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Development and evaluation of an EMP course to teach fMRI technology and brain science in handwriting for university nursing students

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Abstract

In traditional nursing education, brain science is often limited to physiology, anatomy, and pathology, with little emphasis on advanced diagnostic tools like fMRI or the brain's functional processes, such as language learning and handwriting. This study developed an English for Medical Purposes (EMP) course to teach university nursing students about fMRI technology and brain science related to handwriting, highlighting the importance of interprofessional education. The study aimed to (a) assess the course's effectiveness in enhancing students' knowledge in fMRI, brain science, and handwriting; and (b) evaluate the students' satisfaction and perceptions toward the course. A single-group quasi-experimental design with pre/post-tests involved 49 nursing students. Data were collected using the Brain Science Related Knowledge Test (BSKT), assignments, and a Course Satisfaction Questionnaire (CSQ). Results showed significant improvements in students' knowledge of fMRI and brain science in handwriting, with high assignment scores and overall course satisfaction. Students also reported increased awareness of reading professional English journals and learned about fMRI safety issues. This pioneering EMP course effectively introduced nursing students to fMRI technology and brain science in handwriting, potentially enhancing their understanding of normal brain function and its contrast with brain injury cases.

Keywords: English for medical purposes, Functional MRI, Brain science, Handwriting, Interprofessional nursing education

Introduction

English for Medical Purposes (EMP) is a specialized branch of English for Specific Purposes (ESP) that focuses on the language skills and terminology needed by healthcare professionals to effectively communicate in medical settings. EMP courses are designed to enhance the proficiency of non-native English-speaking medical practitioners, students, and caregivers in using medical terminology, understanding medical texts, and engaging in professional communication with colleagues and patients (Choi, 2021). The curriculum typically includes medical vocabulary, reading and interpreting medical literature, writing medical reports, and practicing spoken interactions in clinical contexts (Lai, 2016). EMP is essential for ensuring that healthcare professionals can provide high-quality care, collaborate with international colleagues, and stay updated with the latest medical research and practices published in English (Su et al., 2022). By improving their medical English skills, healthcare workers can enhance patient safety, improve healthcare outcomes, and advance their careers in the global medical community (Tai et al., 2021).

The development of an EMP course for nursing students is grounded in the necessity of equipping future nurses with the linguistic skills required to navigate the increasingly globalized healthcare environment. Nurses often encounter medical literature, documentation, and communication scenarios that are predominantly in English (Choi, 2021). By integrating EMP into the nursing curriculum, educational institutions can better prepare their students for the demands of the healthcare profession, both locally and internationally (Tai et al., 2021).

However, the development of an EMP course to teach fMRI technology and brain science for university nursing students is rarely discussed in the literature. Over the past two decades, the application of functional magnetic resonance imaging (fMRI) technology has extended beyond medical diagnostics. It has provided fields such as psychology and neuroscience with a non-invasive way to investigate the brain. For healthy individuals, fMRI serves as an alternative research instrument to collect physiological signals directly from the brain (Wu et al., 2021). Relationships between brain activation areas and behaviors, cognitive development, and learning processes can be identified through image scanning (Wu et al., 2021). The contrast between healthy individuals and patients with brain lesions can have complementary teaching value in medical education (Celone & Stern, 2009).

In the traditional nursing curriculum, few courses address fMRI and brain sciences (Lee et al., 2022). For instance, the national licensure examination for registered nurses in Taiwan includes subjects such as fundamental medicine, nursing basics, medical and surgical nursing, obstetrics and pediatric nursing, and psychiatric and community nursing (Yang et al., 2019). Brain science is often covered at an advanced level for nurse practitioners (NPs) or physicians. Additionally, understanding medical imaging technology is typically not included in the curriculum (Alghamdi et al., 2022). Only an elective course on X-ray image interpretation is taught by hospital radiologists. Introduction to medical imaging technologies, such as computed tomography (CT), MRI, and angiography, is considered non-nursing knowledge. Even in clinical practice, nurses may need to accompany patients to these departments without fully understanding the procedures (Madl et al., 2022). For frontline nurses, a lack of awareness and knowledge about fMRI and brain sciences is a significant gap (Alghamdi et al., 2022).

While it is true that the current nursing shortage in Taiwan and the requirements for the national nursing exam do not mandate knowledge of advanced topics like fMRI technology and brain science, there are compelling reasons to include these subjects in an EMP course for nursing students. The inclusion of advanced content can help bridge the gap between basic nursing education and the demands of modern healthcare environments (Santarém Semedo et al., 2020). As medical technology evolves, nurses are increasingly expected to be familiar with advanced diagnostic tools and their applications, even if they are not specializing in critical care. Understanding fMRI technology and brain science can enhance a nurse's ability to interpret and communicate complex medical information, improving patient care and outcomes (Alyami et al., 2024). This knowledge is particularly valuable in critical care units, neurology, neurosurgery, psychiatry, emergency rooms, and radiology departments.

Furthermore, integrating advanced medical content into EMP courses aligns with the educational philosophy of developing well-rounded healthcare professionals equipped with the technical skills and linguistic competence to excel in a globalized medical community (Jiang et al., 2024). This approach enhances the cognitive and professional skills of nursing students and prepares them for potential future roles that may require a deeper understanding of medical technology and brain science.

Alternatively, the development of neurolinguistics in language research may help to compensate for the gap in medical/nursing education. Cognitive science and brain neurophysiology are topics that language scholars are eager to explore, with significant literature accumulated (Enge et al., 2020). The application of fMRI and brain science in language topics extends beyond neurolinguistics to second language learning (Liu et al., 2021) and handwriting (Planton et al., 2017). However, this knowledge is not incorporated into professional courses in foreign languages or linguistics, nor in general (language) education. In medicine and nursing, it is rarely mentioned. Introducing handwriting research in brain science into nursing education may provide inspirations for human learning, knowledge acquisition, and normative contrasts between healthy individuals and patients.

Regarding the research framework, this study applied the Technological Pedagogical and Content Knowledge (TPACK) model as shown in Figure 1. The TPACK model provides teachers with a scaffold to effectively deliver subject-specific content (Ammade et al., 2020; Tai et al., 2015). It integrates technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPACK) to organize and adjust the teaching of a specific subject. Technologically, MRI machines, scan features, and image processing are TK to be taught. Pedagogically, a thematic approach selects a topic and carries out related teaching content, emphasizing the relationship between disciplines and real-life knowledge (Moyer, 2016). Contently, fMRI, brain science, handwriting, and EMP are multidisciplinary CK to be delivered.

Background

In Taiwan's two-year vocational system, nursing students generally exhibit low English reading ability. Before entering university, the educational focus of a five-year junior college is centered on the development of technical and professional subjects (Su et al., 2022). In contrast, the number of teaching hours and the depth of course requirements for fundamental subjects like English and mathematics are significantly fewer than those in senior-high schools (Tai et al., 2021). The cultivation of English capability in junior colleges emphasizes listening and exposure to basic language knowledge (Tai et al., 2015). Graduation thresholds are typically set at the Common European Framework of Reference for Language (CEFR) A2 level, which is designed for junior-high school students. This low threshold can result in a low pass rate for general English competence tests when students enter university, which requires a higher graduation threshold of CEFR B1. While lower learning motivation contributes to this issue, the critical reasons may include a lack of reading and vocabulary skills (Tai et al., 2016). Regular departmental reports indicate that students have a higher pass rate in listening tests but a lower rate in reading (Lai, 2016). When students were asked about their low reading ability, they responded that English had not been a focus since their time in five-year junior colleges. Instead, the emphasis was on passing the registered nurse license and developing clinical skills, which are crucial for both the colleges and the nursing students (Tai et al., 2021).

The teaching of English reading ability may better integrate the medical and nursing content to meet the learning needs of nursing students. In the process of language learning, knowledge involves at least two levels: one is linguistic knowledge in semiotics, which is the surface or explicit knowledge of vocabulary and grammar that EFL (English as foreign language) teachers most often teach. The other is the content/domain knowledge, or implicit knowledge contained behind the language (Dienes & Perner, 1999). The interleaving design of these two kinds of knowledge makes language teaching reflect different levels of difficulty and orientation. Most EFL textbooks focus on the delivery of linguistic knowledge but not the domain knowledge (Sun & Dang, 2020). Especially for those designed for low proficiency students, the teaching materials usually contain insufficient content knowledge. The basic assumption is that students with low competence should pay attention to linguistic knowledge first.

However, the linguistics-focused content may not be suitable for the cognitive development of university nursing students. Topics of daily conversations, travel and shopping, cultural customs, English movies, and English songs may not align with the university's philosophy of nurturing professional knowledge and skills. Nursing students tend to perceive a general English course is similar to those taught in junior-high schools and five-year junior colleges, nothing but continuing to learn extensively (Tai et al., 2021). Alternatively, the development of English for specific purposes (ESP), English for medical/nursing purposes (EMP/ENP), and English for academic purposes (EAP) (Liu & Hu, 2021) may offer an option for the content selection (Su et al., 2022). The integration of domain knowledge empowers EFL teachers to have greater flexibility and pedagogical options to design courses that may better meet the learning needs. The theme of this study integrates two kinds of knowledge, linguistics and content, to deepen the content of language learning and achieve a virtuous circle of teaching and learning. The content knowledge of fMRI, brain science, and handwriting, which is relevant to the medical fields of neurology, neurosurgery, psychiatry, emergency rooms, and radiology, may help improve nursing students' understanding of human brain.

