Original article

Development and validation of Manipal Inventory for Curriculum Evaluation (MICE): A comprehensive tool for evaluation of hybrid medical curriculum

Short title: Development and validation of MICE

Asha Vashe[1], Vasudha Devi[2], Vinod Pallath[3], Reem Rachel Abraham[4], Asha Kamath[5]

Abstract:

Background: In outcome-based education, the components of the curriculum must facilitate the students to attain expected outcomes. Hence, it is imperative to evaluate the components of the curriculum. ***Objective:*** The study aimed to develop and validate a comprehensive questionnaire, Manipal Inventory for Curriculum Evaluation (MICE) to evaluate the outcomes of a hybrid physiology curriculum. ***Methods:*** The development and validation of the questionnaire consisted of three stages. The first stage comprised generation of items through literature survey. A three-round modified Delphi technique was used in the second stage to gain consensus across the eleven panel members about the items in the questionnaire. The resulted questionnaire was administered to volunteers from first year undergraduate medical students which comprised the third stage. Principal Component Analysis with Varimax rotation and Kaiser Normalization, and Chronbach's alpha were performed to analyze the data. ***Results:*** The preliminary questionnaire had two sections; section one had forty seven items, and section two had six items. After the Delphi rounds, the first section had only forty three items, however, there were no changes in the second section. Factor analysis of the first section resulted in seven factors. One item did not load on any of the components, and hence it was dropped from the questionnaire. Overall reliability was found to be 0.898 for Cronbach's alpha. ***Conclusions:*** The questionnaire MICE was developed with two sections, one focusing on overall curriculum and the other on outcomes. On validation, it was found that the questionnaire had acceptable levels of validity and reliability.

Keywords: Curriculum evaluation; physiology; medical curriculum; medical students; questionnaire development

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Introduction:

The quality of an educational system in an input-based education is primarily determined by three parameters: inputs, processes, and outputs produced by the system. The inputs are mainly the resources such as finances, infrastructure, and other assets required for teaching and learning. The processes will dictate what needs to happen within the system and are mainly used to organize, control, and deliver curriculum to facilitate learning. The outputs are the products or results of providing such education.[1,2] However, in recent years there is a paradigm shift

1. Dr Asha Vashe, Division of Physiology, Department of Basic Medical Sciences, Manipal Academy of Higher Education, Manipal, India.
2. Dr Vasudha Devi, Department of Pharmacology and Centre for Cardiovascular Pharmacology, Kasturba Medical College, Manipal, Manipal Academy of Higher Education, Manipal, India-576104.
3. Dr Vinod Pallath, Medical Education and Research Development Unit, Faculty of Medicine, Universiti Malaya, Kuala Lumpur, Malaysia.
4. Dr Reem Rachel Abraham, Department of Physiology, American University School of Medicine Aruba (AUSOMA), Wilhelminastraat 59, Oranjestad, Aruba.
5. Dr Asha Kamath, Department of Data Science, Prasanna School of Public Health (PSPH), Manipal, Manipal Academy of Higher Education, Manipal, India.

Correspondence: Dr. Vasudha Devi, Deputy Director, Centre for Doctoral Studies, Directorate of Research, Associate Professor of Phatmacology, Coordinator, Centre for Cardiovascular Pharmacology, Kasturba Medical College, Manipal, Manipal Academy of Higher Education, Manipal, Karnataka, India-576104, Email: vasudha.devi@manipal.edu

in the above philosophy, and there is an increasing emphasis on outcome-based education (OBE), wherein, the focus is on the attainment of outcomes rather than the inputs and processes. In OBE, the inputs and processes are enablers of the outcomes and are controlled to achieve the stated outcomes.[3,4] Hence, the curriculum in OBE is designed with a top-down approach with the outcomes to be achieved as the primary focus.[4,5]

Curriculum should be a blend of learning outcomes, course content, educational strategies, assessment, and the overall educational environment.[6] Moreover, it is necessary that the components of the curriculum, which are vital for achieving the outcomes, should be chosen to support the students to attain the expected outcomes.[3] Therefore, it is essential to know if curriculum in general and the components of the curriculum in particular are facilitating in achieving the expected outcomes. This crucial information or feedback on the curriculum can be obtained by curriculum evaluation.[7] Furthermore, another key factor in OBE is a continuous quality improvement which is accomplished by collecting evidence for the attainment of the outcomes.[8] Therefore, it is important to have formal mechanisms put in place to evaluate the curriculum and ensure its effectiveness.

