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Using project-based learning to enhance curricular integration and relevance of basic medical sciences in pre-clerkship years

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ABSTRACT

Achieving high levels of integration in the basic medical sciences' curricula is challenging. Project-based learning (PtBL) is an inquiry-based learning approach that can be used in multiple educational contexts with various designs. We used PtBL to enhance curricular integration during the pre-clerkship years. The study was done at The Faculty of Medicine, Helwan University, Cairo, Egypt. We designed interdisciplinary clinically relevant integrated research project tasks. Tasks followed curricular objectives. Students worked in teams to write and deliver project reports. Based on their understanding of the basic medical sciences, they analyzed the assigned tasks and used reasoning to create diagnoses. They related the condition to the disrupted normal structure/functions, suggested/contraindicated specific treatment and preventive plans. A cross-sectional survey was introduced to assess students' perceptions of the learning approach used. Response rate was 52% (n = 694). Students' responses were analyzed. Most students (84.6%) were satisfied by the integrated interdisciplinary PtBL. They (57.9%) preferred substituting the traditional lectures completely by it. Students understood the relation between objectives of disciplines after PtBL completion (mean 3.66, SD ±0.92) higher than before it (mean 3.46, SD ±0.91), (P = 0.000). Students' ranking for the degree of integration between basic/clinical sciences in the PtBL was significantly associated with the developed clinical reasoning rank (P = 0.000). It was also associated with responses supporting the future implementation of the PtBL again (P = 0.002). Various ways of adding PtBL approach to the curricula were suggested. The PtBL can be used as a complementary learning method to elevate the level of integration within a multidisciplinary approach to boost students' learning.

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1. Introduction

Medical schools are on different integration levels on Harden's ladder[1]. Many schools face a lower integration level in the basic medical preclinical years. Students also do not fully appreciate the relevance of this academic phase to clinical practice due to little clinical data integration. The basic years' curriculum in the Faculty of Medicine, Helwan University, is mainly multidisciplinary with some interdisciplinary themes.

Project-based learning (PtBL) is an inquiry-based learning approach grounded on constructivism theory [2,3]. It is a student-centered collaborative form of instruction that is context specific, interactive, and starts with a problem(s) that should be relevant to real world[4]. It is simply based on the concept of learning by doing. In this learning approach, students combine their previously acquired knowledge, skills, and experience with the new activities they do to find the solution to a given problem[5]. Students acquire new knowledge, skills, and experiences through engaging in solving the introduced problem/challenge. This type of learning requires social interaction for

experience exchange, so students work in small teams[4]. Students are required to construct an end product to complete their project. The product form may vary according to the nature of the project. It may be a report, presentation, video, photos, models, or any other appropriate product[3]. Project-based learning can be facilitated by using digital technology[6]. Digital methods have proved more engaging and feasible in medical education and result in better learning outcomes [7,8]. The PtBL creates a challenging learning environment for students resulting in more engagement[9].

The benefits of using the PtBL approach in higher education are documented[9]. Using PtBL to improve undergraduate medical education has started to be investigated and initially reported good results [10–13]. However, since PtBL is context-specific, its design varies according to the setting and purpose of its use.

To increase the level of integration in the basic years and increase the relevance of the curriculum for students, we adopted a project-based approach. Our purpose was to boost students' learning in pre-clerkship years through enhancing the integration

levels between basic sciences together, and between basic and clinical disciplines. Also, to evaluate and upgrade our curriculum to achieve a higher level of integration in the next years, based on the needs discovered while linking various disciplines' objectives during the process of preparing these research project tasks. We assessed students' perceptions of the approach used.

Our research results can be of help for any medical school that is still at a multidisciplinary-level integration in the pre-clerkship years in national, regional, or international learning context.

2. Materials and methods

2.1. The context

The study was carried out on phase 1 medical students (first – and second-preclinical years) in the Medical School of Helwan University, a public university in Egypt. It was carried out between February and June 2020. The first 2 years are mainly concerned with teaching basic medical sciences (pre-clinical, phase 1). We carried out our approach at the end of two modules in year 1; gastrointestinal (G.I.T.) and Locomotor, and two modules in year 2; Genitourinary and Blood/Endocrine. All lectures, practical lessons, and problem-based learning (PBL) sessions were given online before assigning the projects' tasks.