Therefore, this study is designed to implement an EMP course integrating the content knowledge of fMRI, brain science, and handwriting for nursing students in an EFL classroom. The two main purposes are to: (a) examine effectiveness in enhancing students' content knowledge; and (b) survey students' satisfaction and perceptions.

Method

Research design

This study employed a single-group quasi-experimental design to compare the outcomes of nursing students' competences between pre- and post-tests, without including a comparison group. A mixed-methods approach was adopted, integrating both quantitative and qualitative data to provide a comprehensive analysis of the teaching intervention. The research was conducted over one semester, from February to September 2022. Figure 1 illustrates the research framework, outlining the various stages and components of the study.

The quantitative component included pre- and post-tests to measure changes in students' knowledge and skills related to fMRI technology and brain science. These tests evaluate cognitive capabilities, practical skills, and overall understanding of the subject matter. The quantitative data were analyzed using descriptive statistics and Repeated-measure MANOVA (multivariate analysis of variance) to determine the effectiveness of the intervention. The qualitative component involved surveys to gather in-depth insights into students' experiences and perceptions of the course.

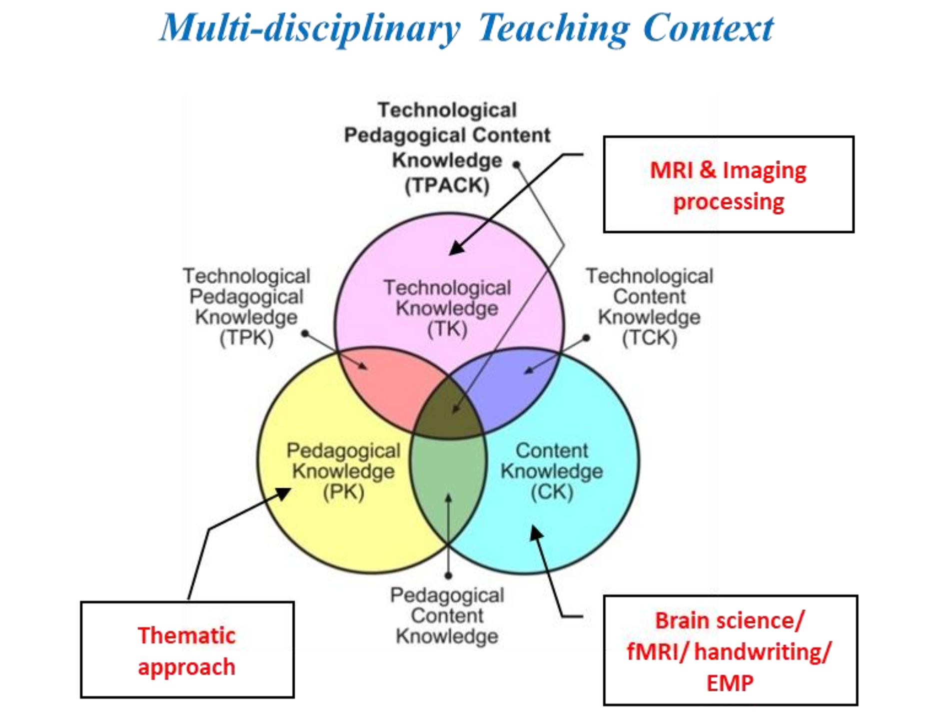


Fig. 1 Research framework of this study

Data collection procedures

Data collection procedures for this study are illustrated in Figure 2. In the first week, a pre-test was conducted to assess the students' knowledge of brain science. The EMP course

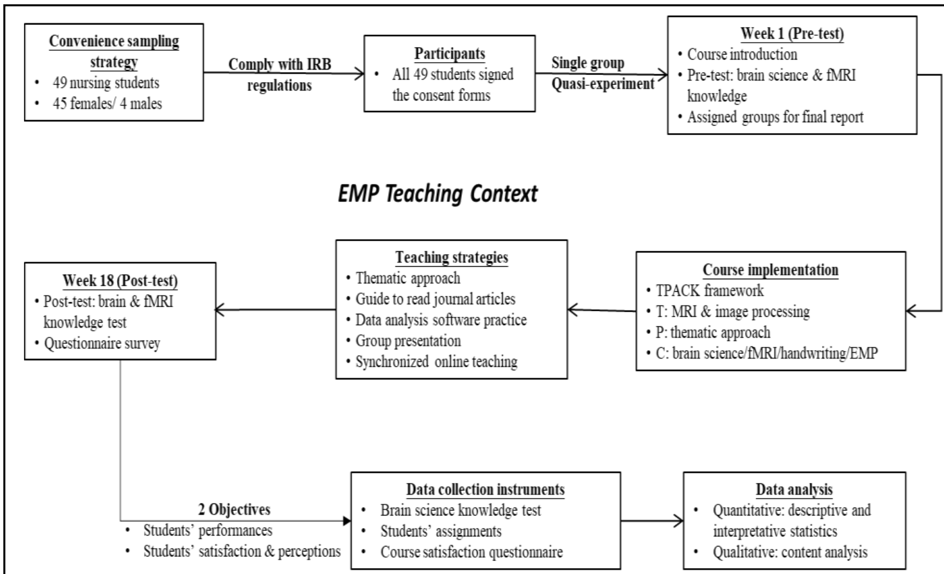


Fig. 2 Data collection procedures of this study

was developed using five teaching strategies based on the three dimensions of the TPACK model (Technological, Pedagogical, and Content Knowledge). In the last week, a post-test with two instruments was administered. Three instruments were utilized to collect quantitative and qualitative data, aimed at addressing the two objectives of the study: evaluating the students' performance, course satisfaction, and perceptions.

Participants

A total of 50 participants, including 49 nursing students and one EFL teacher who also served as the Principal Investigator (PI) and main researcher, were invited to participate in the study. The nursing students (mean age: 20.9 ± 0.38) were conveniently selected from a class taught by the PI. These students were in their first year of a two-year vocational education system at a University of Science and Technology in southern Taiwan.

The inclusion of the EFL teacher as a participant is noteworthy. The EFL teacher's dual role as both educator and researcher offered several advantages and potential influences on the study. Firstly, the EFL teacher's direct involvement in teaching allowed for an integrated perspective on curriculum implementation and student responses. This facilitated a deeper understanding of the educational context and the nuances of student interactions and learning processes. Secondly, being actively engaged in the classroom, the teacher-researcher could provide immediate feedback and make necessary adjustments to teaching strategies in real time. This responsiveness helped tailor the EMP course to better meet student needs. However, the dual role could also introduce bias, as the teacher-researcher might unconsciously influence student responses or interpretations of data. To mitigate this, rigorous data triangulation and validation methods were employed.

Course implementation

A semester's thematic teaching and learning activities were aimed at enhancing students' knowledge in four areas: (a) the application of fMRI technology in brain science, (b) the application of fMRI technology in handwriting, (c) the practice of fMRI data analysis, and (d) the reading comprehension of professional journals in English.

Five teaching strategies – thematic approach, fMRI data analysis software practice, guidance on reading English journals, group presentation, and synchronized online teaching - were implemented. Their categorical features in the TPACK model are shown in Appendix 1. The first strategy - thematic approach - is a commonly used pedagogy in education, which advocates that the curriculum should be linked with real life (Cook & Pitre, 2021). An objective of the thematic approach is to apply the teaching of cognitive skills, such as reading, mathematics, science, and writing, into practice of the real world (Norris, 2019). It has been practiced in many fields like language, science and technology, medicine, and engineering, and has been proven quite effective in the literature (Moyer, 2016). Based on the notion of the thematic approach, a semester of teaching schedules, collaborative teachers, and tasks around the topic of brain science are shown in Appendix 2.

In the first week, a routine introduction to the course, including teaching materials and pedagogy, syllabus, assessment criteria, and detailed weekly schedule, was delivered. Then, a pre-test of cognitive ability measurement, including the ability test of brain science knowledge and the basic understanding of fMRI, was conducted. In the second week, the nursing professor specialized in anatomy assisted nursing students in reviewing basic anatomy of the brain. In the third week, the hospital's attending radiologist taught about the fundamentals of fMRI machines, patient safety in the fMRI room, and interpretations of fMRI images of common clinical cases. During the fourth and fifth weeks, the neuropsychologist shared his insights and experiences on functional fMRI experiments and research. He also taught students about current trends in fMRI in brain science and applications in healthcare education.

The second strategy - guidance on reading English journals - was taught during the 7th to 9th weeks for the first journal, and the 13th to 15th weeks for the second. The PI, who is also a professional English teacher, led the students to read two journal articles written in English. The first paper concerned the application of fMRI technology to the handwriting activities, and the second was about a meta-analysis of previous research of the same topic.

The third strategy - fMRI data analysis software practice - was held by a one-day workshop integrated at the 10th to 12th weeks of classes. A professional data analyst instructed the nursing students step by step on how to use the fMRI image processing software to learn some simple techniques. The results of these easy-to-use analyses were submitted as the interim reports for assessment (see Appendix 3).

