

Article

“You’re not too old for learning”: Exploring EFL Teachers’ Developing Practices and Cognitions about Neuroscience

Michael Burri*

Anthony Wotring

University of Wollongong, Australia

Yuen Sze Michelle Tan

University of British Columbia, Canada

Wendy Nielsen

University of Wollongong, Australia

Joshua Amiel

Blue Gum Community School, Australia

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Abstract

Neuroscience is gaining increasing attention in English language teaching as recent research seeks to provide new insights into learning and second language acquisition. However, understandings from neuroscience have yet to inform English language teacher learning. This article addresses this gap by reporting on a 2.5-year longitudinal research project in which seven Japanese university English language teachers learned about neuroscience by initially participating in a 15-week teacher professional learning approach, namely, Learning Study. To enable accessible and applicable learning of neuroscience principles for our participants, teacher learning was focused on specific brain-based principles generally considered to be important in English language teaching (e.g., memory storage and retrieval, and the brain-body connection). Data were triangulated through focus group meetings and pre-, immediate post-, and delayed post-Learning Study interviews, enabling an exploration of teacher-participants’ developing practices and cognitions (i.e., beliefs and knowledge) about brain-based principles. Findings revealed substantial development of participants’ practices and cognitions about brain-based principles with each teacher-participant focusing on a different area of interest intertwined with facilitating and impeding factors. This paper offers novel insights into the use and development of sustainable teacher-professional learning.

Keywords

English as a foreign language teaching, professional learning, neuroscience, practices, cognitions

*Corresponding author. Email: mburri@uow.edu.au

1 Introduction

The developing understanding of the human brain and its complexities has led to increased advocacy for education professionals to utilise current scientific knowledge (Coch, 2018; Tokuhamas-Espinosa et al., 2024). Following this advocacy, researchers are exploring mainstream teachers' beliefs, engagement with, and uptake of neuroscience understandings in teacher education and in-service teacher professional learning (TPL) contexts (e.g., Grospietsch & Mayer, 2018; Howard-Jones et al., 2020; Tan & Amiel, 2022). These studies have shown that teachers are interested in knowing more about the brain, but also resist releasing commonly held misconceptions, such as the existence of learning styles (Im et al., 2018; McMahon et al., 2019; Newton & Miah, 2017). Key to these findings is the potential pathways by which neuroscience may inform teachers' classroom practice and support student learning.

As for effective language teaching and learning, recent research exploring the nexus between neuroscience and English language teaching (ELT) is crucial. Neuroscience understandings can afford fresh perspectives into traditional ELT concerns, including the second language (L2) acquisition process (van Hell, 2023), the importance of social learning (Jeong et al., 2021; Li & Jeong, 2020), language transfer (Perkins & Zhang, 2022), explicit and implicit learning (Suzuki et al., 2022; Williams, 2020), and the effects of auditory processing on L2 speaking (Saito et al., 2022; Saito et al., 2021). This relatively recent line of inquiry suggests that neuroscience provides important and constantly evolving understandings of the brain that can help advance ELT practices and learning in the L2 classroom.

However, unlike in mainstream education, neuroscience has yet to gain traction among researchers investigating L2 teacher learning, despite a growing number of studies exploring the professional learning of pre- and in-service English language teachers (e.g., Farrell, 2015; Freeman & Johnson, 1998; Johnson & Golombek, 2011, 2020; Kubanyiova, 2012; Richards, 2008; Woodward et al., 2018; Wright, 2010; Wright & Beaumont, 2015). To address this empirical gap, we investigated L2 teachers' learning about neuroscience. We carried out a 2.5-year longitudinal research project centred on a particular 15-week teacher professional learning approach, Learning Study, to examine the development of English as a foreign language (EFL) teachers' practices and cognitions¹ about neuroscience (i.e., brain-based principles; see Appendix A for an overview and definition of principles relevant to this paper). Learning Study is a job-embedded approach to TPL in which teachers collaborate, investigate, and address classroom issues (Lo, 2012; Pang & Runesson, 2019).

