Advances in Medical Education and Practice

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Exploring the Use of Associative Analogy Teaching in BME Computer Courses in Medical University

Fugui Qi[1,*], Yizhu Chen[2,*], Zhao Li[1], Tao Lei[1], Jianqi Wang[1], Guohua Lu[1]

[1]Department of Biomedical Engineering, The Fourth Military Medical University, Xi'An, 710032, People's Republic of China; [2]The Primary School Attached to Xi'an Jiaotong University, Xi'An, 710065, People's Republic of China

*These authors contributed equally to this work

Correspondence: Guohua Lu, Email lugh1976@fmmu.edu.cn

Purpose: Current approaches to teaching Biomedical Engineering (BME)-related computer courses in medical universities often have unsatisfactory outcomes. A "Microcomputer Principles and Interface Technology" course was taken as a typical example to explore a new teaching method based on the idea of associative analogy.

Methods: Associative analogy was used as a core teaching principle. This puts special emphasis on the use of systematic associative analogies to promote systematic understanding and memorization of scattered knowledge points. Associative analogies form a multi-branch extension or logical-chain extension surrounding one practical example. This approach is also committed to transforming associative analogies into a constant feature of students' self-learning. Associative analogy teaching was applied over 2 years in a medical university in China and end of course questionnaires were given to students, teachers, and school experts.

Results: The three-level evaluation results show that associative analogy teaching not only assists teachers and enhances the classroom atmosphere and interest in learning, but also helps cultivate an associative analogy learning mindset amongst students.

Conclusion: Associative analogy teaching has a beneficial impact on students' acquisition of course knowledge, independence of learning, and divergent thinking. It also has positive possibilities for education and teaching reform, and teachers' capacity for innovative teaching. Next directions will include the application of this teaching method to more computer courses to collect more teaching data. This will help to inform a more refined quantitative evaluation of the method's future potential.

Keywords: associative analogy, biomedical engineering, microcomputer principles and interface technology, computer course, medical university

Introduction

Biomedical Engineering (BME) is an interdisciplinary subject combining science, engineering and medicine.[1] It requires that graduates have a basic theoretical knowledge of computer technology with microprocessor and computer application capabilities and be able to conduct BME application development. Microcomputer Principles and Interface Technology (MPIT) is an important foundational professional course for a BME major.[2] It mainly involves acquiring a basic knowledge of computer hardware, assembly language programming, and commonly used interface technology, with the goal of improving students' abilities in the development and application of microcomputers.

At present, a number of issues confront the teaching of MPIT:[3] 1) It only occupies a small number of hours in the BME curriculum, making it difficult to cover the necessary ground; 2) It involves a lot of knowledge of hardware and software, and ranges from abstract and theoretical to practical, such that students find it difficult to comprehend; 3) Other computer-related pre-curriculum courses are relatively simple, so the students have weak foundational knowledge; 4) The students exhibit low interest in learning the subject because it is hard to personally observe the internal structure of the processor, making the purpose of what they are learning unclear. In addition, there is an increasing tendency for students to become bored when faced with abstract concepts and obscure theories.[4] Taken together, these issues have made it very challenging to teach MPIT using traditional lecture-style approaches. As a result, MPIT teachers have been obliged to

Received: 28 September 2023
Accepted: 17 February 2024
Published: 1 April 2025

look for new and innovative ways of teaching the subject, hence our interest in exploring the possible advantages of using associative analogy-based teaching techniques.

A number of studies related to the Scientific Psychology of Learning[5] and Cognitive Neuroscience[6,7] have suggested that associative analogy theory might offer a new way of teaching abstract and complex knowledge. This is an inductive approach that uses structured comparisons based on psychological representation, thereby facilitating associated imagery that can underpin a more concrete understanding of abstract knowledge. The key advantages of associative analogy lie in:1) The derivation of a direct relationship between two concrete objects by using points of similarity instead of taking general principles as a basic intermediary. This makes it relatively straightforward to establish a bridge between heterogeneous objects, such that leaps can be made from one to the other. 2) The facilitation of a transformation from abstract ideas to imagery, enhances students' interest and confidence in their learning. Associative analogy was originally applied to primary and secondary school lessons[8,9] where studies have demonstrated its effectiveness in extracting perceptual materials from daily life and work to serve as analogous objects to assist in understanding abstract knowledge. Simultaneously, associations and analogies based on prior knowledge can help teachers explain new ideas, improving students' capacity to transfer knowledge, and their interest in learning. Associative analogy-based teaching has now also been successfully applied in theoretical courses in higher education.[10,11]