The fourth strategy - group presentation - was implemented in the last two weeks. Students were divided into 12 groups of four to five people each to conduct a group presentation as their final-term report. The language teacher prepared four papers on topics related to brain science and writing, with each paper reported by three groups. Every paper was divided into three sections: abstract and introduction, research methods and results, and discussion and conclusions. This arrangement aimed to reduce the students' workload and make it easier for them to learn from each other, given the challenging nature of the papers written in English. These presentations were conducted through the Webex teaching platform and assessed on content accuracy, presentation clarity, and audience engagement.

The fifth strategy was synchronized online teaching. Due to the epidemic situation, the two final-report sessions were conducted online in a synchronous manner. Each group first uploaded the content of the report to the online teaching platform (e-Campus), and then orally reported the content they were responsible for online via Webex software (see Appendix 4).

Instruments

The first two instruments, the students' competence test and assignments, are designed to answer the first research question; while the third one - the course satisfaction questionnaire - is for the second research question listed as follows.

Students' competence test (BSKT)

The first instrument, designed by the researchers, is a brain science-related knowledge test (BSKT). The BSKT was developed by selecting crucial concepts from the lecture notes of the three collaborative teachers. It includes 25 multiple-choice questions: four items regarding the anatomy of the brain, 13 on the fMRI machine and safety issues, and eight on handwriting-relevant brain areas (see Appendix 5). The BSKT was administered both before and after the course, whilst results were not considered in the formal assessment of this course. Each question was worth 1 point, with a total possible score of 25. A score of 15 (60%) was considered a passing grade, while a score of 20 (80%) or above was considered a high grade. Reliability (Cronbach's α) of the instrument for the pre- and post-test were 0.78, 0.77, and 0.95 respectively.

Students' assignments

Three assignments, an in-class quiz, a mid-term report, and a final report, were appointed for the students to learn, and they served as quantitative data. Cronbach's α of the evaluation tool for assignments was 0.66. Regarding the in-class quiz, the language teacher picked up 20 medical terms from the two journals that he had guided reading. Students were required to memorize and recited these 20 words at home and were tested on 10 among the 20 at the beginning of the next week's class (see Appendix 6). Each term was worth 10 points, with a total possible score of 100. A score of 60 (60%) was considered passing, and a score of 80 (80%) or above was considered high. Since this course still included the cultivation of EFL ability for medical and nursing purposes, vocabulary memorization and reading comprehension of English journals were necessary. These medical terminologies were helpful for the students' clinical work in the future.

For the mid-term report, a sample of a set of real brain imaging data collected from handwriting experiments conducted by our lab in the previous studies was carefully designed to allow the students practice some simple analysis. Led by the radiologist and fMRI image data analyst, we combined three weeks' classes into a one-day workshop (6 hours) for the students to experience and understand the fMRI data analysis. Three free software, MRIConvert (Robert and Beverly Lewis Center for Neuroimaging, 2016), MRIcroGL (Rorden & Brett, 2000), and RadiAnt (Medixant, 2021), were introduced for installation and practice. Students submitted the analysis and processing results as the assignments for the mid-term assessment, which were graded out of 100 points. A score of 60 points was passing, and 80 points or above was high (see Appendix 3).

As for the final report, this EFL course aimed to improve the nursing students' competences in reading and comprehending English journals related to brain sciences. After reading the assigned articles, students in 12 groups worked together and submitted a written report to the online learning platform of e-Campus. In the last two weeks, a short presentation was arranged for each group to report the important findings of the literature in the form of slides through synchronized online teaching via the Webex teaching platform (see Appendix 4). The final report was also graded out of 100 points, with a score of 60 points considered passing and 80 points or above considered high (see Appendix 7).

The group presentations served as a collaborative exercise to enhance students' communication skills and ability to synthesize and present scientific information. While these presentations were part of the overall course activities, the primary evaluation of the course's effectiveness relied on individualized assessments through pre- and post-tests results (BSKT) and the course satisfaction questionnaire (CSQ). The group presentations complemented these assessments by providing an opportunity for students to engage deeply with the course material in a team setting.

Course Satisfaction Questionnaire (CSQ)

The third instrument, the Course Satisfaction Questionnaire (CSQ), is specifically designed for this course by the researchers to collect the nursing students' feedback on the course. It contains two parts: the first part has 26 quantitative questions using a five-point Likert scale to investigate the students' opinions about the course from three dimensions of the TPACK model (see Appendix 8). Cronbach's α of the CSQ was 0.94. Each question was rated from 1 (strongly disagree) to 5 (strongly agree), with higher mean scores indicating greater satisfaction. In addition, an exploratory factor analysis was performed, and three factors - labeled as "brain science", "journal reading", and "course design" - were identified. These three factors could explain 91.7% of this instrument. The second part is a structured qualitative survey with six open-ended questions to investigate the students' perceptions of the TPACK model.

To ensure expert validity for the survey, we invited a panel of experts in neuroscience, radiology, nursing education, and language teaching. We developed an initial draft of the survey, focusing on key areas of the integration of fMRI into the English course, including: brain sciences, safety issues of the fMRI room, teachers' teaching, assessments and reports, and students' English reading competence and learning strategies. This draft was distributed to the experts, who provided feedback on the clarity, relevance, and comprehensiveness of each question. Based on their feedback, we revised the survey to improve clarity and ensure all relevant topics were covered.

To increase the reliability of our qualitative survey, we standardized the administration process to ensure all participants received the survey under the same conditions and were provided clear instructions. We trained survey administrators to follow consistent procedures. We developed clear, concise, and unambiguous questions, using a consistent format throughout the survey. We created a reliable coding scheme for open-ended responses so that multiple researchers who helped code the same responses and resolving discrepancies.

Finally, the quizzes and tests were carefully designed to assess the students' understanding and cognitive processing of key concepts in fMRI technology and brain science. For instance, the quizzes included questions that required students to identify and explain fundamental principles of fMRI, such as the mechanisms of brain imaging and safety protocols. Additionally, the mid-term and final tests incorporated practical application tasks where students analyzed brain imaging data, interpreted results, and discussed their implications in a clinical context. These assessments were aligned with the course objectives to ensure that they effectively measured the students' cognitive capabilities in understanding and applying fMRI technology and brain science knowledge.

Data analysis

Data were analyzed quantitatively and qualitatively. Quantitative data, generated from the BSKT, were processed using SPSS software version 26 (IBM Corp., 2019), which mainly performed repeated-measure MANOVA and descriptive statistics.

For the qualitative data, six open questions from the CSQ were coded through a content analysis method (Roller, 2019). For each code, we wrote clear definitions and included examples from the data to illustrate their application. These codes were then organized logically into a coding book, grouping related codes together into categories such as positive and negative themes. To ensure consistency, we applied the initial codes to a subset of the data, checking for clarity and revising as necessary. We also conducted inter-coder reliability checks where multiple coders independently coded the same data and compared results, resolving discrepancies and refining the coding book accordingly. For example, the code "Innovative" was defined as responses indicating that the course or teaching method was seen as new or creative, with criteria specifying its use when responses explicitly mentioned the novelty or uniqueness of the course. The code "Difficult" captured responses indicating that the course content or teaching method was challenging, with examples provided for clarity.

To ensure the reliability of the coding process, we conducted panel meetings with three coders, beginning with individual coding of a subset of data using a preliminary coding framework. In the first meeting, coders discussed their initial codes, refined definitions, and resolved discrepancies, updating the codebook accordingly. After re-coding the data with the revised framework, a second meeting finalized the codes, ensuring consistency. Coders then independently coded the full dataset, followed by a third meeting to review results and resolve any remaining discrepancies, aiming for high inter-coder reliability.

Ethical considerations

Ethical review had been applied for and permission had been granted from the Institutional Review Board (IRB) of Chang-Gung Medical Foundation (issue no: 202101276A3C501) before commencement of the teaching experiment.

Results

The first two results - students' performance after implementation and assignments - attempt to answer the first research question, while the third and fourth, students' satisfactions and perceptions about the course - address the second research question, as demonstrated as below.

Students' performance after course implementation

From the comparison of the test results before and after the course implementation, repeated-measure MANOVA test showed that the students' knowledge of brain science demonstrated significant statistical differences (see Table 1). A further contrast analysis of the BSKT also showed significant differences in each of the three dimensions. Descriptive statistics of the BSKT are shown in Table 2.

Table 1 Students' performance evaluation after the EMP course implementation

Multivariate tests	Test method	Value	F	df	*error df*	*p*	Partial η^2	Observed Power
Teaching intervention	Wilks' Lambda	.60	7.70	4	46	.000***	.40	.995
Univariate tests	**Dimension**	**Mean Square**	**F**	**df**	***error df***	***p***	**Partial η^2**	**Observed Power**
Within Subjects	fMRI	2959.360	29.809	1	49	.000***	.378	1.00
	Anatomy	243.360	14.531	1	49	.000***	.229	.96
	Handwriting	595.360	11.741	1	49	.001***	.193	.92
	Total	8836.000	25.547	1	49	.000***	.343	1.00

Table 2 Descriptive statistics of the BSKT

Descriptive statistics	Dimension	N	Items	Min	Max	Mean	SD
Pre-test	fMRI	49	13	0	40	27.60	8.86
	Anatomy	49	4	0	16	8.80	4.12
	Handwriting	49	8	0	32	18.80	7.10
	Total	49	25	0	76	55.28	14.18
Post-test	fMRI	49	13	0	52	38.48	12.90
	Anatomy	49	4	0	16	11.92	4.68
	Handwriting	49	8	0	32	23.68	8.12
	Total	49	25	0	100	74.08	23.61

*** *p<.001*

Students' assignments

The three scores of the nursing students' assignments are: in-class quiz (M = 97.20; SD = 4.76), mid-term report (M = 97.84; SD = 2.94), and final report (M = 92.70; SD = 3.38).