As per Prideaux,[9] evaluation is assessing the design, implementation, and outcomes of a program by systematic application of scientific methods. Evaluation is also concerned with deciding on the value of a learning process and the effectiveness with which it is being carried out[10] and hence, it needs to focus on the process and outcomes of the program. One way of conducting evaluation is by gathering relevant information from the stakeholders using an appropriate questionnaire that is purposeful, reliable, and valid.[7,11] Such a questionnaire plays a vital role in curriculum evaluation and needs to be developed for the program based on the established theoretical framework and systematic process.

The OBE is based on the belief that schools and teachers regulate the conditions that decide whether or not students are successful in school learning.[5] As per Spady[5] learning is not significant unless the outcomes reflect their deep learning and are able to apply in their career after they have completed their formal education. It is reported that curriculum involving only didactic lectures lead to passive learning[12,13] whereas, curriculum which has additional components like problem based learning (PBL) helps promotion of deep learning.[14] Therefore, a hybrid curriculum is often used to promote deep learning which involves learning opportunities such as didactic lectures and PBL sessions. With the aim of promoting higher order thinking at Melaka Manipal Medical College (MMMC), Manipal, India, the hybrid curriculum is adopted which has didactic lectures, practical sessions, and PBL components. In addition, students are also exposed to self-directed learning (SDL) sessions to improve SDL skills. When the curriculum involves such multiple components it is all the more essential to evaluate their effectiveness in facilitation of expected outcomes. In the past, researchers have developed and used questionnaires to evaluate courses or specific programs.[11,15-18] However, as there was lack of questionnaires to evaluate the outcomes of a hybrid curriculum in the literature, a comprehensive questionnaire named Manipal Inventory for Curriculum Evaluation (MICE) was developed, which was the aim of this study. It was decided to use grounded theory to generate the items in the questionnaire. In this study, one course of MBBS program namely, physiology curriculum was chosen as a representative, and a questionnaire was developed to evaluate the physiology curriculum. However, care was taken to see that it could be used to evaluate other curricula as well by customizing them appropriately.

Materials and Methods:

A Delphi technique coupled with statistical validation was used to develop the questionnaire, MICE, and subsequently copyrighted for the authors.[19] The questionnaire was developed in three stages: 1) Item generation 2) Delphi technique to develop and determine content validity of the tool 3) Pilot study.

Stage 1: Item generation

The items were generated by the literature review and qualitative data gathered from first year MBBS students and teachers of physiology at MMMC Manipal. The items thus developed were reviewed and modified based on the relevance to physiology curriculum by the research team consisting of physiologists and medical educationists having teaching experience of more than five years.

Stage 2: Content validation

The Delphi technique utilized an expert panel to reach consensus for a particular purpose. In this study, a three-round modified Delphi technique was used to gain consensus across the panel members about the items in the questionnaire. The expert panel comprised eleven experts (including four international faculty members) with teaching and previous research experience in the area of medical education. Each member of the panel independently (without discussing or sharing with other panel members) responded to the questionnaire.

The members identified for the Delphi panel could be categorized into at least one of the following: physiology faculty member, medical education expert, and clinical faculty member with a minimum five years' experience. The members with the eligibility criteria listed above were invited to become part of the panel through mail or personally face to face. All participants were assured that anonymity would be maintained and an e-mail/written consent was obtained. The questionnaire, an outline of the research proposal, and a consent form were mailed to each panel member.

The panel was asked to rate each item using a Likert scale where a score of 0 = not necessary, 1 = desirable, 2 = important and 3 = absolutely essential so as to obtain the consensus. The panel members were also asked to modify, add new items, or give their remarks. The items with median score ≥ 1 were incorporated into the next round. Comments expressed by the panel members were noted, and the necessary modifications were done in the items after discussion with the research team. This questionnaire was evaluated again by the panel members and according to their suggestions, the questionnaire was modified for the third (final) round. In this round, the inclusion of items in the questionnaire was indicated through agreement or disagreement, or uncertainty. Panel agreement ≥ 75% was necessary for inclusion of the item into the final questionnaire.[20]

Stage 3: Pilot study

The questionnaire was administered to volunteers from first year MBBS students of MMMC who were admitted to the program in April 2015 and October 2015 respectively (n=275) to determine construct validity and internal consistency. Written informed consent was obtained from students before they responded to the questionnaire. The response received was completely anonymous.