2.2. The tool used

Project-based learning was used to increase the level of integration in the basic years and increase the relevance of the curriculum for students. We designed “Clinically-applied Team-based integrated research projects” tasks for students for four modules in the first two academic years. The level of integration in the tasks was interdisciplinary.

The authors volunteered to review the modular curricula and design a wide variety of interdisciplinary-integrated project' topics (cases/symptoms/signs) that followed each module's objectives (40–65 tasks/module). Disciplines' instructors modified the tasks to suit the intended learning outcomes.

Each research project topic is a designed case/symptom/sign that integrates all disciplines represented in the module. Students were requested to discuss with each other, search through their books, previously studied material, and online to write an integrated report on the task. Students had to analyze the topic of the task and use clinical reasoning to create a reasonable differential diagnosis and/or a provisional one based on their understanding of the sciences of diseases in the preclinical phase (e.g. pathology). The students are required to discuss and relate the condition to the normal bases that were disrupted (i.e. anatomy, histology, physiology,

and biochemistry). Besides, they had to discuss/suggest/contraindicate specific treatment plans (i.e. pharmacology), as well as create a preventive plan (i.e. epidemiology) whenever possible.

Students were divided into teams each is formed of five members. The evaluation rubrics and the project requirements were clear to students and evaluators at the beginning of implementation. Instructors responded to the students' inquiries. Students uploaded their finished tasks to their learning management system (LMS) before the announced due dates.

2.3. Study design and implementation

To assess students' perceptions on the tool used, the study employed a cross-sectional design. After the students delivered their projects, their perceptions were evaluated. An online survey created on Google Forms was administered on the students' Learning management system. Students were asked to voluntarily participate in it.

The survey was self-structured to assess the expected learning outcomes (higher integration, developed skills, better learning experience ... etc.). It consisted of a descriptive 16-item questionnaire regarding the students' perceptions on the impact of the PtBL approach used. Responses were on closed-ended yes/no questions and a 5-point Likert scale (1: extreme negative response, and 5: extreme positive response)[14]. Adding open-ended written feedback was optional for which breakdown analysis was done.

Before the wide dissemination of the survey to the target population, it was first sent to two experts in medical education for revision and validation, and then slight modifications were done based on their opinions, regarding the phrasing and structure of questions. The survey was also piloted on 30 students. The survey items were internally consistent as the calculated Cronbach's alpha for the closed-ended questions was 0.77.

2.4. Population

The study population were medical students in the first – and second years at Helwan University. The total number of students on which the survey was distributed was 1334. A convenience sample was done as students filled in the survey according to their willingness to do so. Inclusion criteria were being a current first- or second-year medical student in the faculty that completed the required tasks and agree to participate in the survey. Exclusion criteria were students who did not deliver the projects' tasks. Response rate was 52%.

2.5. Data collection

The survey data were collected on Excel spreadsheets. Data about missing topics that need to be added to the modular curriculum and topics that can be involved in

more interdisciplinary themes were collected and written in a report during the process of the curricular review for tasks' design.

2.6. Statistical analysis

The survey data were analyzed using IBM-SPSS (Statistical Package for Social Sciences) Version 25.0; Chi-square and t-tests were used to compare were used to compare qualitative and quantitative variables, respectively. Z-tests were used to compare proportions. The level of significance was $P < 0.05$. Cronbach's alpha test was used to analyze the internal consistency of the survey items, and a value >0.7 is considered internally consistent. Shapiro–Wilk test was performed and revealed normally distributed data.

2.7. Ethical approval

The study complied with Helwan University Ethics Committee Guidelines for research with humans and has been approved by the Helwan University Ethics Committee (Serial number: 48–2020), organized, and operated according to the declaration of Helsinki 1975. Participants gave their consent electronically before starting to respond to the survey questions by answering a question at the beginning of the survey taking participants' consent to participate in the study by "Yes." Participants acknowledged that they could not be identified via the paper, and that they had been fully anonymized in the research.