Students' satisfactions about the course

Table 3 shows the nursing students demonstrated a fairly satisfied attitude toward this course (M = 4.00 ± 1.02). The highest score ranked by the students was the teachers' effort devoted to the teaching (M = 4.63 ± 0.53), whilst the lowest was about the learning activities which were quite demanding and strenuous (M = 3.60 ± 1.07).

Students' perceptions about the course

The six open-ended questions responded by the nursing students are synthesized in Table 4. Positive themes were coded from the first five questions, which were 56.8%, 66.7%, 80%, 75.6%, and 51.1% respectively. The most frequent codes formed by these themes were "innovative (37.8%)", "interesting (37.8%)", "increase awareness (60.0%)", "professional (60.0%)", and "overall good (28.9%)" respectively. For the sixth question in terms of the "English reading competence", students believed that "overall English ability (28.9%)" was the key to their "improvement needs (75.6%)", and "reading more journals (44.4%)" was critical to the "improvement strategies (77.8%)".

Table 3 Students' satisfaction scores about the EMP course

Mean	Lowest	Highest	Range	Low/High	Variance	Items	N	Cronbach's α
4.00	3.60	4.63	1.02	1.28	0.07	26	49	.94

Item	Questions	Mean	S.D.
14	I believe the teachers were responsible for teaching in this semester.	4.63	0.53
10	In the process of learning to read professional journals in English, I believe that I needed to strengthen my vocabulary skills the most.	4.46	0.58
24	I think the guidance and response of the teachers in this semester's learning activities is appropriate.	4.27	0.77
11	In the process of learning to read professional journals in English, I feel that grammar skills are the most in need of strengthening.	4.23	0.72
9	I believe it is important to learn to read professional journals in English.	4.23	0.66
5	I'd like to learn about fundamentals of MRI machine, and issues related to patients' and staffs' safety.	4.19	0.70
13	I believe that my classmates dedicated themselves to participating in the learning activities of this course.	4.19	0.70
22	The design of the performance evaluation in each learning activity is appropriate.	4.17	0.81
12	I've been involved in the learning activities of the course during this semester.	4.17	0.66
26	The implementation and feedback of the final report is appropriate.	4.15	0.74
25	The implementation and operation of the mid-term report is appropriate.	4.10	0.86
21	Overall, I think the curriculum design is helpful to acquire knowledge of brain science.	4.02	0.76
16	Overall, I think the implementation of the fMRI thematic English course is helpful to improve my medical and nursing professional ability.	3.98	0.89
20	I think the learning activities designed in this course have created a good English learning environment.	3.98	0.81
2	I'd like to learn knowledge about brain science.	3.94	0.81
23	There is a class designed to be taught in English as medium of instruction (EMI); and I think this kind of learning experience is appropriate.	3.88	0.73
3	I'd like to learn knowledge about MRI machine and infrastructure.	3.83	0.88
15	Overall, I think the implementation of fMRI thematic English course is helpful for improving my English ability.	3.83	0.86
8	I'd like to learn the skills of reading professional journals in English.	3.81	0.73
19	I think the semester's curriculum design is appropriate for the English course.	3.79	0.94
7	I'd like to know how to graphically present fMRI experimental results.	3.79	0.90
4	I'd like to know how the application of fMRI technology in language research.	3.75	0.89
18	I think this semester's learning activities have given me a lot of ideas on how to improve my English language proficiency.	3.73	0.79
6	I'd like to know the procedures and software operation of fMRI data analysis.	3.67	1.02
17	Overall, I think the learning activities implemented in this semester were helpful in improving my interpersonal communication skills.	3.67	0.91
1	I think this semester's learning activities are quite demanding and strenuous.	3.60	1.07

Table 4 Students' perceptions about the EMP course

Question	Theme	Code	Student responses
1. Perceptions about integration of fMRI into English course	Positive (n = 25; 56.8%)	Innovative (n = 17; 37.8%)	The course is interesting, and the way of teaching is innovative. (ID.13)
		Helpful (n = 8; 17.8%)	I think the course is great. It combines medicine and English, and it also increases my knowledge about clinical equipment. (ID.20)
	Negative (n = 16; 35.6%)	Difficult (n = 10; 22.2%)	I found it a little more difficult. It would be easier to understand if we could read it from a simpler journal or watch some videos. (ID.30)
		Not interested (n = 3; 6.7%)	I don't have much interest in the topic of fMRI, which makes it difficult for me to listen in the classes. (ID.39)
		Not helpful (n = 3; 6.7%)	I don't think it will help much if you are not going to specialize in this clinical track. (ID.4)
2. Perceptions about the brain sciences	Positive (n = 30; 66.7%)	Interesting (n = 17; 37.8%)	I think brain science is cool. The researchers asked subjects to write by hand and then recorded their brain activities by measuring of cerebral blood flow. (ID.38)
		Helpful (n = 13; 28.9%)	This course provides an understanding of the importance of MRI in medicine. It can be used to study brain science and can also assist doctors in diagnosis. (ID.35)
	Negative (n = 5; 11.1%)	Difficult (n = 4; 8.9%)	It is kind of difficult. (ID.15)
		Boring (n = 1; 2.2%)	There may be other ways that are more interesting and engaging to help learn it. (ID.10)
3. Perceptions about safety issues of MRI room	Important (n = 36; 80.0%)	Increase awareness (n = 27; 60.0%)	Every protective procedure and facility have a reason. After understanding the principle, I will pay more attention to the details when accompanying patients for an imaging examination in the future. (ID.5)
		Explain to patients (n = 9; 20.0%)	I am more aware of how the scanning room is constructed. I am also able to explain the safety of MRI to the patients. (ID.10)
	Neutral (n = 7; 15.6%)	No comments	No comments
4. Perceptions about the teachers' teaching	Positive (n = 34; 75.6%)	Professional (n = 27; 60.0%)	The teachers are all very attentive in teaching the content of their professional fields. What impressed me the most was the part where the radiologist explained the safety of fMRI for the patients. (ID.14)
		Interesting (n = 7; 15.6%)	Brain imaging technology is fascinating. (ID.1)
	Neutral (n = 9; 20.0%)	No comments	No comments
	Negative (n = 1; 2.2%)	Demanding (n = 1; 2.2%)	There is too much content to prepare for the presentation of the final report. (ID.13)

5. Perceptions about assessments and reports	Positive (n = 23; 51.1%)	Overall good (n = 13; 28.9%)	The teacher was not too strict with exams and reports and did not put us under too much pressure. I feel great, and I also understand where we need to improve. (ID.14)
		Mid-term report (n = 7; 15.6%)	The midterm report was special. The teacher taught us to practice the imaging processing software. He guided us patiently to understand how the images are analyzed and presented, and the meanings of the colors. (ID.21)
		Final report (n = 3; 6.7%)	The final report required us to report the literature to other students. On one hand, it allowed me to understand the content of many other related literatures, and these contents have also been taught by the teacher in class. (ID.21)
	Negative (n = 17; 37.8%)	Final report (n = 11; 24.4%)	Reading papers and translation in general English is OK. But if it comes to the type of research, it will be a bit difficult to comprehend those professional literature, such as fMRI in language learning. (ID.37)
		Mid-term report (n = 3; 6.7%)	Although the lecturer took us step by step to make the process easier, I still didn't understand why the midterm exam results were assessed through imaging analysis. (ID.23)
		Overall bad (n = 2; 4.4%)	For the English course, I still prefer paper-based exams, such as multiple-choice, terminology exams, grammar exams, and sentence exams...all of them are fine. Or, perhaps, the topics of the English report could be changed to daily life experience, for example, food, travel, etc. I think reporting on topics of personal interest in English would be better. (ID.9)
	Neutral (n = 10; 22.2%)	No comments	No comments
6. Perceptions about English reading competence	Improvement needs (n = 34; 75.6%)	Overall English ability (n = 13; 28.9%)	My English abilities need to be greatly strengthened very much. It is difficult for me to deal with medical journals and professional terminology. (ID.32)
		Vocabulary (n = 10; 22.2%)	After reading the literature given by the teacher, I found that the words I did not know made up as much as 80%. (ID.35)
		Terminology (n = 9; 20.0%)	After reading the journals, I found that I need to learn more professional terms. However, I can feel my progress in learning some of these terms. (ID.5)
		Grammar (n = 2; 4.4%)	My grammar ability needs to be strengthened. (ID.33)
	Improvement strategies (n = 35; 77.8%)	Reading more journals (n = 20; 44.4%)	I think it is better to first understand the topic well, list common words, and draw a concept map to develop a contextual understanding. Then, read the journal so that I can grasp the key points faster and avoid reading it sentence by sentence. (ID.27)
		More vocabulary (n = 12; 26.7%)	I hope that I can increase my vocabulary to comprehend the journal correctly. (ID.31)
		Listening news more and reading journals (n = 3; 6.7%)	I can listen to English news and read journals and magazines. (ID.34)

Discussion

This research may be a pioneer study conducted in the context of nursing education that is consistent with contemporary brain science research in education (Wu et al., 2021). Regarding the first research question, teaching and learning outcomes of the EMP course were assessed from two aspects. Firstly, students' cognitive abilities in fMRI technology and brain science significantly improved. The BSKT confirmed the students' content knowledge in all four dimensions, including fMRI, anatomy, handwriting, and overall, had been enhanced effectively. The domain/content knowledge, or implicit knowledge (Dienes & Perner, 1999), which is equally important for professional English comprehension, was successfully delivered through the EMP course design and instruction. On the other hand, because of the complexity and difficulty of the linguistic knowledge in medical English, it was difficult to measure the progress of students' linguistic knowledge acquisition. Nevertheless, the design of the final report did show a significant improvement in the students' ability to read professional English journals. Although we did not collect quantitative data, it is evident that without the guidance of this course, these journal articles would have been almost completely incomprehensible to the students.