In view of the noted complexity and abstract character of BME MPIT, it would seem that associative analogy teaching has great potential to improve the current situation. It is surprising in that case that an inspection of the literature reveals very little relevant research on this topic.[12,13] The literature that does exist only focuses on associative analogies for specific scattered knowledge points to serve as examples within a preliminary exploration of the feasibility of applying an association analogy approach in MPIT teaching. Therefore, adhering to the notion that "It's better to teach students ideas than to give them knowledge. It's better to let them learn methods than to let them learn facts", our teaching group decided to take a series of steps towards applying the associative analogy method in MPIT teaching: 1) By systematizing the associative analogy approach, which involved reducing the number of fragmented analogies associated with scattered knowledge points and promoting instead systematic analogies for blocks of knowledge; and 2) By devoting ourselves to transforming the associative analogy teaching method into a method that could be adopted by the students themselves. To fulfill its potential, associative analogy needs to not only be used to assist teachers in teaching and explaining knowledge points, but to also be cultivated amongst students so that it becomes associative analogy learning and a part of their own mindsets. In this way, one gives students a basic way of ensuring that they master and understand relevant knowledge wherever they encounter it, thereby enhancing their capacity for both self-learning and ongoing learning throughout their lives.

In this paper, we provide the results of a three-way evaluation of a two-year implementation of associative-analogy teaching in a BME MPIT course in a medical university in China. The implementation was evaluated by a total of 33 students, the course tutors, and a group of course experts. As these three groups of stakeholders are most directly affected by any change in teaching method, it was felt their evaluations would be the most informative. The study reported here set out to explore: 1) The effectiveness of an associative-analogy approach to teaching in this kind of context in comparison to more traditional approaches to teaching; and 2) The extent to which the students were able to internalize the approach for their own future use. A descriptive statistical analysis of the results is provided that shows that the approach was extremely successful, implying that a similar approach may be adopted for the teaching of other highly abstract and complex courses in the future.

Theoretical Basis of Associative Analogy Teaching

Associative analogy is a kind of divergent thinking. It is recognized to be an important link in the cultivation of creative ability, has solid cognitive science foundations, and has a special function in teaching. Cognitive science believes that the phenomenon largely depends on working memory and other executive functions supported by the prefrontal cortex.[6,7] By retrieving structured knowledge from long-term memory representing operating roles in working memory to accomplish fill-binding, and identifying elements that play corresponding roles, new reasoning and learning of abstract models can take place. The philosopher Aristotle pointed out that: "Our thinking starts with something similar to and opposite to what we are looking for, and then pursues something related to it, resulting in association". People who are good at association can always communicate, analyze, and compare similar, identical, or opposite and related things, thereby bringing about insight, absorption, and the formation of their own learning, thinking, and methods.

Primary and secondary school teaching theory and practice have proved that[8,9] an associative analogy method can provide intuitive and vivid perceptual examples from daily life and work experience, which serve as great sources of analogy, providing a conversion bridge to abstract knowledge and understanding. This can turn abstract ideas into images, rigid propositions into something vivid, and make difficult problems easy to understand, enhancing students' interest in learning and confidence. At the same time, through association, old and new knowledge can be linked to an analogy, which can accelerate their integration and cultivate a student's capacity for knowledge transfer.

Inspired by this, we recognized the scope of associative analogy to improve the current teaching of undergraduate computer basic courses in BME-related MPIT, where the material is frequently highly abstract and theoretical, and requires complex hardware-software knowledge. A few previous studies have pointed out the effectiveness of using analogies in the teaching of complex subjects at university, such as in the life sciences,[14,15] and in science, technology, engineering, and mathematics (STEM) in general.[16,17] However, the literature on this topic is still sparse and tends to refer to the use of analogies in a rather scattered fashion, rather than as systematic strategy with analogies building upon one another in a structured way, as described in this paper. When it comes to the teaching of BME-related MPIT, there appear to be no relevant studies of applying associative analogy teaching.

In the next section, we explain our structured approach to associative analogy teaching and how we sought to apply it in the context of MPIT.

Application of Associative Analogy Teaching in MPIT

This section takes a typical knowledge module in MPIT as an example to introduce and analyze the application of associative analogy teaching.