3. Results

Some deficient basic sciences topics in the modular curricula, which need to be added by the disciplines to complete a picture relevant to the clinical application, were discovered during the projects' topics design, as well as reported by students in their written feedback. Also, some objectives were being educated separately although they can be related to other disciplines in an interdisciplinary approach. A report was written on deficiencies and suggestions to be discussed, modified, and implemented in the future curriculum.

Regarding the survey responses, 694 students of phase 1 (first and second years) medical students participated in the study. They represented 52% of the total phase 1 students. Students' age range was between 17 and 19 years. Demographic data of study participants are shown in (Table 1).

Most students (84.6%, $n = 587$) preferred doing one integrated interdisciplinary PtBL task instead of multiple separate tasks in all disciplines. Students ranked their perceived level of connection between disciplines before and after implementation of the PtBL in the survey. Students appreciated the connection between

Table 1. Demographic data of study participants.

Character	No.	%
Academic year		
First	408	58.8
Second	286	41.2
Gender		
Male	361	52
Female	333	48
High school background		
Egyptian high-school education (Thanaweya Amma)	410	59.1
IGCSE	52	7.5
American diploma	17	2.4
Stem	13	1.9
Arabic non-Egyptian	193	27.8
Other international certificates	9	1.3
Academic performance (Grade)		
A	269	38.8
B	182	26.2
C	86	12.4
D	34	4.9
F	56	8.1
Postponed previous exams	67	9.7
Total	694	100

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disciplinary objectives of their tasks higher (mean 3.66, $SD \pm 0.92$) after doing the PtBL required tasks compared to before it (mean 3.46, $SD \pm 0.91$), ($P = 0.000$) using the paired t-test. The level of integration between disciplines in the tasks varied in the four modules; the very good and excellent ranking for integration between basic sciences ranged between 35.2% ($n = 244$) to 85.9% ($n = 596$) and for basic/clinical integration between 33.3% ($n = 231$) to 78.8% ($n = 547$). Overall, most students (60.6%, $n = 420$) ranked their appreciation of the relationship between all basic sciences in each research topic by ranks 4 and 5, and 56.1% ($n = 389$) ranked the relation between basic and clinical sciences through the integrated research tasks by ranks 4 and 5 (Tables 2 & 3).

Most students (57.5%, $n = 399$) ranked their developed reasoning skills by the PtBL experience as ranks 4 and 5. Results were significantly related to the perceived degree of basic and clinical sciences integration in the tasks ($P = 0.000$) (Tables 3 & 4).

Most of the students (76.2%, $n = 529$) perceived their level of developed teamwork skills by the PtBL tasks used as ranks 5 and 4. Most students (80.4%, $n = 558$) preferred to do the task in a team. On a range of 1 to 10 members, most students preferred teams formed of 5 members (64.9%, $n = 452$). Also, most students (74.1%, $n = 514$) ranked their perceived level of developed research skills as ranks 4 and 5 (Tables 2 & 3).

Most students (59.5%, $n = 413$) recommended making a short presentation by each team for the prepared PtBL task to be discussed in front of all other students to expand the benefit. They preferred learning by integrated cases with all topics included like the PtBL experience (57.9%, $n = 402$) over the traditional disciplinary lectures (Table 2).

Table 2. Students' responses to the survey questions measuring their learning preferences regarding the Project-based learning approach used.