Secondly, the results of the three assignments submitted by the students were also in line with expectations, and most of the students met the assessment criteria. Their cognitive abilities in both linguistics and domain knowledge were enhanced through practice. The theme of fMRI, brain science, and handwriting, which covered the two fields of neuroscience (Planton et al., 2017) and neurolinguistics (Enge et al., 2020), were integrated into this study. As this EMP course was a relatively difficult, complex, and innovative attempt, it was quite demanding for the students. Therefore, we aimed to give high scores on the assignments to encourage the students and reduce their learning anxiety and cognitive load. The effect of this grading scheme was reflected in the CSQ, where students did not perceive the course as overly demanding and strenuous.

A highlight might be the design of the midterm report. The handling and manipulation of imaging data has rarely been taught in nursing education (Wu et al., 2021). Students may often see many diagnostic images in the clinical settings, but may not know what processes occur behind the scenes of these images. Through simplified presentations and exercises, the students were introduced to some initial concepts in an in-depth manner, which was sufficient for nursing students.

Regarding the second research question, according to the CSQ results, students were fairly satisfied with the EMP course (M = 4.00 ± 1.02). Two of the top five highest satisfaction ratings were for teachers' teaching (M = 4.63 ± 0.53) and vocabulary reinforcement (M = 4.46 ± 0.58). The other three were for effective guidance (M = 4.27 ± 0.77), grammar reinforcement (M = 4.23 ± 0.72), and the recognition of training in reading professional English journals (M = 4.23 ± 0.66) in improving reading skills. Such results are consistent with some previous studies in similar contexts (Su et al., 2022; Tai et al., 2015). In the field of EMP/ENP, reading professional journals is an important skill in clinical practice (Tai et al., 2021), and vocabulary and grammatical competences are the core skills for reading comprehension (Tai et al., 2016).

Regarding the students' perceptions, two prominent issues raised from the responses, which were the safety awareness in the fMRI scanning room (n = 36; 80.0%), and the teachers' teaching (n = 34; 75.6%). First, safety issues in the MRI scanning room are probably the most directly relevant training for the clinical competence of the nursing students. The awareness is hardly ever mentioned or taught in the current curricula (Alghamdi et al., 2022), yet it is so important that the radiologists often need to remind the healthcare professionals in the clinical settings (Madl et al., 2022). The nursing students also expressed their concern and affirmation about the inclusion of this issue. Furthermore, this was also reflected in the design and dedication of the teaching instructed by the professional teachers.

However, not all students appreciated this innovative teaching experiment. Some students preferred the traditional way of EFL instruction. They may have believed that English lessons should be an extension of their past learning, and that they should continue with the daily life content without designing a specialized EMP course (Su et al., 2022). A few of them may have perceived that they only need to do the routine work in clinical practice and did not need to learn the unrelated departmental and/or domain knowledge. Despite the researcher considering the difficulty of the course content when designing the curriculum and making many adjustments to reduce the cognitive load of the students. For example, using a variety of assessment methods, presenting in-depth content in an easy-to-understand way, and arranging step-by-step instructional guidance from cooperating teachers. A few students still mentioned that fMRI and language learning-related content were quite hard to follow. As an innovative curriculum designed for the nursing students who did not have much background knowledge before learning the theme, more caution should be taken to cater to those who had difficulties following the content.

Finally, there may be a teaching implication suggested by this study. Most medical and nursing education focuses on pathology and treatment, and less on the normal functioning of the human body. This is especially true for an organ as complex as the brain. Nursing students may see the lesions caused by the brain damage in a patient without knowing what would be expected under normal function. Therefore, interprofessional nursing education can help students gain a deeper understanding of medical and nursing knowledge, thereby enhancing their ability to apply it in clinical practice and improve patient safety.

Limitations

Three limitations can be noted for this study. First, the study only included an experimental group without a comparison group. The complexity of the course implementation made a comparison group less feasible. Second, while one of the instructional focuses was on students' English reading skills, the emphasis on domain knowledge means that a proficiency measure for the students' linguistic knowledge was not designed. Third, the conclusions of this study may not be directly generalizable to other teaching contexts, as each teaching situation is unique. Replicating the exact results of this experiment in other settings would likely be impractical. Instead, this study is intended to serve as a reference for teachers in similar contexts.

Conclusion

This pioneering EMP program introduced university nursing students to essential knowledge in fMRI technology, brain science, and handwriting, offering valuable insights into the normal functioning of the human brain. By contrasting these insights with clinical observations of brain injury patients, the curriculum enhanced students' understanding and application of brain science in nursing practice. The students' performance and course satisfaction results indicated that the program significantly improved their cognitive abilities in brain science.

The study's findings highlighted the importance of integrating advanced brain science content into nursing education. By increasing awareness of the differences between normal brain function and lesions, this EMP curriculum provided nursing students with a deeper understanding that can ultimately enhance the quality of patient care. As interprofessional nursing education continues to evolve, incorporating such interdisciplinary approaches will be crucial in preparing future healthcare professionals for the complexities of clinical practice.

Appendix

Appendix 1. Teaching strategies and the TPACK model

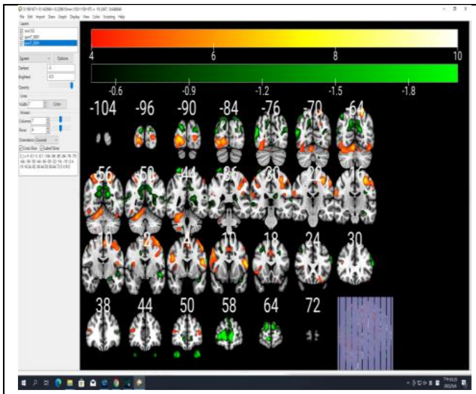
Teaching strategy	TPACK model	Elements
Thematic approach	PK	PK: thematic approach
fMRI data analysis software practice	TPCK	TK: fMRI PK: thematic approach CK: brain science
Guide to read English journals	PCK	PK: thematic approach CK: fMRI, brain science, handwriting, English journals reading
Group presentation	PCK	PK: thematic approach CK: fMRI, brain science, handwriting, English journals reading
Synchronized online teaching	TPCK	TK: fMRI & Internet PK: thematic approach CK: fMRI, brain science, handwriting, English journals reading

Note: TK: technological knowledge; PK: pedagogical knowledge; CK: content knowledge;
TPK: technological pedagogical knowledge; TCK: technological content knowledge;
PCK: pedagogical content knowledge; TPCK: Technological pedagogical content knowledge.

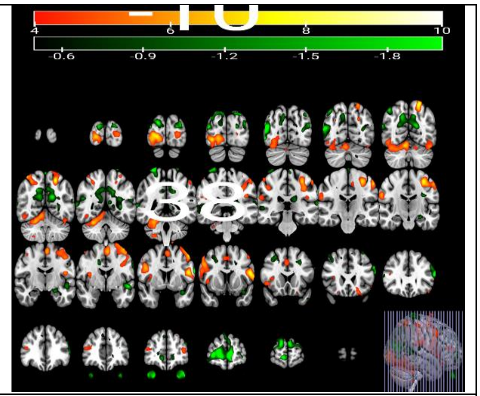
Appendix 2. Teaching schedules, collaborative teachers, and tasks

Week	Topic	Teacher	Task
1	Course Introduction and Signing IRB Consent Form	Principal investigator (PI)	**Pre-test**
2	Physiological Structure of the Brain	Nursing professor	
3	Principles of MRI Imaging	Radiologist	
4	Application of fMRI to brain research	Neuropsychologist	
5	fMRI applied to language research	Neuropsychologist	
6	Independent study (no lecture)		TED Talks
7 8 9	A Guide to the Reading of fMRI Journal written in English (1): "Karimpoor et al. (2018). Functional MRI of handwriting tasks: A study of healthy young adults interacting with a novel touch-sensitive tablet."	EMP teacher/PI	 Quiz 1 Quiz 2
10 11 12	Practice of experimental data analysis on computer lab	Data analyst	**Mid-term Report**
13 14 15	A Guide to the Reading of fMRI Journal written in English (2): "Planton, Jucla, Roux, and Démonet (2013). The "handwriting brain": A meta-analysis of neuroimaging studies of motor versus orthographic processes."	EMP teacher/PI	Quiz 3 Quiz 4 Quiz 5
16	Independent study (no lecture)		TED Talks
17	Presentation of Journal Reading: Final Report (1)	EMP teacher/PI	**Final Report**
18	Presentation of Journal Reading: Final Report (2)		**Post-test**