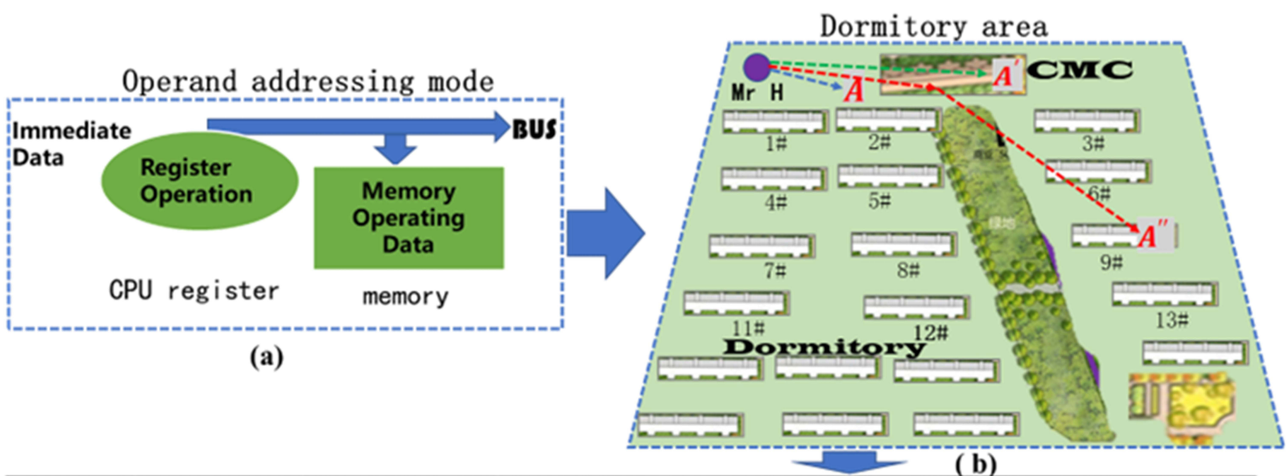
Systematic Associative Analogy

The systematic associative analogy method we advocate is committed to reforming the traditional "scattered knowledge analogy" model. First, piecemeal knowledge points are connected in blocks or by linear logic wherever possible, then an analogic approach to block divergence or linear extension is carried out based on the same case. In other words, the systematic associative analogy of multiple related knowledge points is based on the expansion of one particular case. This can effectively reduce the number of associative analogies and their dispersion, thereby promoting a systematic understanding and recall of the relationship between scattered knowledge points.

We will take here the important module of 8086 CPU (central processing unit) data storage as an example. It can be understood according to the analogy process illustrated in Figure 1:

1. As shown in Figure 1a, the bidirectional process of storing and addressing 8086 CPU data includes the immediate number given by the instruction, the register operation number stored in the CPU register, and the memory operation number stored in the memory.
2. To explain the memory operand process as an entity within the computer world, data needs a storage space, which must correspond to an address. Therefore, as shown in Figure 1b, an analogy can be that each room in a dormitory must correspond to a specific room number, so each room can be found by means of its number.
3. Operator addressing is an inescapable requirement in operand storage (an operand is the address a computer instruction refers to when there is data to be operated upon in some way). Three types of operands, Immediate Data (ID), Register Operand (RO), and Memory Operand (MO), correspond to three modes of address: immediate address; register address; and memory operand address; respectively.

In this case, MO address is relatively complex and includes Direct address, Register indirect address, Register relative address, Base indexed address, Base index plus relative address, and so on. It is multifaceted and abstract, which makes it difficult to remember. To this end, an analogy for the address processes above can be the different ways in which one might find a target room for Mr. H according to different information conditions, where the target room exists in his