Data analysis:

The data were recorded in SPSS version 15 and factor analysis was done to determine construct validity of the questionnaire. The factor analysis included Principal Component Analysis with Varimax rotation and Kaiser Normalization. The psychometric and interpretability criteria used in the factor analysis[21] are provided in the box. Cronbach's coefficient alpha was calculated to determine internal consistency.

Psychometric and interpretability criteria used in the factor analysis

Psychometric criteria:

- Point of inflexion on the Scree plot
- Eigenvalues > 1
- Proportion of variance accounted for is minimally approximately 5%

Interpretability criteria:

- At least 3 variables with a loading > 0.4 per factor
- Variables of the same component measure the same construct
- The rotated factor pattern demonstrates simple structure

Ethical clearance:

The approval for conduction of the study was obtained from the Institutional Ethics Committee, Kasturba Medical College and Hospital, Manipal Academy of Higher Education, Manipal, India before the commencement of the study.

Results:

The preliminary questionnaire had two sections; section one had forty seven items, and section two had six items. Results of Delphi rounds are provided in Table 1.

Table 1: Summarised results of Delphi rounds

Delphi rounds	Total items	Items added	Items deleted
1	47 +6	8	8
2	47 +6	--	3
3	44+6	--	1

Delphi technique resulted in removal of eight items, addition of eight items, and modification of twenty statements in section one to improve the clarity. After the second round, three items were removed, and forty four items were retained. Following

the last round one item was removed and the final questionnaire, therefore, had only forty three items. There were no changes in the second section during the Delphi rounds.

Construct validity was assessed by performing factor analysis. Exploratory factor analysis (Principal Components Analysis with Varimax rotation) was done on the forty two items of the first part of the questionnaire. As the response scale of the remaining items was different from the rest, those items were not included for factor analysis (item no. 43 and second section of the questionnaire). The analysis revealed adequacy of sampling with a Kaiser-Meyer Olkin (KMO) test value of 0.826 and Bartlett's test was found to be statistically significant ($p < 0.001$). Eight components were extracted accounting for 65% of the total variance using eigenvalues above one. The scree plot suggested extraction of seven factors

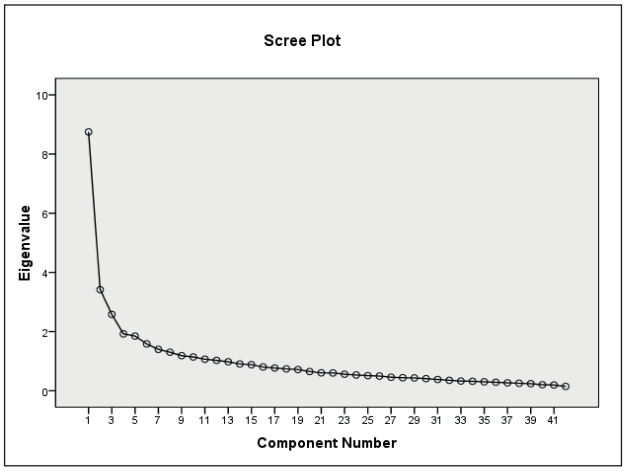

Figure 1: Scree plot obtained on factor analysis

(Figure 1). Hence the factor analysis was performed with a seven-factor solution which was explaining 51% variance (Table 2).