Our Learning Study project was conducted in a Japanese undergraduate English language program and focused on specific brain-based principles (e.g., memory storage and retrieval, and the brain-body connection) generally considered important for L2 teaching and learning. The motivation for conducting this project was empirical evidence suggesting that learning about neuroscience can positively impact teachers' practices and cognitions (e.g. Tan & Amiel, 2022; Tan et al., 2019; Deans & Larsen, 2022). Hence, in the present study we focused on specific principles with the goal of augmenting teachers' engagement with and application of neuroscience knowledge in the EFL classroom. This was hoped to facilitate classroom practices, which, given our own global teaching experiences, was deemed particularly important for EFL contexts. Students in these contexts often encounter limited English outside the classroom and therefore effective teaching practices are essential for EFL students' language learning process.

Thus, underpinned by a theoretical framework postulating that teachers' cognitions are inseparable from their practices (Borg, 2006) and that the human brain requires social interaction to thrive and learn (Cozolino, 2013), the aim of the research was an exploration of whether and how EFL teachers engage with brain-based principles when reflecting on their own TPL and classroom practice. Also explored were the teachers' initial perceptions of our Learning Study approach (see Burri et al., 2023b), their engagement with neuroscience, and their views about the importance of specific brain-based principles for classroom practices and student learning. Overall, this study advances the field by providing insights into the overall TPL process.

2 Literature Review

2.1 Teacher learning

Teacher learning during formal coursework and short-term professional learning opportunities has attracted substantial empirical attention. Some scholars question the effectiveness of traditional, institution-focused learning models, often facilitated through conference attendance or professional development days led by external experts. Researchers now call for new approaches to undertake in-context, ongoing TPL (e.g., [Anderson, 2018](#); [Hayes, 2019](#)). Borg (2015) suggests that effective teacher learning be examined through the interaction of practitioners' cognitions, training, experiences, and institutional and contextual systems. Consequently, job-embedded opportunities have been proposed as an effective TPL method, as they allow for immediate and contextual learning ([Crandall & Christison, 2016](#)).

Besides embedding TPL within the work context, collaboration also appears important for enhancing teacher learning. Lefstein et al. (2020) suggest collaborative teacher talk provides practitioners with opportunities to discuss pedagogical concerns, share different perspectives, and explore avenues to respond accordingly in the classroom. Jiang and Gu's (2022) collaborative action research demonstrates effective support for EFL teachers' classroom integration of digital literacy. Based on their findings, Jiang and Gu propose teacher learning to include cooperative planning, individual classroom implementation, peer observations, and collaborative reflection. Similarly, Benson et al. (2018) argue that collaborative practices can significantly augment TPL when reflection is grounded in exploring existing curricula and teacher practice. However, to date, there appear to be few investigations into collaborative EFL teacher learning about neuroscience.

2.2 Teacher professional learning and neuroscience

The present study focused on neuroscience due to its importance in informing teachers' pedagogical skills and knowledge, a topic of growing discussion among scholars, researchers, and teacher educators ([Ansari et al., 2017](#); [Tokuhamas-Espinosa, 2011, 2018](#); [Willis & Willis, 2020](#)). In the same vein, neuroscience is beginning to attract considerable attention and discussion in the language teaching, learning, and research community (e.g., [Burri, 2023](#); [Jeong et al., 2021](#); [Li & Jeong, 2020](#); [Perkins & Zhang, 2022](#); [Suzuki et al., 2022](#); [van Hell, 2023](#); [Williams, 2020](#)). However, a paucity of research on EFL teachers' cognitions about the brain persists, despite research with mainstream teachers demonstrating practitioners' need for an understanding of neuroscience ([Serpati & Loughan, 2012](#)). This must be noted because obtaining new knowledge about the brain enhances mainstream teachers' neuroscience literacy and subsequent classroom practices ([Grospietsch & Mayer, 2018](#); [Im et al., 2018](#); [Tan & Amiel, 2022](#)). Whether this is also the case with EFL teachers remains unknown at this point.