Survey item	No.	%
Do you prefer doing separate research tasks in each subject or one integrated research as you did?		
Separate research tasks	108	15.6
One integrated research	586	84.4
Do you prefer learning by explaining as in usual lectures or by explaining cases with all topics integrated like in the research?		
usual lectures	293	42.2
explaining in cases	401	57.8
Did you prefer to do the research individually or in a team?		
Individually	137	19.7
In a team	557	80.3
In your opinion, what was the suitable number of students that should form each team?		
1	137	19.7
2	5	0.7
3	23	3.3
4	36	5.2
5	450	64.8
6–10	40	5.8
Other	3	0.3
Generally speaking, do you suggest changing scoring of some tests/assignments as pass/fail instead of discriminative ranks?		
Yes	392	56.5
No	302	43.5
In future years, do you recommend making a short presentation by each team for the integrated research to be discussed in front of all other students to expand the benefit?		
Yes	414	59.7
No	280	40.3
In case integrated research tasks were used as a future method of learning, select most suitable approach		
For revision at the end of the module	163	23.5
Each case become the theme of the week and all subjects discuss it	203	29.3
As an assignment during the module	122	17.6
Cases discussed in integrated lectures	148	21.3
As part of the portfolio cases for self-learning	44	6.3
Other (please specify)	14	2.0
Total	694	100.0

No.: Number

Students' acceptance to future use of this PtBL was significantly related to their esteemed degree (i.e. ranking) of integration between basic and clinical sciences in the tasks ($P = 0.002$) (Table 5), but not to the degree of integration between basic sciences together.

Most students (66.2%, $n = 459$) were satisfied by ranks 4 and 5 on changing the scoring system to pass/fail instead of discriminative ranks in evaluating the projects. They (56.6%, $n = 393$) agreed to future changes in the scoring of some tests/assignments as pass/fail instead of discriminative ranks (Tables 2 & 3).

Methods of future learning through the interdisciplinary PtBL selected were: making these project themes for learning weeks; and with all disciplines discussing a task each week (29.3%, $n = 203$). Also, assigning these tasks at the end of the module as a method for concluding work and revision (23.5%, $n = 163$). Some students (21.3%, $n = 148$) preferred the discussion of the topics in integrated lectures (21.3%, $n = 148$). Others (17.6%, $n = 122$) preferred making the integrated interdisciplinary task assignments during the modules (Table 2).

4. Discussion

In our study, we implemented PtBL by assigning "clinically-applied team-based integrated research project tasks" students in the pre-clerkship years studying basic medical sciences. A cohort of 694 students shared their perceptions of the PtBL used. Most were satisfied by implementing the one integrated interdisciplinary research project task, team-based work with five members in each team, and the pass/fail scoring system. A significant relation was detected in the students' ranking of the relation between the task's disciplinary objectives after completing it compared to before it, and between the integration with clinical sciences on one side, and both the developed clinical reasoning and the students' choice of implementing future teaching via the integrated project tasks on the other side.

Project-based learning (PtBL) is an inquiry-based approach based on constructivism theory[2]. It is sometimes confused with problem-based learning (PBL) and some even put the same abbreviation PBL for both. Both are applied to small students' groups,

Table 3. Students' ranked perceptions of the Project-based learning approach used Survey Item.

	Rank*									
	1		2		3		4		5	
	No.	%	No.	%	No.	%	No.	%	No.	%
Developed student's clinical reasoning skills	21	3.0	70	10.1	204	29.4	256	36.9	143	20.6
The appreciated relation between basic sciences and their clinical application	17	2.4	62	8.9	226	32.6	256	36.9	133	19.2
The appreciated relation between all basic sciences	15	2.2	47	6.8	212	30.5	286	41.2	134	19.3
Developed research skills	6	0.9	8	1.2	166	23.9	369	53.2	145	20.9
Developed teamwork skills	57	8.2	22	3.2	106	15.3	244	35.2	265	38.2
Satisfaction on changing the scoring system to pass/fail instead of discriminative ranks	31	4.5	42	6.1	161	23.2	187	26.9	273	39.3
The degree of integration between the disciplines involved in the students' tasks before doing the task	17	2.4	69	9.9	268	38.6	258	37.2	82	11.8
The degree of integration between the disciplines involved in the students' tasks after finishing the task	14	2.0	49	7.1	221	31.8	286	41.2	124	17.9

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Table 4. The relationship between students' rank of appreciated link of basic to clinical and the perceived rank for developed clinical reasoning skill.