Table 2: Factor loadings of the items on each component

Rotated component matrix							
	Component						
	1	2	3	4	5	6	7
Variance explained in % (total variance explained: 51.19%)	7.23	9.15	7.36	9.3	7.71	4.96	5.49
1. Learning opportunities in cognitive development 1) Lecture classes assisted me to learn Physiology	0.79						
2) Physiology lecture classes were understandable	0.76						
3) Use of the teaching aids (blackboard, PPT presentations, etc.) by the Physiology teachers enhanced learning	0.62						
4) Lectures in Physiology were interactive	0.44						
5) Resource materials (e.g., handouts/class notes) provided/ suggested in the Physiology class were useful in learning the content	0.43						
6) Teaching-learning activities in Physiology were conducted in an organized manner	0.48						
2. Learning opportunities for self-learning 7) SDL sessions in Physiology motivated me towards deep learning		0.76					
8) SDL sessions in Physiology helped to develop my self-directed learning skills (self-directed learning: Identifying what to learn and how to learn)		0.85					
9) SDL sessions in Physiology motivated me to involve in self-study		0.83					

Rotated component matrix							
	Component						
	1	2	3	4	5	6	7
10) SDL sessions in Physiology helped to develop my presentation skills		0.64					
11) SDL sessions in Physiology helped to develop my collaborative learning skills (collaborative learning: Two or more students learning with and from each other)		0.57					
12) Feedback provided by the facilitator (teacher) in the session enhanced learning		0.48					
13) Facilitator provided required information during Physiology SDL session to understand the topic better		0.47					
3. Problem based learning (PBL) 14) PBL sessions facilitated the learning of Physiology by correlating/integrating with other disciplines			0.57				
15) PBL sessions enabled me to apply my Physiology knowledge while analyzing the PBL case			0.59				
16) Facilitator's feedback during PBL sessions made it more effective in terms of learning			0.59				
17) PBL sessions motivated me to involve in deep learning			0.58				
18) Discussions with peers (friends) regarding PBL helped to improve my knowledge in PBL topic			0.77				
19) Presentations by my peers during PBL sessions enhanced my understanding of the topic			0.61				
4. Learning opportunities for skill learning 20) Laboratory based learning sessions (practical classes) in Physiology helped me to develop my practical skills				0.77			
21) Laboratory based learning sessions in Physiology gave me an opportunity to learn collaboratively with peers				0.68			
22) Laboratory based learning in Physiology helped me strengthen theoretical concepts				0.75			
23) Laboratory based learning in Physiology motivated me to involve in deep learning				0.68			
24) 2Laboratory based learning sessions in Physiology helped me to understand the right approach (e.g., taking informed consent prior to the clinical examination) I should be having with patients				0.71			
25) Facilitator helped me to learn the skills during Physiology laboratory based learning sessions				0.65			
26) Physiology journal book was a valuable resource for learning the laboratory based experiments				0.48			

Rotated component matrix							
	Component						
	1	2	3	4	5	6	7
5. Assessments 27) A fair (in terms of structure of questions, scoring, time allotted for the exam) assessment system was followed (block essay and MCQ, OSPE, viva, class tests) in Physiology					0.62		
28) Questions asked in the assessments were in line (aligned) with the Physiology learning objectives					0.65		
29) Cases in the Physiology theory question paper facilitated critical thinking					0.66		
30) Questions seeking physiological basis of some physiological concepts in the Physiology theory question paper facilitated critical thinking					0.63		
31) Performance stations in Physiology practical examination helped me to reflect on my abilities to perform skills				0.40	0.53		
32) There were adequate number of class tests in Physiology					0.52		
33) Assessment system in Physiology motivated me to involve in deep learning					0.58		
6. Resources 34) Recommended textbook was useful for understanding the topic						0.71	
35) I could understand the topic of the SDL session from the given reference/textbook						0.74	
36) I could understand the topic of the PBL sessions from the given reference/textbook						0.69	
7. Other learning enablers 37) In Physiology SDL sessions, the group size was optimum							0.59
38) Group size in physiology laboratory based learning was ideal to learn the experiments							0.67
39) The Physiology content was distributed evenly in all blocks							0.58
40) Peers helped me in learning Physiology content–whenever needed							0.55
41) Contact hours within planned curriculum were adequate to deliver the Physiology content							0.47
Item which did not load in any scale							
42) Class tests in Physiology motivated me to prepare for SDL sessions							

Forty items were loaded uniquely on one of the seven components. However, one item (*Performance stations in physiology practical examination helped me to reflect on my abilities to perform skills*) cross loaded, and it was located with higher component loading. One item (*Class tests in physiology motivated me to prepare for SDL sessions*) did not load on any of the components, and it was dropped from the questionnaire.

