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REVIEW ARTICLE

Application of Gagne's Theory of Instructional Design in Training Statistics to Medical Students

Mila Nu Nu Htay[1], Htay Lwin[1], Htoo Htoo Kyaw Soe[1], Soe Moe[1], Adinegara Lutfi Abas[1]

Corresponding Author Email id: drmlnnh@gmail.com

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ABSTRACT

Research methodology and statistical training are relevant to both undergraduate and postgraduate healthcare students. Medical educators play a crucial role to provide well-planned, effective training on statistics, which should be student-centered to equip the skill in data analysis and interpretation. In order to deliver effective teaching or training, educators use the instructional design models and integrate them into the curriculum. In this article, Gagne's theory of nine-step instructional model design is applied to the biostatistics training of undergraduate medical students. It will provide a sample framework for future statistical training programmes.

INTRODUCTION

A new paradigm of evidence-based medicine has been emphasized in the medical practice worldwide (1, 2). Evidence-based medicine covers the scope of individual clinical expertise, patient values and circumstances, and research evidence, that aims to improve the patient outcome (3). Therefore, medical research and statistics training is essential and integrated into the undergraduate curriculum (4). Medical students revealed that learning statistics is challenging to comprehend which could negatively

[1] Department of Community Medicine, Faculty of Medicine, Manipal University College Malaysia, Jalan Batu Hampar, 75150 Bukit Baru, Melaka, Malaysia.

affect their future application and interpretation of medical research (4). Therefore, medical educators play a crucial role to provide well-planned, effective training on statistics, which should be student-centered to equip the skill in data analysis and interpretation.

In order to deliver the effective teaching or training, educators use the instructional design models to create a session, course, or curriculum (5). There are several instructional model designs in medical education, however, most of them include the essential phases of setting learning outcomes, designing the activities to achieve the learning outcomes, implementation, evaluation, and reflection (6). Gagne's framework a useful and systemic in designing a lesson plan, which is based on the information processing model (7). It has been applied in various teaching sessions including for communication training, skills improvement, and web-based instructional courses (7-9).

In this article, we will present the application of Gagne's theory of instructional model design for training statistics to undergraduate medical students. Gagne proposed nine phases of instructions will include the example of training biostatistics by using Epi info statistical software (10).

PRE-REQUISITE LEARNING

In Gagne's framework, the pre-requisite is considered as "internal conditions for learning" that must be fulfilled prior to the current teaching session (7, 11). The consideration of prior knowledge is an essential step in lesson planning. Based on the prior knowledge, the teaching or training session could be planned to add new knowledge. This concept is in line with the constructivism learning theory in which new knowledge is added to the pre-existing learning (12, 13).

In our medical university, early exposure to research is encouraged and students participated in the mentored student projects (MSP) during their pre-clinical years. When the students get to the clinical years, student-led medical research projects are conducted which is mentored and supervised by the medical educators.

This lesson plan is intended for the clinical-year undergraduate medical students to train statistical analysis by using Epi info software. In this statistical analysis training, the pre-requite should be prior knowledge on types of variables, selection of statistical tests based on the variables and objectives, basic knowledge on data processing, and analysis in Microsoft excel during their MSP. Based on this prior knowledge, students will be able to proceed with learning practical session for Epi info software.

GAGNE'S NINE STEPS OF INSTRUCTIONAL DESIGN

1. GAINING ATTENTION

In this first step, the teacher will introduce and welcome the students who attend the session. After that student will do self-introduction and will share their prior experience with statistics.

As an educator, the first step is important to grasp students' attention, which could be further maintained in the next steps of learning Cheung (5). Students' attention will be attained by emphasizing the importance of statistical analysis in medical research. The importance of data analysis skills will be explained with examples of research studies. This will stimulate the learner's intrinsic motivation that could enhance the subsequence of training (5).

2. INFORMING LEARNER OF OUTCOMES

In this step, we would prefer to include learning outcomes although the original Gagne's framework described as "learning objectives" (11). Learning outcomes describe a broader perspective, which provides an overview and is usually student-centred (14).

The learning outcomes for this training session are prepared according to Bloom's taxonomy (15).

1) Select the appropriate statistical test for categorical and continuous variables

The first learning outcome aims to achieve cognitive domain, comprehension of the learned information.

2) Analyse the descriptive statistics for the research project data

The second learning outcome aims to achieve cognitive domain, analysis by breaking into different parts of the statistic procedure.

3) Analyse the inferential statistics for the research project data

The third learning outcome aims to achieve cognitive domain, analysis of inferential statistics tests (eg, t-test, ANOVA, correlation, regression) by breaking up into individual tests.