			Rank of developed clinical reasoning skill					Total
			1	2	3	4	5	
Students' rank of appreciated link of basic to clinical	1	No.	6	7	2	1	1	17
		%	0.9%	1.0%	0.3%	0.1%	0.1%	2.4%
	2	No.	7	25	15	14	1	62
		%	1.0%	3.6%	2.2%	2.0%	0.1%	8.9%
	3	No.	3	23	124	63	13	226
		%	0.4%	3.3%	17.9%	9.1%	1.9%	32.6%
	4	No.	3	14	56	140	43	256
		%	0.4%	2.0%	8.1%	20.2%	6.2%	36.9%
	5	No.	2	1	7	38	85	133
		%	0.3%	0.1%	1.0%	5.5%	12.2%	19.2%
Total		No.	21	70	204	256	143	694
		%	3.0%	10.1%	29.4%	36.9%	20.6%	100.0%

P = 0.000 (Chi Square Tests)

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and both start with a problem. However, the focus of the PtBL approach is to make learners construct a product, while the problem-based learning focus is to make learners study. In PtBL, the teacher role is only advisory when needed, not a facilitating role present in the whole session like in PBL. As a result, learners in PtBL have more control over the learning process. Problem-based learning also has certain methods/steps of application that require to be followed, while PtBL is more flexible[15].

Our approach has proved helpful for learning. Project-based learning research experience is well perceived by students in other studies[13]. In medical education, it was also used to increase medical students' empathy, teach medical bioethics, and microbiology[10–12].

Harden (2000) [1] proposed 11 levels of integration simulating the steps of the ladder. The higher the ladder step, the higher the integration level of the curriculum. He describes the multidisciplinary approach to integration (Step 9) as bringing disciplines together around themes. He proposed that themes can be certain clinical conditions or body

systems. Interdisciplinary integration (Step 10) is a higher level of integration in which no disciplinary boundaries are obvious. Disciplines melt into each other in the course. Multidisciplinary curricula that are organized around body systems require effort to organize the disciplines within each system in a careful way to avoid reverting to a lower level of integration inside the system. For example, in the G.I.T. body system, disciplines should be organized around the esophagus, around the stomach, around the liver, etc. Teaching every discipline on its own within the body system without good organization with other disciplines decreases the level of integration. Multidisciplinary curricula differ in the organization of their disciplinary content. Melting disciplines together in projects inside a multidisciplinary curriculum takes a further step toward interdisciplinary integration. Based on this experience, the degree of integration within the body system modules was variable from one module to another. This affected the degree of integration within our project tasks. Students' ranking of the level of integration achieved between all basic sciences together, and between basic and clinical sciences in the objectives of each research topic was 4 and 5 in 60.6%, and 56.1%, respectively, as perceived by students. These objectives were following the preset curricular objectives. Curriculum revision is needed to adjust the preset objectives and increase the integration level both vertically and horizontally.

Potentiating the link between basic sciences together, on the one hand, and between the basic and clinical sciences, on the other hand, helps develop clinical reasoning skills in students starting from basic sciences years [16]. Medical students are aware of the aim of the educational reform and are more willing to higher levels of integration; they preferred doing one integrated research task in each module instead of multiple separate tasks in each discipline. The perceived degree of integration between disciplines also significantly affected the perceived levels of developed clinical thinking (reasoning) skills. Other authors concluded similar results[17].

Table 5. The relationship between students' responses regarding future learning by the integrated research method and the degree of perceived integration between basic and clinical sciences in the case.

		Future learning in integrated cases as in research		Total	
		Future learning in integrated cases as in research	Usual learning		
Perceived rank for the link between basic and clinical sciences in the integrated research	1	No.	8	7	15
		%	1.2%	1.0%	2.2%
	2	No.	25	22	47
		%	3.6%	3.2%	6.8%
	3	No.	119	93	212
		%	17.1%	13.4%	30.5%
	4	No.	171	115	286
		%	24.6%	16.6%	41.2%
	5	No.	78	56	134
		%	11.2%	8.1%	19.3%
Total		No.	401	293	694
		%	57.8%	42.2%	100.0%

P = 0.002 (Chi-square tests)

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Percentage of students preferring future learning through cases with all topics integrated as in the research tasks instead of the multidisciplinary learning was significantly related to increasing the level of integration between basic and clinical sciences. Similarly, Senti et al. [18] showed the increased students interest, acquired knowledge, and skills of adopting basic/clinical integrated programs.