Operand	Addressing mode	Addressing process	Process of searching target room
ID	Immediate	/	/
RO	Register	/	direct to the CMC
MOD	Direct	PA	Direct address (building No. : room No.)
	Register indirect	PA=(DS/SS)*16+{(SI, DI,BX)/BP}	**Provided information:** Room No. stored in the CMC{(SI, DI,BX)/BP}, default correspondence with the building No. in CMC (DS/SS) . Indirect query via CMC
	Register relative	PA=(DS/SS)*16+{(SI, DI, BX)/BP}+DISP	**Provided information:** Number of No.1 Room in the same floor with target room{(SI, DI,BX)/BP} backup stored in CMC, default correspondence to building No. (DS/SS), room No. difference to No.1 Room (DISP). Indirect query via CMC and calculation.
	Base indexed	PA=(DS/SS)*16+{BX/BP}+{SI/DI}	**Provided information:** Number of No.1 Room in the same building with target room{BX/BP} and room No. difference to No.1 Room {SI/DI} in CMC, default correspondence to building No. (DS/SS), Indirect query via CMC and calculation.
	Base index plus relative	PA=(DS/SS)*16+{BX/BP}+{SI/DI}+DISP	**Provided information:** Number of the first room in the building{BX/BP} and number of the first room in the same floor with target room {BX/BP}in CMC, default correspondence to building No. (DS/SS), and room No. difference to first room in the same floor (DISP). Indirect query via CMC and calculation.

(c)

Figure 1 Diagrammatic sketch of analogizing operand addressing process with searching target room in dormitory area. (**a**) The 8086 CPU data in the bidirectional process of storing and addressing, (**b**) Examples of searching target room in dormitory area for analogical purpose, (**c**) Analogical relationship between operand addressing and searching target room in dormitory area.

range of sight (A), comprehensive management center (CMC) (A'), and as a room in the dormitory (A"). If so, immediate address means there is no need to find the room and register address corresponds to finding the target room in the CMC. In that case, for multiple memory operand addresses, we perform the corresponding analogic processes shown in Figure 1c. This makes it possible to analogize the abstract data address process in the virtual computer world by taking a familiar and vivid process in daily life, namely finding a target room in a dormitory area. This can help students intuitively understand the key knowledge points and the logical process. More importantly, the two knowledge modules of operand storage and address are both learned analogically by using the same case.

Beyond this, unified address and independent address involve specific kinds of hardware. This is more abstract and difficult to understand, so it can again be analogized according to the above case. If the address is analogized as the target room number and the memory address and interface address are analogized as the building number and the corresponding room number, respectively, this makes it more intuitive to understand them. By analogizing the unified address to the unified serial room number of all the buildings, then all room numbers will fall in the range of 0001- N (the total number of rooms in all the buildings). The independent address analogy is then the number of each building, so each room number in each building can be noted as the building number combined with the room number in the corresponding building.

Transforming Associative Analogy Teaching Thinking into How Students Think About Learning

Inspired by the classic teaching saying "It's better to teach a man fishing than to give him a fish", we also want to stress the importance of progressively teaching the concept of associative analogy itself to students so that they can build it into their own learning practice. The goal is to promote it in such a way that it is internalized into students' own way of thinking about their learning, as shown in Figure 2. There are several steps to accomplishing this.

Step 1: Strengthening the basic concepts and functions of associative analogy in the early stages of the course. A large number of multi-level (everyday general knowledge, working experience, etc.) and multidisciplinary (biology, physics, architecture, aerospace, etc.) examples were used to help students understand the abstract concepts and theories in the MPIT course and to stimulate their enthusiasm for learning. At the same time, this made the importance of associative analogy in abstract complex knowledge learning visible to the students. For example, the process of data pushing in and popping out of the stack (the first data in and last out) was analogized in terms of a bullet pressing in and ejecting out of a clip (the bullet last in the back is first shot), with stack clearance being similar to all the bullets being ejected from the clip. Moreover, when explaining the bus concept and its relationship with different computer components, it can be analogized as a highway connecting different provinces and cities, with different regions being connected together via numerous highways.

Step 2: In the later stages of the course, associative analogy techniques are further internalized into how student think about their learning. 1) In a number of ways, such as through pre-class task arrangements, classroom questioning, group discussion, open homework, and so on, diverse analogies were expressed around target knowledge points, so that the students could think about and understand knowledge actively through the use of analogy. This helps to cultivate thinking about learning and developing associative analogy habits. Taking learning the basic concepts of Assembly Language Programming as an example, we arranged preliminary tasks before class that required students to engage in divergent thinking and find similar processes to the implementation process of assembly language (Assembly language-Assembly language source program-Target program-Implementation), such as the implementation process for the pre-course