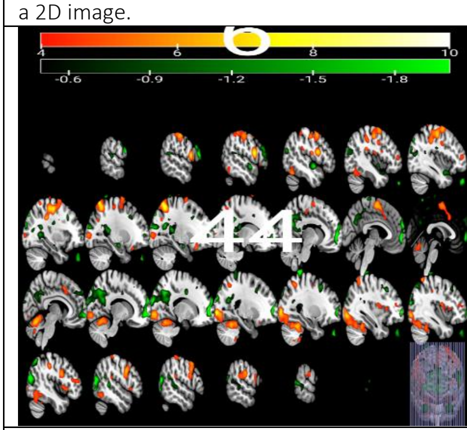
Appendix 3. A sample of the mid-term assignment



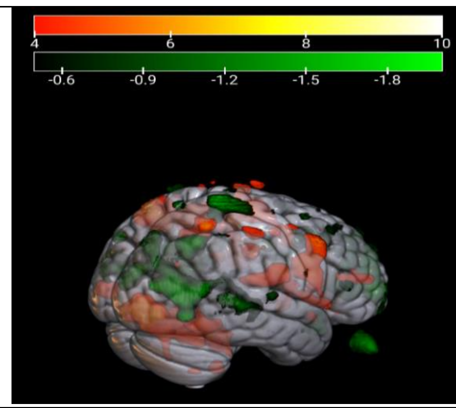
Using MRIcroGL software, the fMRI T-maps are overlaid on the structural image to output a 2D image.



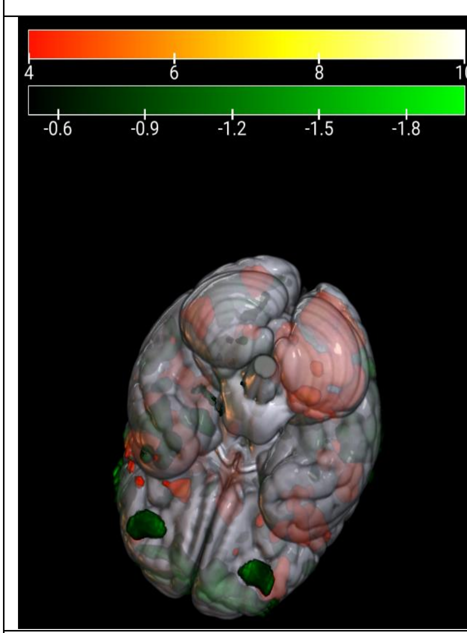
MRIcroGL can output 2D overlays of three different views.



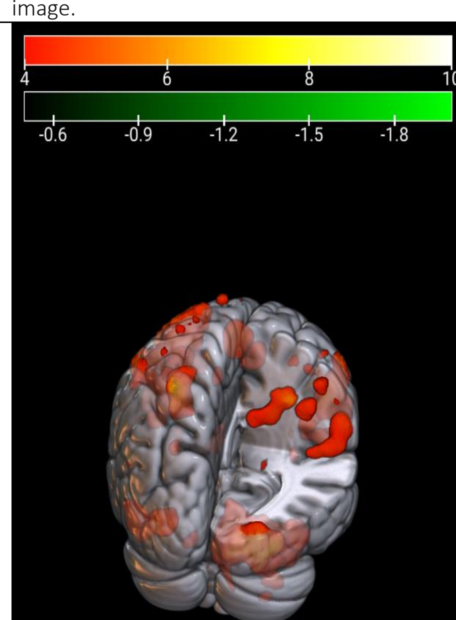
A 2D overlay of another section.



Using MRIcroGL software to overlay the T-maps on the structural image to output a 3D image.



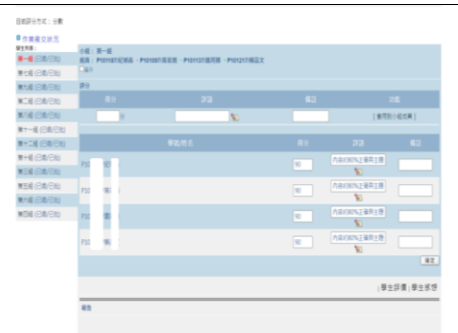
3D images can be rotated to different angles using MRIcroGL.



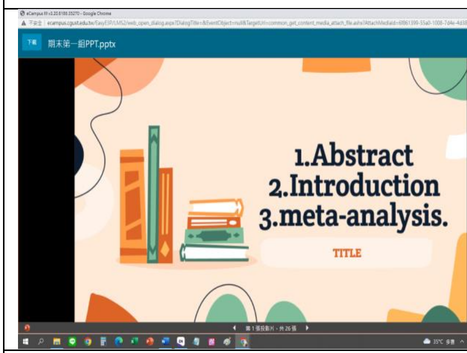
Using MRIcroGL to cut in the 3D image to see the internal view.

Appendix 4. Synchronized online teaching sessions and final report procedures

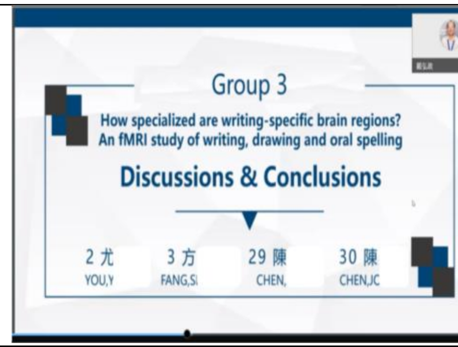
Learning platform – e-Campus. Assessment criteria were provided when giving the assignments



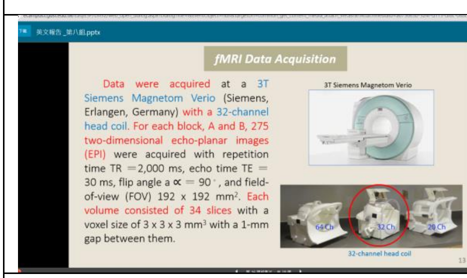
The interface of e-Campus: final reports of 12 groups of students



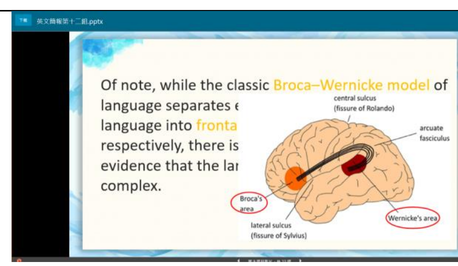
Title page of the final report of the first group of students



Group presentation via Webex software synchronized sessions



Final report of Group 8: Parameters of the fMRI machine



Final report of Group 12: Description of brain regions related to language processing

Appendix 5. The brain science-related knowledge test (BSKT)

Dear participants,
The primary purpose of this questionnaire is to understand your knowledge and understanding of MRI technology and brain science. Your responses are very valuable and will help improve the teaching of this course. The information you provide will be used solely for academic research and will remain confidential. This is not an exam and does not affect your school grades, so please answer honestly based on your own knowledge. Thank you for your cooperation, and best wishes for your academic success.
Sincerely,

1. Which of the following statements about Magnetic Resonance Imaging (MRI) is false?
   a. It can help diagnose malignant tumors.
   b. It can help diagnose joint and ligament injuries caused by sports.
   c. The contrast agent used in MRI has significant harm to the human body.
   d. MRI is invasive to the human body and contains radiation like CT and X-rays.

2. What is the main purpose of using radiofrequency shielding in MRI?
   a. To reduce harm from radiofrequency to the radiologist.
   b. To reduce harm from radiofrequency to the patient.
   c. To reduce the effect of external environmental radiofrequency on MRI signals.
   d. To reduce radiofrequency leakage from the examination room to the outside.