Table 3: Cronbach's Alpha if Item Deleted

Item	Cronbach's Alpha if Item Deleted
Lecture classes assisted me to learn Physiology	0.9
Physiology lecture classes were understandable	0.9
Use of the teaching aids by the Physiology teachers enhanced learning	0.9
Lectures in Physiology were interactive	0.9
Resource materials provided / suggested in the Physiology class were useful in learning the content	0.9
Teaching-learning activities in Physiology were conducted in an organized manner	0.9
SDL sessions in Physiology motivated me towards deep learning	0.89
SDL sessions in Physiology helped to develop my self-directed learning skills	0.89
SDL sessions in Physiology motivated me to involve in self-study	0.9
SDL sessions in Physiology helped to develop my presentation skills	0.9
SDL sessions in Physiology helped to develop my collaborative learning skills	0.9
Feedback provided by the facilitator (teacher) in the session enhanced learning	0.89
Facilitator provided required information during Physiology SDL session to understand the topic better	0.89
PBL sessions facilitated the learning of Physiology by correlating/integrating with other disciplines	0.9
PBL sessions enabled me to apply my Physiology knowledge while analyzing the PBL case	0.9
Facilitator's feedback during PBL sessions made it more effective in terms of learning	0.89
PBL sessions motivated me to involve in deep learning	0.9
Discussions with peers (friends) regarding PBL helped to improve my knowledge in PBL topic	0.9
Presentations by my peers during PBL sessions enhanced my understanding of the topic	0.9
Laboratory based learning sessions (practical classes) in Physiology helped me to develop my practical skills	0.9
Laboratory based learning sessions in Physiology gave me an opportunity to learn collaboratively with peers	0.9
Laboratory based learning in Physiology helped me strengthen theoretical concepts	0.9
Laboratory based learning in Physiology motivated me to involve in deep learning	0.9
Laboratory based learning sessions in Physiology helped me to understand the right approach I should be having with patients	0.9
Facilitator helped me to learn the skills during Physiology laboratory based learning sessions	0.9
Physiology journal book was a valuable resource for learning the laboratory based experiments	0.9
A fair assessment system was followed in Physiology	0.9
Questions asked in the assessments were in line (aligned) with the Physiology learning objectives	0.9
Cases in the Physiology theory question paper facilitated critical thinking	0.9
Questions seeking physiological basis of some physiological concepts in the Physiology theory question paper facilitated critical thinking	0.9
Performance stations in Physiology practical examination helped me to reflect on my abilities to perform skills	0.9
There were adequate number of class tests in Physiology	0.9
Assessment system in Physiology motivated me to involve in deep learning	0.9
Recommended textbook was useful for understanding the topic	0.9
I could understand the topic of the SDL session from the given reference/text	0.9
I could understand the topic of the PBL sessions from the given reference/textbook	0.9
In Physiology SDL sessions, the group size was optimum	0.9
Group size in physiology laboratory based learning were ideal to learn the experiments	0.9
The Physiology content was distributed evenly in all blocks	0.9
Peers helped me in learning Physiology content–whenever needed	0.9
Contact hours within planned curriculum were adequate to deliver the Physiology content	0.9

The components were named after discussion with the research team. The first component was named as learning opportunities for cognitive development (six items) and the second component became learning opportunities for self-learning (seven items). The components three, four, five, six, and seven were named problem based learning (six items), learning opportunities for skill learning (seven items), assessments (seven items), resources (three items), and other learning enablers (five items) respectively (Table 2).

Further analysis of this sample showed that the items had internal consistency reliability of 0.898 (Cronbach's α). Table 3 provides details about the internal consistency reliability if a particular item is deleted from the tool.