4) Interpret the statistical analysis results

The last learning outcome aims to achieve the cognitive domain, evaluation which is the ability to make a judgment, consideration based on the statistical analysis outputs (16, 17).

When the training section clearly describes the learning outcomes, and the programme is designed as goal-directed, learners' intrinsic motivation will be stimulated, and aspire to achieve the outcomes (18).

3. STIMULATE RECALL OF PRIOR LEARNING

In this stage, students will be asked to reflect on their prior experience with their mentored student project. They will be asked to focus specifically on the data analysis process by using Gibb's reflective cycle framework including six steps (19). The students will be reflecting on (1) a description of the data analysis process during MSP, (2) the feelings they had at that time, (3) an evaluation of the statistical analysis process

on what went well and what did not go well, (4) analysis of the situation, (5) conclusion on what they had learned at that time and what else could have done better, and (6) action plan for improvement in future (19, 20).

Furthermore, they will be asked to recall theory lectures on choosing the statistical test that they recently learned. Cognitive reflection intervention fostered the motivation to achieve deep learning and has proven benefits on the exam assessment in a prior study (21).

4. PRESENTING STIMULUS

The teacher will be presenting a practical research scenario using the PowerPoint slide and projector. The scenario is related to the cross-sectional survey on insomnia among the university student population. Research objectives will be explicitly shown to the students. Practical or clinical scenarios have been applied in learning and teaching strategies (22). In educational intervention research, problem-based scenarios have shown an improvement in knowledge and achievement goals (23, 24).

5. PROVIDING LEARNING GUIDANCE

In this section, the teacher will demonstrate data processing using Microsoft excel and data analysis using Epi info statistical software. The computer screen will be projected to the class and step by step explanation will be done.

The teacher will demonstrate the data process in the Microsoft Excel sheet for computing the total score and recoding continuous variables into categorical variables. After that, the teacher will demonstrate data analysis in the Epi info software including importing data files, descriptive analysis, inferential analysis, and interpretation of results. The details of the steps are mentioned in Appendix 1. In Merrill's principles of instruction, the learning process is explained as follows (1) engagement in real-world problem-solving process, (2) activation of prior knowledge, (3) demonstration of new knowledge, (4) application of new knowledge, and (5) integration of new knowledge to learners' world (25). Providing learning guidance is a demonstration to the students in my training and that could lead to the next step to apply this new knowledge.

6. ELICITING PERFORMANCE

When the demonstration session is over, the students will be asked to perform data analysis as an individual task. They will be using the data file provided to them with a clear explanation of the study objectives. Based on each objective, the student will select the variable, decide the statistical test to use, and run the analysis with the Epi info software. Visualization of statistical analysis screencast was found to be more effective compared to the reading of hardcopy guides (26). In our lesson plan, the teacher will first perform and visualize the process with the projector to enhance learning.

Once students have done the analysis individually, they will be transferring the findings to the tables in a Microsoft word document. The tables and interpretations document will be directed and submitted to the teacher for the assessment (part 2).

7. PROVIDING FEEDBACK

Providing feedback to students is an integral part of medical education (27). The cognitive level of providing feedback could be in various levels, such as feedback on the task-learning process which is directed to complete the assigned tasks, feedback on the task-motivating process which is encouraging the effort of students, and meta-task process which is self-regulation and putting efforts repeatedly to accomplish the task (28). In this training session, feedback will be informally given to the whole small group on the common challenges they faced during the data analysis. Teachers should provide constructive, relevant, motivational feedback while supporting students for further reflection to be constructivist in their learning process (27). The feedback provision and clarification of students' doubts would be beneficial for students to improve the data analysis process.

8. ASSESSING PERFORMANCE

The concept of assessment in medical education is designed to promote the learning process (29). In this training, computer-based MCQ assessments will be tested at the end of the session. Furthermore, the submission of exercise results and interpretation will be assessed for their performance, skills, and understanding of the subject matter. This classroom assessment type could enhance the students to achieve higher-order thinking, can assess achievement of learning outcomes, can integrate with the ongoing teaching or training session, could formatively support the students, could enhance students to be active in assigned tasks (30).

9. ENHANCING RETENTION AND TRANSFER

As the last step, the teacher will recap the statistical analysis training section and will link back with the learning objectives. Bernard and Coldevin reported that recap strategies were effective for recall and retention of memory (31). Providing the handout could be beneficial for self-practice in the future. Furthermore, reference books will be provided to expand their knowledge regards to statistical analysis.