Semin et al. (2018) implemented a multidisciplinary case-based small group discussions to integrate basic medical sciences with clinical situations for 39 students in 5 body systems and found that 62% of students find the integrated cases useful for their learning[19]. They carried out discussions on 3 hours sessions and without enough prior knowledge for students and set the outcomes for each case. Compared to Semin et al. study, our study was carried out on a larger number of participants (694). Students had previous knowledge from all disciplines. We derived the projects topics (e.g. cases) from the curriculum that was targeted for evaluation and improvement to report the deficiencies present.

Yune & Jung (2018) [20] showed that students' academic performance significantly increased upon doing a curricular revision that enhanced integration between basic and clinical sciences in the pre-clerkship years. Deeper understanding with easier retrieval and transfer of basic medical knowledge happens better when linked to the clinical context[21]. This is also supported by the adult learning theory, which points out that adults are mostly engaged in learning subjects with immediate practical relevance[22].

The majority of students preferred to do the tasks in a team rather than individually. Five-members were the most reported suitable number for building a team. This number proved helpful in developing the academic research skills for postgraduates also [23]. The nature of scientific material educated seems to potentiate their tendency for teamwork[24]. Explaining the basics of effective teamwork at the students' admission and augmenting the clinical application in curricula may be considered.

Most students showed positive attitudes toward changing the scoring system to pass/fail instead of discriminative ranks. Moreover, most students agreed to the suggestion of future changing the scoring of some tests as pass/fail instead of discriminative ranks. The pass/fail scoring system resulted in a good performance and great satisfaction in other preclinical medical courses[25]. It exerts positive influences on learning by supporting students' psychological health and wellbeing[26].

Our study limitations include that no control group with academic performance was performed, being carried out in a single institution. In addition, only half of students responded to the survey and this renders the generalizability of the study doubtful.

5. Conclusion

The interdisciplinary PtBL can be used to enhance the integration level between disciplines in pre-clerkship medical years. Advantages include emphasizing the integration between basic sciences together and with clinical application, developing research, team-work, and clinical reasoning skills, which are needed for future medical practice. The team-based integrated research project tasks and the pass/fail scoring system are well perceived by students. Students' acceptance to future use of the interdisciplinary PtBL is related to their esteemed degree of integration between basic and clinical sciences in the projects' tasks. The process of preparation of the tasks helps the staff evaluate the curriculum and discover areas that need modifications for a higher level of integration.

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Data availability

The datasets generated and analyzed during the current study are available to the corresponding author upon request.

