4	0	0	13	40	45
B5	0	3	16	46	32
B6	0	1	1	29	66
C1	0	0	8	40	49
C2	0	6	12	45	34
C3	2	2	10	47	36
C4	0	4	14	55	25
C5	0	1	10	47	39
C6	2	4	8	51	32
D1	0	6	8	48	35
D2	0	1	7	49	41
D3	0	10	16	38	35
D4	0	5	5	56	31
D5	0	0	2	35	61
D6	1	2	4	46	45
D7	0	2	8	40	46
D8	0	1	3	36	57
D9	0	2	7	48	40
D10	0	0	1	32	64
D11	0	0	0	34	63
D12	0	0	1	43	53

Fig. 2.- Heat-map of responses from all three medical schools, where shades in red indicate disagreement while those in orange are neutral responses.

In the strengths section, one of the students commented that he/she was able to appreciate those anatomical structures which were difficult to study through 2D. Another student stated that *"It improved our confidence level and increased our presentation skills"* while some students found it interesting and enjoyable. As far as the recommendations were concerned, one of the students suggested that *"Histological features should be included"*, while the other stated that *"More labeling should be added".* One of the students found Goggles a bit heavy.

Relationship of gender and year of study with mixed reality satisfaction

The mean level of satisfaction for mixed reality model among males was 85.84% compared to 86.66% among females, with no significant difference between genders (*p=0.34*, independent sample t-test). However, the year of the study was significantly associated with satisfaction level, with second-year students showing significantly more satisfaction (88%) than first-year students (85%) (p=0.03).

Relationship of medical schools with mixed reality satisfaction

The level of satisfaction for the mixed reality model also differed significantly among the medical schools (p=0.000, ANOVA). Pairwise comparisons in post-hoc revealed that there was no statistically significant difference between medical school A and B (p=1.00). However, there was a statistically significant difference between medical schools A (87%) and C (80%) (p=0.000) and medical school B (88%) and C (80%) (p=0.000).

DISCUSSION

The 21st century has shown an explosive advancement in the medical field. Because of continual update and discovery of newer treatments and diagnostic testing, there is an increased burden on the new generation doctors to constantly learn and enhance their skills (McLachlan and Patten, 2006). This has added an immense cognitive load on medical students to not only remember but also apply knowledge learned in their initial years of medical school later to their work place. This study of ours was an effort to evaluate whether innovative teaching and learning strategies can be of some assistance to the students facing the aforementioned challenges (Yousafzai et al., 2018). Interestingly, these approaches are not new, as the advanced techniques employed in other fields, such as simulators used by the aviation industry, are now being used to simulate real surgeries for doctors. Still, it is quite challenging to develop engaging learning environments that are user-friendly and support the learning requirements of professional students (Salem et al., 2020). Advances in simulation technology, however, have led to a paradigm shift where learners have reportedly enjoyed their learning through these gadgets. Similarly in our study, the high level of satisfaction seen indicates the acceptability of the tool for learning anatomy. Although some students rated the traditional lecture system better than the new innovative approach as novel strategies take a while to be accepted and implemented (Ali and Evans, 2013), a great majority of them (~70%) regarded the mixed reality mode of teaching as more informative than the traditional methods. This was supported by a study on the undergraduate pharmacy students (Salem et al., 2020). The novelty of the idea and the fun element of a gaming modality may be one of the reasons for the higher acceptance by the students (~86%) as the PAL questionnaire item "I enjoyed the session" received a 100% positive response. A review published in 2017, suggested computer-assisted learning (CAL) as a partial replacement of dissection to enhance student learning, though total replacement still requires more in-depth studies (Losco et al., 2017). Birbara et al. (2020) carried out a pilot study on anatomy students and their tutors by comparing their perceptions regarding the use of less and more immersive virtual reality methods. Although, the students found virtual-reality-based methods engaging, some experienced these methods mentally taxing. Conversely, in our study, 97% of the students regarded mixed reality as an interesting experience that every undergraduate student should undergo. A similar observation was made when the educational efficacy of the virtual-reality skull model was compared with that of cadaveric skulls and atlases, where participants found the VR model as efficient as the cadaveric skull and more effective than the 2D atlases (Chen et al., 2020).

Apart from a novel teaching tool, we also tested the effectiveness of PAL approach, which is regarded as an interactive student-centered learning method (Ali and Evans, 2013). PAL or even (near-) peer teaching programs have proven to enhance all three learning domains (Bulte et al., 2007; Secomb, 2008). PAL approach was used to inculcate not only a collaborative approach among students but we also wanted to determine whether the PAL would befit mixed reality model, which was evident as the students expressed maximum satisfaction as a peer group. A qualitative study carried out to assess the experience and motivation of the lab tutors showed similar results (Bugaj et al., 2019). The students displayed great passion and motivation as peer teachers owing to the likelihood of developing their skills and knowledge simultaneously.

Although a great majority of our study participants were female (71%), we did not see any gender predisposition (p=0.34). A similar observation was made on university students regarding the adoption of augmented reality (Cabero-Almenara et al., 2019). These results were interesting in a way that they negated the ideology of the gender-based digital divide (Hohlfeld et al., 2013), and advocated the concept of gender equality in technology literacy (Felnhofer et al., 2012). Interestingly, second-year students showed a greater degree of satisfaction as compared to first-year students (p=0.03). This may be attributed either to their higher cognitive ability as compared to their junior peers, or more self-confidence owing to the greater amount of time spent within the same academic environment. Since this was a preliminary study, we further intend to undertake a randomized trial to directly compare the satisfaction levels between traditional methods and mixed-reality model and to assess the in-depth effects of mixed-reality models on learning, skills, and behavior of the medical students.

CONCLUSION

In the present study, the students appear satisfied with the mixed reality model using the PAL approach as learning and teaching tool. This not only complements the existing body of knowledge by signifying the importance of new innovations in anatomy education, but also shows higher satisfaction and acceptance by the students towards the novel methods. Such new innovative methods would need time to develop and therefore should undergo continuous evaluation by using higher levels of the Kirkpatrick model of program evaluation.

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