Student feedback is an effective tool for the further improvement of training and faculty development (32). It is essential to understand the perspective of students and suggestions for improvement. Therefore, the teacher will be collecting student feedback at the end of the training. This feedback will serve as a tool for teachers to the reflection on their teaching process (33).

CONCLUSION

As medical educators, we aim for our students' acquisition of good learning experience, knowledge, retention, and application of knowledge in real-life situations. Planning a lesson or training in advance helps the educators and students to teach and learn systematically. Our review article serves as an example of planning and implementing biostatistics training for healthcare students. It could be adjusted and amended according to the learning outcomes of the intended lesson or training in the future.

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Appendix: Gagne Lesson Plan Template

Session title: Statistical analysis by using Epi info software

Student / trainee level: Undergraduate Medical Students (clinical years)

Level		Activity
1	Gaining attention (10 minutes)	Hello and welcome to the statistical analysis training session Inform the students about the importance of data analysis in the research project.
2	Informing learner of outcomes (5 minutes)	By using the PowerPoint, the students will be informed of the learning outcomes of this session. At the end of this session, the students should be able to 1) Select the appropriate statistical test for categorical and continuous variables 2) Analyse the descriptive statistics for the research project data 3) Analyse the inferential statistics for the research project data 4) Interpret the statistical analysis results
3	Stimulate recall of prior learning (15 minutes)	Students will be asked to reflect on their previous mentored student project (MSP) data analysis. Printed sheets of Gibb's reflective cycle will be distributed. Students will be asked to reflect and share their experiences during MSP data analysis. (10 minutes) After 10 minutes of the reflection process, we will continue to recall choosing appropriate statistical tests that have been discussed in small group teaching before this Epi info software training. (5 minutes)
4	Presenting stimulus (5 minutes)	The teacher will provide the example research project scenario, study objects, and raw data. This session will be conducted in the computer lab, and therefore, each student will have access to the computer, Epi info downloaded software, and soft copy of research project scenario and raw data. **Research scenario** "A cross-sectional study was conducted among undergraduate students in a private institution in Malaysia to identify the prevalence of insomnia and its association with academic performance. The respondents were recruited by using simple random sampling from the undergraduate student population in that institution. The estimated sample size was 253. The data was collected between August 2021 to September 2021."

		Research objectives 1. To estimate the prevalence of insomnia among undergraduate students 2. To identify the association between demographic characteristics (gender, ethnicity, personality) and insomnia among undergraduate students 3. To identify the association between the insomnia and academic performance among undergraduate students
5	Providing learning guidance (45 minutes)	This section will be hands-on training for data analysis. The teacher will demonstrate the data process in the Microsoft excel sheet as follow. - Computing the total score - Recoding the age variable to categorical data After that, the teacher will demonstrate data analysis in the Epi Info software. - Opening Epi info software - Importing excel data file to Epi info software - Analysing frequency distribution of gender, age, ethnicity, and personality - Analysing "Chi-square test" to assess the association between categorical independent and dependent variables - Analysing "Unpaired T-test and ANOVA" to assess the association between the categorical independent variable and continuous dependent variables - Conducting correlation analysis between two continuous variables (independent and dependent variables) - Conducting logistic regression analysis to identify the association between categorical (or) continuous independent variable and categorical dependent variable This demonstration will be projected (with a projector) while the teacher is conducting a demonstration of analysis and application of Epi Info software.
10 minutes break		
6	Eliciting performance (60 minutes)	Students will ask to perform data analysis with Epi info software (individual task) to analyse the findings for the research objectives. The teacher will move around and will be facilitated if they have any issues or any questions. Once students have done the analysis, they will be transferring the findings to the tables in Microsoft word document. The tables and interpretations document will be directed submitted to the teacher for the assessment (part 2).

7	Providing feedback (10 minutes)	Feedback will be informally given to the whole small group on the common challenges they faced during the data analysis. The teacher will invite the students' questions and will ask their difficulties in the data analysis process. The teacher will address all the issues raised by the students.
10 minutes break		
8	Assessing performance (15 minutes)	Assessment will include 2 parts. Part 1. Computer-based MCQ assessment. 10 MCQs will be assessed, and the questions are related to choosing the type of variables, choosing the appropriate statistical tests, and interpreting the analysis outputs. Part 2. Assessment of the exercise result tables and interpretations Students' knowledge and skills on data analysis will be assessed by the submitted documents during the practical section.
9	Enhancing retention and transfer (10 minutes)	The teacher will recap the statistical analysis training section and will link back with the learning objectives. Provide the handout for self-practice which includes a step-by-step guide for data analysis. Provide the list of reference books for further study. At the end of the session, students will fill up a feedback form for the Epi info data analysis training.