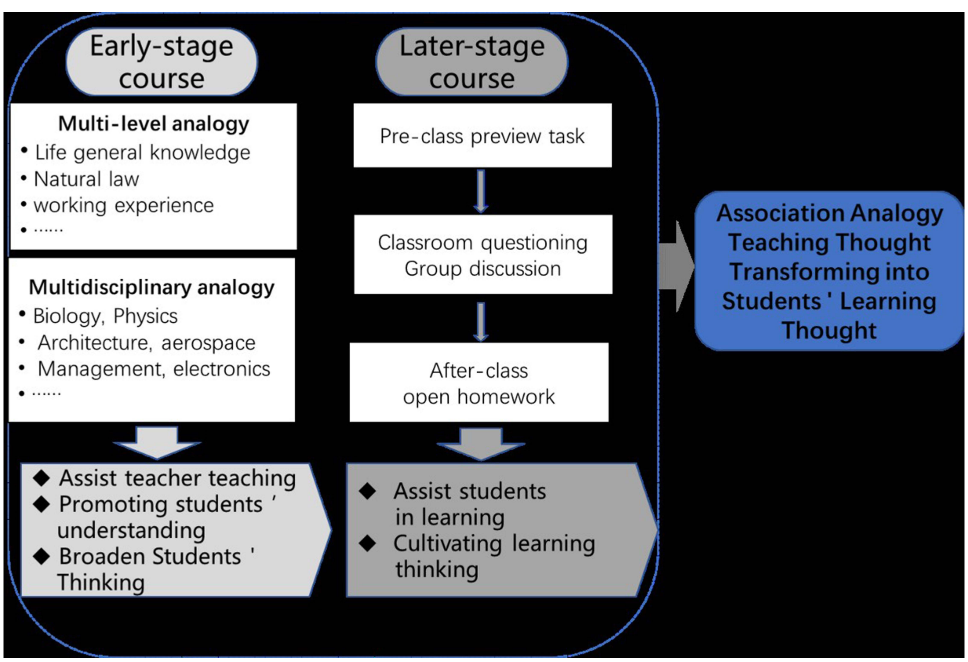


Figure 2 The teaching process diagram of transforming association analogy teaching thought into students "learning thought".

https://doi.org/10.2147/AMEP.S436882

C language program. 2) In class, through questions, group discussions, etc., comparisons were undertaken centered around assembly language that aimed to clarify the implementation process and operating principles of the Assembly Language Source Program. 3) In practical computer experiments and after-school homework, students were required to analyze and discuss the application and effect of associative analogy in learning knowledge. In this way, students were encouraged to analyze and explore problems based on associative analogy thinking habitually in their subsequent learning.

The basic hypothesis we were testing was that associative analogy teaching could promote the more effective teaching of computer courses (like MPIT) for BME students in medical universities. To summarize, we would expect the application of associative analogy teaching to have a number of important outcomes amongst the students: 1) an improved grasp of notably abstract, challenging, theoretical, and complex concepts within the course material; 2) a better capacity to group together difficult concepts by analogy, such that prior analogies are being constructively used to support new learning; 3) a significant improvement in engagement, interest and motivation during the course; 4) notably improved lesson dynamics and active student participation, evidencing an improved willingness to learn; 5) a displayed capacity to locate and use analogies in other course material without prior prompting by teachers, suggesting that students have internalized the approach and are beginning to use it as a part of their own learning practice. Various aspects of these prospective outcomes were probed through 3-way course evaluations amongst students, teachers, and experts. The results of these evaluations are presented in Methodology.

Methodology

Incoming undergraduates for the years 2018 and 2019 majoring in BME at the Fourth Military Medical University in China were subjects of our use of an associative analogy teaching method in their MPIT courses. Over the course of the trial, the focus was on promoting the systematization of associative analogies and striving to transform associative analogy thinking into something the students would accommodate within their own learning strategies. The effect of applying the method was comprehensively evaluated by a combination of student questionnaire-based surveys, teacher evaluation, and expert evaluation.

The questionnaire-based evaluation took place after the end of each semester's course and, in particular, after the students' final exam review, because we judged that the second period of autonomous learning involved in undertaking the review was when the students would feel the advantages of the method most deeply. The student questionnaire was organized into three principal parts. In the first part, questions were posed to assess whether, compared to traditional approaches that focus on the direct teaching of knowledge, associative analogy teaching was improving the students' understanding (eg, classroom mastery of theoretical knowledge; completion level of after-class homework; and the completion time and effectiveness of practical computer experiments). The second part focused on whether the method was more effective in arousing students' interest in learning (eg, active previewing of the course materials; length of time of active participation in class; participation in post-class discussions; etc.). The third part explored the extent to which there was some preliminary formation of associative analogy learning as an internalized strategy amongst the students (eg, whether they were actively learning new knowledge in the course using associative analogy methods; whether they were actively reviewing knowledge in the course using associative analogies; whether they were actively learning new knowledge in other courses using associative analogy methods; etc.). The questionnaires were distributed to 33 students.