3. Which of the following is not a magnetic material or metal?
   a. Iron
   b. Cobalt
   c. Nickel
   d. Gadolinium

4. When planning a new MRI examination room, which of the following is not an absolute necessity?
   a. Building sturdiness and floor load-bearing capacity
   b. Available space size
   c. Installation floor level
   d. Power supply

5. In an MRI machine, what material is used for the primary magnetic field shielding?
   a. Iron
   b. Copper
   c. Tungsten
   d. Molybdenum

6. Which of the following statements about magnets used in clinical MRI machines is correct?
   a. Only superconducting electromagnets
   b. Only permanent magnets and superconducting electromagnets
   c. Only resistive magnets and superconducting electromagnets
   d. Permanent magnets, resistive magnets, and superconducting electromagnets can all be used

7. Which of the following is the main source of resonance signals in MRI scanning used in clinical settings?
   a. Helium atoms
   b. Nitrogen atoms
   c. Oxygen atoms
   d. Hydrogen atoms

8. Which of the following is most likely to cause a change in the MRI resonance frequency and affect image resolution?
   a. Echo time (TE) settings
   b. Strength of the main magnetic field
   c. Receiver settings
   d. Repetition time (TR) settings

9. In an MRI examination room, which of the following does not have radiofrequency shielding?
   a. Examination bed
   b. Walls
   c. Ceiling
   d. Door

10. What is the principle of MRI?
   a. Injecting a drug like glucose (FDG) into the human vein and collecting signals with a detector
   b. Using X-rays to penetrate the body, obtaining images, and then reconstructing two-dimensional images with a computer to observe the inside of the body
   c. Placing an object in a magnetic field and irradiating it with appropriate electromagnetic waves to change the spin alignment of hydrogen atoms, making them resonate and collecting data for imaging
   d. Blood oxygen level-dependent (BOLD) contrast related to neuronal activation

11. What is the principle of functional MRI (fMRI)?
   a. Injecting a drug like glucose (FDG) into the human vein and collecting signals with a detector
   b. Using X-rays to penetrate the body, obtaining images, and then reconstructing two-dimensional images with a computer to observe the inside of the body
   c. Placing an object in a magnetic field and irradiating it with appropriate electromagnetic waves to change the spin alignment of hydrogen atoms, making them resonate and collecting data for imaging
   d. Blood oxygen level-dependent (BOLD) contrast related to neuronal activation

12. Regarding radiofrequency shielding (RF shielding) in MRI, which of the following statements is incorrect?
   a. The door of the scanning room is equipped with RF shielding
   b. The purpose of RF shielding is to protect the radiologist
   c. Improving RF shielding can reduce zipper artifacts
   d. Copper is the material used for RF shielding

13. Can a person with a pacemaker undergo an MRI scan?
   a. Yes, but it should be avoided if possible
   b. Yes, without any danger
   c. No, the magnetic field will interfere with its operation and cause fatal danger
   d. No, because it will affect image quality

14. When looking up words in a dictionary, the brain’s cortical area controlling the rapid scanning of the eyes is located where?
   a. Frontal lobe
   b. Parietal lobe
   c. Temporal lobe
   d. Occipital lobe

15. Which of the following diseases does not cause impairment in handwriting function?
    a. Alzheimer's disease
    b. Developmental delay
    c. Autism
    d. Schizophrenia

16. Which of the following statements about Activation Likelihood Estimate (ALE) is true?
    a. It is used for meta-analysis of different literature and experiments
    b. Also called maximum likelihood estimation; it is a method used to estimate the parameters of a probability model
    c. It is suitable when there is a model at hand and you want to derive the most likely model parameters to produce these sample results
    d. Often used in language literature analysis

17. Which of the following brain functions is unrelated to handwriting?
    a. Vision
    b. Motor
    c. Language
    d. Hearing

18. Which of the following brain areas is not directly related to the function of writing?
    a. Left superior frontal gyrus (SFG)
    b. Left middle frontal gyrus (MFG)
    c. Left intraparietal sulcus (IPS)
    d. Occipital lobe

19. Which of the following brain areas is related to the motor function of writing?
    a. Left superior frontal gyrus (SFG)
    b. Left middle frontal gyrus (MFG)
    c. Supplementary motor area (SMA)
    d. Left intraparietal sulcus (IPS)

20. In the process of writing, what is the function of the thalamus in brain function areas?
    a. It is a relay station for up and down messages, responsible for transmitting various signals to relevant areas
    b. Mainly involved in self-generated and controlled motor functions
    c. Helps regulate visceral activities and generate emotions
    d. Plays an important role in spatial orientation and navigation in the brain

21. In the process of writing, what is the function of the left posterior inferior temporal cortex (PITC) in brain function areas?
    a. It is a relay station for up and down messages, responsible for transmitting various signals to relevant areas
    b. Helps process shape recognition, language and text processing, and memory of shape and meaning
    c. Helps regulate visceral activities and generate emotions
    d. Plays an important role in spatial orientation and navigation in the brain

22. In the process of writing, what is the function of the Visual Word Form Area (VWFA) in brain function areas?
    a. It is a relay station for up and down messages, responsible for transmitting various signals to relevant areas
    b. Helps process shape recognition, language and text processing, and memory of shape and meaning
    c. Responsible for reading functions and coordinating other text-related information and brain areas
    d. Plays an important role in spatial orientation and navigation in the brain

23. In the process of writing, what is the function of the right cerebellum in brain function areas?
    a. It is a relay station for up and down messages, responsible for transmitting various signals to relevant areas
    b. Helps process shape recognition, language and text processing, and memory of shape and meaning
    c. Responsible for reading functions and coordinating other text-related information and brain areas
    d. Motor control, cognitive function, attention, and language processing

24. In the process of writing, what is the function of Broca's area in brain function areas?
    a. It is a relay station for up and down messages, responsible for transmitting various signals to relevant areas
    b. It is the central hub for language processing, responsible for processing language information and generating speech
    c. Plays an important role in spatial orientation and navigation in the brain
    d. Motor control, cognitive function, attention, and language processing

25. In the process of writing, what is the function of the graphemic/motor frontal area (GMFA) in brain function areas?
    a. Responsible for integrating visual and language processing results, then outputting to motor-related areas
    b. It is the central hub for language processing, responsible for processing language information and generating speech
    c. Plays an important role in spatial orientation and navigation in the brain
    d. Motor control, cognitive function, attention, and language processing

Appendix 6. A sample of the in-class quiz

Quiz 12 (The handwriting brain)

1.	**parietal**	頂葉
2.	**agraphia**	失寫症
3.	**thalamus**	視丘
4.	**putamen**	殼核
5.	**cerebellum**	小腦
6.	**meta-analysis**	統合分析
7.	**angular gyrus**	角回
8.	**inferior frontal gyrus (IFG)**	額下回
9.	**supramarginal gyrus (SMG)**	緣上迴
10.	**superior frontal gyrus (SFG)**	額上回

Appendix 7. Group presentation assessment criteria for the final report

Dimension	Criteria	100	95	90	85	80
Content	Comprehensive Well-researched use of material Understanding thoroughly	Very well achieved	←		→	Not well achieved
Delivery	Clearly presented Organized and easy to follow Engaged with the audience					
Visual aids	Clear and readable slides Visually appealing slides Suitable use of figures/data/diagrams					
Team work	Coherent group presentation Individual work well-integrated into whole					

Appendix 8. The course satisfaction questionnaire (CSQ)

Dear participants,

Hello! The primary purpose of this questionnaire is to understand your feedback and suggestions regarding the practical English scenarios conducted this semester. Your opinions are very valuable and will help improve the teaching of this course. The information you provide will be used solely for academic research and will remain confidential. This is not an exam, and there are no correct answers, nor will it affect your school grades, so please answer honestly based on your own experiences. Thank you for your cooperation, and best wishes for your academic success.

Sincerely,

Part one:

Please circle the number on the right that best matches your personal feelings

I think that the learning activities this semester...	Disagree←→Agree				
1. were quite demanding and challenging.	1	2	3	4	5
2. I really enjoyed learning about brain science.	1	2	3	4	5
3. I really enjoyed learning about MRI technology.	1	2	3	4	5
4. I really enjoyed learning about the application of fMRI in language-related research.	1	2	3	4	5
5. I really enjoyed participating in fMRI experiments myself.	1	2	3	4	5
6. I really enjoyed learning how to operate and analyze data using SPM software.	1	2	3	4	5
7. I really enjoyed learning how to present fMRI experimental results using graphs.	1	2	3	4	5
8. I really enjoyed learning techniques for reading professional English journals.	1	2	3	4	5
9. I believe that learning to read English journals is very important.	1	2	3	4	5
10. During the process of reading English journals, I felt that vocabulary was the area I needed to improve the most.	1	2	3	4	5
11. During the process of reading English journals, I felt that grammar was the area I needed to improve the most.	1	2	3	4	5
12. Throughout this semester, I have been very serious about participating in the course activities.	1	2	3	4	5
13. Throughout this semester, my classmates have been very serious about participating in the course activities.	1	2	3	4	5

I think that the learning activities this semester...	Disagree←→Agree				
14. Throughout this semester, the teachers have been very serious about teaching the course.	1	2	3	4	5
15. Overall, implementing situational English activities has been very helpful in improving my English.	1	2	3	4	5
16. Overall, implementing situational English activities has been very helpful in improving my professional skills.	1	2	3	4	5
17. Overall, implementing writing activities has been very helpful in improving my interpersonal communication skills.	1	2	3	4	5
18. It gave me a lot of motivation to improve my English.	1	2	3	4	5
19. It was very appropriate for an English course.	1	2	3	4	5
20. It created a very good English learning environment.	1	2	3	4	5
21. Overall, the course design for brain science knowledge was very appropriate.	1	2	3	4	5
22. The course evaluation design was very appropriate.	1	2	3	4	5
23. The participation and experience activities related to MRI experiments were very appropriate.	1	2	3	4	5
24. The guidance and responses from the instructors were very appropriate.	1	2	3	4	5
25. The implementation and feedback of the midterm report were very appropriate.	1	2	3	4	5
26. The implementation and feedback of the final report were very appropriate.	1	2	3	4	5

Part two:

This section aims to understand your personal background and your learning situation or perceptions to facilitate data analysis. Please fill in the blanks. Feel free to elaborate and do not leave out any information. If you need more space, please continue the back.