Table 3: Cronbach's Alpha if Item Deleted

Discussion:

As the quality of education in general and medical education, in particular, is of paramount importance it needs continuous monitoring and improvement of the curriculum. The curriculum evaluation finds great utility in meeting the above requirement and hence plays a vital role in medical education. Moreover, evaluation tools should focus on expected outcomes in order to obtain valid data on the real impact of teaching.[22] In line with the above observation, the present study laid emphasis on developing a valid and reliable questionnaire for the evaluation of the outcomes of the physiology curriculum of a medical program. The evaluation of process was also given enough prominence during the questionnaire development. The first section focussed on overall curriculum. It consisted of 42 items which included items on different learning opportunities, assessments, and learning resources. The other section had six items that were specifically focused on outcomes. The validity of the questionnaire was tested in terms of content and construct validity. The reliability was tested in terms of internal consistency. On completion of the questionnaire development process, the questionnaire was found to have acceptable validity and reliability.

Evidence for content validity was established by assessing the items using the Delphi technique. The factor analysis was employed to establish the construct validity. Overall reliability was found to be 0.898 for Cronbach's alpha which is considered a good value.[23] Looking at the adequacy of sampling of the data, the Kaiser-Meyer-Olkin (KMO) test gave a value of 0.826, which showed that the sample size was adequate.[24]

The main features of the Delphi technique include the multiple discussion rounds, structured information flow, and the opportunity for experts to give qualitative inputs. It also ensures the anonymity of the panel, and participation of experts across the geographical boundaries precluding their physical presence.[20] The selection of the Delphi expert panel is vital for the validity of the process. In the present study, the Delphi panel had eleven members who were physiologists/ clinicians/medical educationalists. Jones and Twiss[25] recommended ten to fifty members as adequate panel size while Parenté and Anderson-Parente[26] suggested a minimum of ten with no upper limit. The chosen eleven panel members in the study participated in all the three rounds, which demonstrated a good response rate, their interest, and commitment.

Roff *et al.*[27] used grounded theory to generate the items for the inventory Dundee ready educational environment measure (DREEM) as the available questionnaires were old. Moreover, there were many changes in the educational goals and strategies of health professions over the years. The literature survey conducted during the present study also showed the lack of tools to evaluate the outcomes of hybrid curriculum and hence grounded theory was used to develop the tool. The items of the DREEM inventory were generated by the Delphi panel members[27]. Reports available show the use of modified Delphi technique wherein the initial items were generated from literature review instead of sourcing them from the expert panel.[20,28] In the current study, the items were generated from literature review as well as from the analysis of qualitative data collected from students and teachers. However, the items were validated by panel members in three rounds.[20,29]

Seven factors emerged after the factor analysis of the first part of the questionnaire (Table 2). The first factor consisted of six items, and they were related to the didactic lecture class. Hence, this factor was named '*Learning opportunities for cognitive development.'* The second factor had seven items and it was named '*Learning opportunities for self-learning'* as the items were related to SDL sessions. The third factor contained six items associated with PBL session. Therefore, this factor was named '*Problem based learning.'* The items of the fourth factor represented practical skills. Hence, it got the name '*Learning opportunities for skill learning.'* There were seven items in the fifth factor and related to the assessments.

Therefore, the factor was named '*Assessments.'* The sixth factor had three items and they were linked to learning resources. So, it was named '*Resources.'* The last factor had five factors related to content, group size in SDL, practical, and peers. Hence, it was named '*Other learning enablers.'*

This tool could be used to obtain students' perspectives of physiology curriculum in addition to revealing the strengths and the areas of concern related to the curriculum. It could also give insight into the alignment of curricular components with the expected learning outcomes.

Conclusions:

A questionnaire named Manipal Inventory for Curriculum Evaluation (MICE) was successfully developed and validated. It was designed for evaluation of hybrid curriculum of physiology at MMMC, Manipal which follows an outcome-based approach. The questionnaire helps evaluation of the contribution of curricular components in the achievement of the expected outcomes.

Even though the MICE tool was developed to evaluate physiology curriculum, it could be used by other departments of MMMC as well as by other Institutions with customization to suit their curricular requirements.

Limitations and recommendation:

Although at present, this study was conducted only in one medical college, the versatility of the tool could be achieved by validating it in an international setup.

Source of fund: None

Conflict of interest: None

Authors' contribution

All authors conceptualized the study. AV and VD were involved in data acquisition. AV, VP and AK performed data analysis. AV drafted the manuscript while VD, VP, RRA and AK revised the manuscript. All authors read and approved the final version of the manuscript.

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