The teachers' evaluation was a descriptive evaluation based on their own impressions of the effect of associative analogy teaching and the students' reactions to each class. The expert evaluation was based on a school-college-department three-level online-offline audit evaluation system implemented by the Fourth Military Medical University, which ensured that there was at least one expert evaluation for each class. On-site expert feedback in the classroom and after-school feedback obtained from the educational administration system, together with corresponding descriptive advice and evaluation of the impact of the new approach to teaching, were obtained and statistically analyzed.

A descriptive statistical method was used for all of the data because of the small size of the sample and because the existing content provided by the university's expert evaluation system was primarily descriptive.

The Medical Ethics Committee of the First Affiliated Hospital of the Fourth Military Medical University approved the study. The students were informed at the beginning of each course that an associative analogy teaching method would be used and that any relevant homework and computer practice operations would be recorded for this study. Informed consent was obtained from all the students prior to their participation in the study and the guidelines outlined in the Declaration of Helsinki were followed.

Results and Discussion

Descriptive statistical analysis results from the questionnaires administered to the students are shown in Table 1. The overall teacher-expert evaluation results are shown in Table 2 and historical teaching effect evaluation data for the previous two years (2016 and 2017, where traditional lecture-based teaching was applied) are also presented for reference.

From Table 1 it can be seen that 91% of the students thought that the associative analogy teaching method helped with their understanding, 85% thought that it improved their interest in learning MPIT, and 85% found they had acquired some form of associative analogy learning thinking. These results demonstrate that this approach to teaching can effectively improve students' understanding of abstract knowledge by using multi-level and multi-disciplinary examples that students are familiar with, making it easier to understand through analogy the abstract concepts found in MPIT. The basic reason for the trial's success was that this method could turn abstract and strange ideas into more familiar images and concepts, thus facilitating the acquisition of abstract knowledge. Classroom discussion also helped to increase the students' interest in learning. The early-stage introduction of the thinking underlying associative analogy teaching, together with its multitask promotion in the later stages resulted in the students gradually changing from passive to active use of this method when previewing, studying, reviewing, and even finally pursuing self-learning. It is worth noting that, in a recent study where university students were actively encouraged to use analogies as a learning strategy in a biology course, Tise et al[15] found that the capacity of the students to make their own analogies and use them effectively increased over the duration of the course (though, as a note of caution, the same study did not find that this made a significant difference to the students' final course performance).

In the evaluation by the three teachers and the 96 instances of expert feedback over the two semesters, some comparison can be made between course ratings for the years 2016–2017, when a more traditional lecture-based approach was being used, and the evaluations for the years 2018–2019, when an associative analogy approach was adopted. It is clear from these results that teachers believed that the associative analogy teaching method was effectively promoting more diverse discussions in the classroom (IV 2018–2019 VS II 2016–2017) compared with traditional teaching methods and that the students' own associative analogy thinking in their learning was significantly improved

Table 1 Feedback from Students' Questionnaire Survey on Associative Analogy Method

Student Number	Knowledge Understanding Improvement	Learning Enthusiasm Improvement	Associative Analogy Learning Thinking Forming
33	30	28	28
Percent (%)	91	85	85

Table 2 Teacher and Expert Feedback of Teaching Effect of Associative Analogy Method (Effect Level I–V)

Teacher's Evaluation				Expert's Evaluation	
Grade	Promoting Classroom Divergent Discussion	Associative Analogy Learning Thinking Forming	Classroom Liveness	Logic of Instruction-al Design and Lecture	Classroom Liveness Promotion
2016~2017	II	I	III	III	III
2018~2019	IV	IV	V	IV	V