I. What are your views on neuroscience and fMRI imaging technology?

II. What are your views on the teachers' teaching methods?

III. What are your views on participating in fMRI experiments?

IV. What are your views on the preparation of midterm or final reports?

V. How do you evaluate your ability to read English journals, and what strategies do you have for improvement?

(1) Areas that need improvement:

(2) How to improve:

Abbreviations
BSKT: Brain Science Related Knowledge Test; CEFR: Common European Framework of Reference for Language; CK: Content knowledge; CSQ: Course Satisfaction Questionnaire; CT: Computed tomography; EAP: English for academic purposes; EFL: English as foreign language; EMI: English as medium of instruction; EMP: English for medical purposes; ENP: English for nursing purposes; ESP: English for specific purposes; fMRI: Functional magnetic resonance imaging; IRB: Institutional Review Board; NP: Nurse practitioner; PCK: Pedagogical content knowledge; PI: Principal investigator; PK: Pedagogical knowledge; TCK: Technological content knowledge; TK: Technological knowledge; TPACK: Technological pedagogical and content knowledge; TPK: Technological pedagogical knowledge.

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Authors' contributions
CH involved with the research process regarding conceptualization, methodology, investigation, project administration, and was a major contributor in writing the manuscript. CH also helped proofread and revised the manuscript. YH was responsible for the methodology, resources, and funding acquisition. HC analyzed and interpreted the data collected by the instruments and wrote a part of the manuscript. HC performed the duty of writing review and editing, and supervision of the whole process. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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References

Alghamdi, A., Algamdi, M., Alatawi, K., Alghamdi, B., Alanazi, H., Alamri, S., Alamri, S., & Albishi, Z. (2022). Nurses' roles in managing patient anxiety before MRI scans using informative video. *Reports in Medical Imaging, 15*, 9–19. https://doi.org/10.2147/RMI.S353700

Alyami, A., Majrashi, N., Hazazi, L., Ruqayi, A. A., Amri, B. Y., Abdulmajed, W., Masmali, H. M., Refaee, T., Ageeli, W., Alwadani, B., Madkhali, Y., Althobity, A. A., Madkhali, A. A., & Al-Radaideh, A. (2024). Assessment of undergraduates nursing students' knowledge toward MRI safety: Cross-sectional study. *Journal of Radiation Research and Applied Sciences*, *17*(1), 100801. https://doi.org/10.1016/j.jrras.2023.100801

Ammade, S., Mahmud, M., Jabu, B., & Tahmir, S. (2020). TPACK model based instruction in teaching writing: An analysis on TPACK literacy. *International Journal of Language Education*, *4*(1), 129–140. https://doi.org/10.26858/ijole.v4i2.12441

Celone, K., & Stern, C. (2009). A neuroimaging perspective on the use of functional magnetic resonance imaging (fMRI) in educational and legal systems. *The American Journal of Bioethics*, *9*(1), 28–29. https://doi.org/10.1080/15265160802617985

Choi, L. J. (2021). Implementing English for Medical Purposes (EMP) in South Korea: Nursing students' ongoing needs analysis. *Nurse Education Today*, *10*4, 104989. https://doi.org/10.1016/j.nedt.2021.104989

Cook, M. P., & Pitre, L. (2021). *Exploring relationships and connections to others: Teaching universal themes through young adult novels.* Rowman & Littlefield.

Dienes, Z., & Perner, J. (1999). A theory of implicit and explicit knowledge. *Behavioral and Brain Sciences*, *22*(5), 735–808. https://doi.org/10.1017/S0140525X99002186

Enge, A., Friederici, A. D., & Skeide, M. A. (2020). A meta-analysis of fMRI studies of language comprehension in children. *Neuroimage*, *215*, 116858. https://doi.org/10.1016/j.neuroimage.2020.116858

IBM Corp. (2019). *IBM SPSS Statistics for Windows, Version 26.0*. IBM Corp. https://hadoop.apache.org

Jiang, Y., Wu, Y., Deng, Q., Zhou, R., Jin, Q., Qian, S., Jin, S., Tung, T. H., Ji, W., & Zhang, M. (2024). Using teach-back in patient education to improve patient satisfaction and the clarity of magnetic resonance imaging. *Patient Education and Counseling*, *123*, 108195. https://doi.org/https://doi.org/10.1016/j.pec.2024.108195

Lai, Y. C. (2016). English for nursing: An exploration of Taiwanese EFL learners' needs. *Chang Gung Journal of Humanities and Social Sciences*, *9*(1), 27–52.

Lee, A. S., Rebecca Owings, C., Johnson, J. M., & Carruth, M. S. (2022). Brain science-based innovative collaborative teaching to facilitate nursing education. *Journal of Nursing Education*, *61*(3), 162–166. https://doi.org/10.3928/01484834-20211128-08

Liu, C., Jiao, L., Li, Z., Timmer, K., & Wang, R. (2021). Language control network adapts to second language learning: A longitudinal rs-fMRI study. *Neuropsychologia*, *150*, 107688. https://doi.org/10.1016/j.neuropsychologia.2020.107688

Liu, Y., & Hu, G. (2021). Mapping the field of English for specific purposes (1980–2018): A co-citation analysis. *English for Specific Purposes*, *61*, 97–116. https://doi.org/10.1016/j.esp.2020.10.003

Madl, J. E., Sturmbauer, S. C., Janka, R., Bay, S., & Rohleder, N. (2022). Preparing patients according to their individual coping style improves patient experience of magnetic resonance imaging. *Journal of Behavioral Medicine*, *45*(6), 841–854. https://doi.org/10.1007/s10865-022-00361-y

Medixant. (2021, Version 2021.1.). *RadiAnt DICOM Viewer. Medixant*. https://www.radiantviewer.com

Moyer, C. D. (2016). A thematic instruction approach to teaching technology and engineering. *Technology and Engineering Teacher*, *76*(3), 8–12.

Norris, N. D. (2019). Assessing the learned learner when using a concept curriculum in nursing education. *Research Issues in Contemporary Education*, *4*(1), 35–44.

Planton, S., Longcamp, M., Péran, P., Démonet, J. F., & Jucla, M. (2017). How specialized are writing-specific brain regions? An fMRI study of writing, drawing and oral spelling. *Cortex*, *88*, 66–80. https://doi.org/10.1016/j.cortex.2016.11.018

Robert and Beverly Lewis Center for Neuroimaging. (2016). *MRIConvert and mcverter*. University of Oregon. https://lcni.uoregon.edu/downloads/mriconvert/mriconvert-and-mcverter

Roller, M. R. (2019). A quality approach to qualitative content analysis: Similarities and differences compared to other qualitative methods. *Forum Qualitative Sozialforschung Forum: Qualitative Social Research*, *20*(3). https://doi.org/10.17169/fqs-20.3.3385

Rorden, C., & Brett, M. (2000). Stereotaxic display of brain lesions. *Behav Neurol*, *12*(4), 191–200. https://doi.org/10.1155/2000/421719

Santarém Semedo, C., Moreira Diniz, A., & Herédia, V. (2020). Training health professionals in patient-centered communication during magnetic resonance imaging to reduce patients' perceived anxiety. *Patient Education and Counseling*, *103*(1), 152–158. https://doi.org/10.1016/j.pec.2019.08.003

Su, S. M., Tsai, Y. H., & Tai, H. C. (2022). An ESP approach to teaching nursing note writing to university nursing students. *Education Sciences*, *12*(3), 223. https://doi.org/10.21125/edulearn.2019.2710

Sun, Y., & Dang, T. N. Y. (2020). Vocabulary in high-school EFL textbooks: Texts and learner knowledge. *System*, *93*, 102279. https://doi.org/10.1016/j.system.2020.102279

Tai, H. C., Pan, M. Y., & Lee, B. O. (2015). Applying technological pedagogical and content knowledge (TPACK) model to develop an online English writing course for nursing students. *Nurse Education Today*, *35*(6), 782–788. https://doi.org/10.1016/j.nedt.2015.02.016

Tai, H. C., Pan, M. Y., & Lee, B. O. (2016). Effects of attributional retraining on writing performance and perceived competence of Taiwanese university nursing students. *Nurse Education Today*, *44*, 66–73. https://doi.org/10.1016/j.nedt.2016.05.008

Tai, H. C., Tsai, Y. H., Lee, B. O., & Zagar, M. (2021). A cross-sectional study of university nursing students construal level and core values in learning English as foreign language in Taiwan. *Education Sciences*, *11*(11), 717. https://doi.org/10.3390/educsci11110717

Wu, C. L., Lin, T. J., Chiou, G. L., Lee, C. Y., Luan, H., Tsai, M. J., Potvin, P., & Tsai, C. C. (2021). A systematic review of MRI neuroimaging for education research. *Frontiers in Psychology*, *12*, 617599. https://doi.org/10.3389/fpsyg.2021.617599

Yang, C. I., Lee, L. H., & Chen, S. L. (2019). Students' experiences of studying in an accelerated BSN program in Taiwan. *Journal of Professional Nursing*, *35*(3), 240–244. https://doi.org/10.1016/j.profnurs.2018.12.005

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