References

- [1] Harden RM. The integration ladder: a tool for curriculum planning and evaluation. *Med Educ.* 2000 Jul;34(7):551–557.
- [2] Loyens SMM, Rikers RMJP. Instruction based on inquiry. In: Mayer RE, Alexander PA, editors. *Handbook of research on learning and instruction.* New York: Routledge; 2011. p. 361–381.
- [3] Kokotsaki D, Menzies V, Wiggins A. Project-based learning: a review of the literature. *Improv School.* 2016;19(3):267–277.
- [4] Indrawan E, Jalinus N, Syahril S. Review project based learning. *Int J Sci Res (IJSR).* 2019;8 1014–1018 .
- [5] Hanney R. Doing, being, becoming: a historical appraisal of the modalities of project-based learning. *Teach Higher Educ.* 2018;23(6):769–783.
- [6] Safaruddin S, Ibrahim N, Juhaeni J, et al. The effect of project-based learning assisted by electronic media on learning motivation and science process skills. *Journal of Innovation in Educational and Cultural Research.* 2020;1:1.
- [7] Wassef R, Elkhamisy F. Evaluation of a web-based learning management platform and formative assessment tools for a medical parasitology undergraduate course. *Parasitologists United Journal.* 2020;13(2):99–106.
- [8] Elkhamisy FA, Wassef RM. Innovating pathology learning via kahoot! game-based tool: a quantitative study of students' perceptions and academic performance. *AJM.* 2021;[in print] ID:1954413.
- [9] Guo P, Saab N, Post LS, et al. A review of project-based learning in higher education: Student outcomes and measures. *Int J Educ Res.* 2020;102. DOI:10.1016/j.ijer.2020.101586
- [10] Nerurkar AB, Dhanani JV. Effectiveness of project based learning in teaching microbiology to undergraduate medical students. *IOSR-JRME.* 2016;6(5):19–22.
- [11] Mateo E, Sevillano E. Project-based learning methodology in the area of microbiology applied to undergraduate medical research. *FEMS Microbiol Lett.* 2018;365:13.
- [12] Kim K-J. Project-based learning approach to increase medical student empathy. *Medical Education Online.* 2020; 25(1):1742965. DOI:10.1080/10872981.2020.1742965 Accessed 1 Nov 2020
- [13] Si J. Course-based research experience of undergraduate medical students through project-based learning. *Korean J Med Educ.* 2020;32(1):47–57.
- [14] Likert RA. Technique for the measurement of attitudes. *Arch Psychol.* 1932;22:5–55.
- [15] Bédard D, Lison C, Dalle D, et al. Problem-based and project-based learning in engineering and medicine: Determinants of students' engagement and persistence. *Interdisciplinary Journal of Problem-Based Learning.* 2012;6:2.
- [16] Hege I, Kononowicz AA, Berman NB, Lenzer B, Kiesewetter J. Advancing clinical reasoning in virtual patients – development and application of a conceptual framework. *GMS J Med Educ.* 2018;35 (1):2366–5017. DOI:10.3205/zma001159 Accessed 8 Jan 2021
- [17] Cate O, Custers EJ, Durning SJ, editors. *Principles and practice of case-based clinical reasoning education innovation and change in professional education.* Switzerland: Springer; 2018. DOI:10.1007/978-3-319-64828-6_10
- [18] Sentí M, Miralles R, Bigorra J, et al. A collaborative project to bridging the gap between basic and clinical teachers: the opinion of medical students. *J Biomed Edu.* 2015;2015:Article ID 620348.
- [19] Semin I, Soysal D, Çelik Y, et al. Multidisciplinary case-based small group discussions to integrate basic medical sciences with clinical situations *Turkish Journal of Biochemistry .* 2020 000010151520190184 doi:10.1515/tjb-2019-0184 Accessed 10 Jan 2021 .
- [20] Yune SJ, Jung JS. Changes of academic performance by integration between basic and clinical medicine in pre-clerkship medical education. *Korean J Med Educ.* 2018;30(3):209–218.
- [21] Bransford JD, Brown AL, Cocking RR. *How people learn: brain, mind, experience, and school: expanded edition.* Washington: National Academy Press; 2000.
- [22] Taylor DC, Hamdy H. Adult learning theories: implications for learning and teaching in medical education: AMEE guide no. 83. *Med Teach.* 2013 Nov;35 (11):e1561–72.
- [23] Madariaga MG, Evans AT, Brobbey W, et al. Learning by doing: developing fellows' academic skills through collaborative research. *Med Teach.* 2006;28(1):77–80.
- [24] Aarnio M, Nieminen J, Pyörälä E, et al. Motivating medical students to learn teamwork skills. *Med Teach.* 2010;32(4):e199–e204.
- [25] Bloodgood RA, Short JG, Jackson JM, et al. A change to pass/fail grading in the first two years at one medical school results in improved psychological well-being. *Acad Med.* 2009;84(5):655–662.
- [26] Yusoff M. Associations of pass-fail outcomes with psychological health of first-year medical students in a Malaysian medical school. *Sultan Qaboos Uni Med J.* 2013;13:107–114.