(IV 2018–2019 VS I 2016–2017), making the classroom more active (V 2018–2019 VS III 2016–2017). While, as pointed out in Theoretical Basis of Associative Analogy Teaching, it is hard to find wholly comparable studies to our own in the literature, it is notable that the results here reflect the findings of other studies. For instance, in a study with physics teachers in Latvia, Jonane[18] found that all of the respondents agreed that analogies could "help students to imagine and understand indirectly perceptible objects and processes" and that "the purposeful use of analogy develops students' ability to apply knowledge to new situations and assists development of transfer skills". There are numerous studies with primary and secondary school teachers that similarly cite an overwhelming support of the strategy. At the same time, many of the same studies find that teachers do not currently apply associative analogy teaching in any kind of systematic fashion (cf. Petchey et al 2023[14]). The experts felt that, compared with traditional teaching methods, the associative analogy teaching method improves the instructional design and structure of the lectures (IV (2018–2019 VS III 2016–2017). Additionally, their assessment of the improvement in students' classroom activity was consistent with the teachers' evaluation. Generally, then, using the historical course feedback for reference, it can be seen that both the teachers and experts noted a significant improvement in the diversity of classroom discussion, the liveliness of the classrooms, the logic of the course design, and the use of analogies in students' own thinking, as a result of implementing associative analogy teaching to the BME MPIT course.

Conclusion

A number of challenges confront the teaching of MPIT in BME, including limited course time, abstract and complex learning content, the relatively poor computer knowledge base for BME students, and a low level of interest in abstract theoretical knowledge among contemporary college students. This study has therefore explored the possibility of applying a novel associative analogy teaching method in the teaching of MPIT. The key innovation is to use systematic approach to developing associated analogies so as to connect discrete knowledge as much as possible while creating suitable image-based analogies for abstract concepts. Alongside this, through the progressive use of associative analogy teaching, the goal is to promote the transformation of the method into something that students will use in their own learning, while using it to assist in teaching.

In an evaluation of a two-year application of the associative analogy method in MPIT teaching, teachers felt that it was helping them to explain abstract concepts and theories more intuitively and that the students were more willing to engage in diversified analogic thinking and learning. The students also felt that it was helping them to undertake analogic thinking and learning and that it was improving their understanding of abstract knowledge and interest in learning, which was making the classroom atmosphere more active. At the same time, the method provided a way for teachers to transform images into something that could help them to explain abstract ideas more clearly. As a result, the instructional design, and lecturing process and course structure were significantly improved. Perhaps the most important outcome of the study was that the students formed the initial basis for applying an associative analogy approach to their own learning and thinking, changing the situation from being "teachers teaching students knowledge" to "teachers teaching students how to learn".

Of course, in a study of this order, there are always limitations. In our case, these include two particular categories of concern: limitations attributable to the nature of the sample; and limitations attributable to the available data and its analysis. For the former, the sample size was very small; the duration of the study was constrained; the study was only undertaken in one particular institution rather than across a range of institutions; and the study was only applied in one specific course rather than across a range of different courses. Together, these limitations place some constraints upon how far the findings of this study might be generalized. When it comes to the available data and kind of analysis undertaken, there was no explicit collection of data across the application of different methods to be able to undertake a detailed comparison of the relative results; no assessment was made of the long-term retention of knowledge amongst the students; the statistical approach was rather basic; and no quantitative parametric analysis was undertaken, though the latter was also not possible because of the small sample size and short duration of the study. There is also a need to engage in a comparison of the outcomes of different types of teaching strategies more actively in various subjects, so that the specific improvements attributable to associative analogy teaching can be better identified. Beyond this, compared to a lecture-style teaching method, the associative analogy method does require teachers to spend more time preparing for courses (the specific amount of time varies from person to person). It can require a lengthy search for examples suitable as analogies for abstract knowledge, rigorous argumentation, and time spent on the alignment of various corresponding attributes. However, once a case library is built, it becomes very easy to use for future lesson preparation.

Despite the above limitations, in principle, we believe that associative analogy teaching is something that can be successfully applied across a range of other abstract and theoretical courses in the future, as has already been the case in several other university-level courses in the life sciences[14] and other STEM subjects.[16,19] In particular, we would point to the efforts made in this study to implement associative analogy teaching in a highly systematic fashion. Prior studies[18] have found that, while appreciative of the value of this approach to teaching, teachers often only apply it in a relatively piecemeal fashion. There is therefore significant scope for university level courses where it is already known that students are currently struggling with their abstract or complex character, to engage in advance planning, as was the case in this study, so that associative analogy teaching is implemented with systematic attention being paid to how analogies may constructively build upon one another in a coherent way. As some studies have found that the use of analogy-based reasoning and its internalization by students is not always guaranteed to lead to better student performance, it is important that future research be dedicated to exploring just how best to systematically organize associative analogies so that they have the most optimal effect.

Abbreviations

BME, Biomedical Engineering; MPIT, Microcomputer Principle and Interface Technology.

Acknowledgments

Fugui Qi and Yizhu Chen are co-first authors for this study. Thanks to the undergraduates of grade 2018 and grade 2019 majoring in biomedical engineering in Fourth Military Medical University for their support in this study. Thank you to the school teaching steering committee for their expert feedback about the in-class teaching. This study is supported by 2020 Special research project on epidemic prevention and control of Shaanxi Association of Higher Education (XGH20116) and National Science Foundation of China (62201578).

Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Bronzino JD, Peterson DR. *Biomedical Engineering Fundamentals*. CRC press; 2014.
2. Gao J, Tang Y. Designation and implementation of microcomputer principle and interface technology virtual experimental platform website. *Physics Procedia*. 2012;33:1140–1143. doi:10.1016/j.phpro.2012.05.187
3. Zhou Y, Hongyu XU, Jiang Q, Wang X, Xiulin XU. Research on creative teaching methods of microcomputer principles in BME major. *Prog Biomed Eng*. 2017;2017:1.
4. Sublette VA, Mullan B. Consequences of play: a systematic review of the effects of online gaming. *Int J Ment Health Ad*. 2012;10(1):3–23. doi:10.1007/s11469-010-9304-3
5. Glynn SM. Explaining science concepts: a teaching-with-analogies model. *Psychol Learn Sci*. 1991;1991:219–240.
6. Holyoak KJ. Analogy and relational reasoning; 2012.
7. Richland LE, Zur O, Holyoak KJ. Cognitive supports for analogies in the mathematics classroom. *Science*. 2007;316(5828):1128–1129. doi:10.1126/science.1142103
8. Duncan LG, Seymour PH, Hill S. How important are rhyme and analogy in beginning reading? *Cognition*. 1997;63(2):171–208. doi:10.1016/S0010-0277(97)00001-2
9. Heywood D, Parker J. Confronting the analogy: primary teachers exploring the usefulness of analogies in the teaching and learning of electricity. *Int J Sci Educ*. 1997;19(8):869–885. doi:10.1080/0950069970190801
10. Loc NP, Uyen BP. Using analogy in teaching mathematics: an investigation of mathematics education students in School of Education-Can Tho University. *Int J Educ Res*. 2014;2(7):91–98.
11. Podolefsky NS, Finkelstein ND. Use of analogy in learning physics: the role of representations. *Phys Rev Spec Top-PH*. 2006;2(2):20101.
12. Li J, Zhu J The application of analogy method in the teaching of "Microcomputer Principle and Interface Technology. 2013 International Conference on Educational Research and Sports Education (ERSE 2013); Atlantis Press, 2013:27–28.
13. Chen DB, Yang YJ, Zheng LI, Wang JT, Fang ZG. The application of metaphorical teaching method in teaching of the principle and application of microcomputer. *J Nanjing Norm Univ*. 2013;2013:1.

14. Petchey S, Treagust D, Niebert K. Improving university life science instruction with analogies: insights from a course for graduate teaching assistants. *CBE Life Sci Educ*. 2023;22(2):r24.
15. Tise JC, Sperling RA, Dann MS, Young TM, Talanquer V. Teaching postsecondary students to use analogies as a cognitive learning strategy: an intervention. *CBE Life Sci Educ*. 2023;22(1):r10. doi:10.1187/cbe.22-05-0084
16. Gray ME, Holyoak KJ. Teaching by analogy: from theory to practice. *Mind Brain Educ*. 2021;2:1.
17. Zubrowski B. The role of metaphor, models, and analogies in science education. In: Zubrowski B, editor. *Exploration and Meaning Making in the Learning of Science*. Dordrecht, Netherlands: Springer; 2009:311–339.
18. Jonāne L. Using analogies in teaching physics: a study on Latvian teachers' views and experience. *J Teach Educ Sustain*. 2015;17(2):53–73. doi:10.1515/jtes-2015-0011
19. Coll RK, France B, Taylor I. The role of models/and analogies in science education: implications from research. *Int J Sci Educ*. 2005;27 (2):183–198. doi:10.1080/0950069042000276712