Despite the benefits of mainstream teachers learning about the brain, research has shown that the integration of neuroscience into TPL can be challenging. Teachers, for instance, may resist or are unable to translate theoretical and neuroscientific knowledge into practice. This could be due to teachers' lack of prior exposure to neuroscience ([Dubinsky et al., 2013](#)) or the perceived complexity of the presented subject matter ([Coch, 2018](#)). Additionally, the development of teachers' cognitions around neuroscience does not appear to be a uniform process in TPL contexts. For example, neuromyths, or commonly held misunderstandings about the brain (e.g., the existence of learning styles), covered during formal coursework or in-service TPL opportunities often resist correction ([Im et al., 2018](#); [Newton & Miah, 2017](#); [Tan & Amiel, 2022](#)). Other research has, however, provided evidence that learning about the brain can help refute or minimise teachers' pervasive views on neuromyths ([Grospietsch & Mayer, 2018](#); [Rousseau, 2024](#)). This suggests that the integration of neuroscience into TPL programs can indeed inform and shape various aspects of a teacher's life and skillset, including pedagogical beliefs and

content knowledge (i.e., why, what, and how to teach), classroom practice, and understanding of brain-based learning (Coch, 2018; Deans & Larsen, 2022). These developments can occur even weeks after the completion of relatively brief TPL sessions (Howard-Jones et al., 2020).

Currently unexplored is whether and to what extent these developments may also apply to EFL teachers. This is an important area that warrants research given the rapid growth of English teaching and learning throughout the world, particularly in countries where English is spoken as a foreign language (see, for example, Business Research Insights, 2024). EFL teaching requires unique skills and knowledge because students encounter little English outside the classroom. Our study, therefore, builds on previous research done on mainstream teachers and is expected to reveal new and important insights into EFL teachers' TPL process.

2.3 Learning study

Reflecting Crandall and Christison's (2016) proposition that effective TPL opportunities be job-embedded and contextualised, Learning Study is a collaborative, teacher inquiry approach used to facilitate teacher and, thereby student, learning (Holmqvist, 2011; Pang & Lo, 2012). A variant of collaborative action research (Elliott, 2015), Learning Study affords teachers opportunities to collaborate in studying particular teaching phenomena, designing learning environments, and engaging in research within their classrooms (Lo, 2012; Pang & Runesson, 2019). In Learning Study, teachers are introduced to theoretical perspectives that are subsequently used to frame their lesson planning, enactment, refinement, and reflection on student learning experiences. Teachers often use pre- and post-tests, observe video recordings of their lessons, discuss the enacted theory-framed lessons, and collaboratively reflect on their practice (Tan & Amiel, 2022; Tan & Nashon, 2013). The key affordance to such a research approach is that teacher and student learning are centrally placed in the context of real classrooms.

Since the inception of Learning Study in 2000, the approach has increasingly gained global attention due to its potential to promote TPL (Pang & Runesson, 2019). For example, teachers participating in Learning Study have improved their teaching and assessment practices (Ko, 2019; Tan & Nashon, 2013), refined pedagogical content knowledge (Martensson, 2019), and learned explicit and theoretical concepts to develop their practical and formal knowledge (Runesson, 2015, 2016). Of interest to the present study are contemporary neuroscience efforts through the Learning Study approach.

Tan and Amiel (2022) and Tan et al. (2019) found that a Learning Study framed around neuroscience can positively shape mainstream teachers' familiarization with principles of human memory and learning. Further, teachers from the two studies developed their pedagogical practices' theoretical grounding, articulation, and justification. The researchers concluded that Learning Study supports TPL and serves as an effective bridge between neuroscience, TPL, and mainstream teacher practice.

3 Theoretical Framework

The notion underpinning this study is that the invisible aspects of teachers' cognitions, such as beliefs, thoughts, attitudes, and knowledge, are not only intertwined but inseparable from classroom practices (Borg, 2006). At the same time, the interconnected nature of teachers' practices and cognitions is often shaped by practitioners' personal and professional background, their previous education, the language(s) they speak, and the context in which they are situated (Burri & Baker, 2021). Contextual factors, including, for instance, mandated collaboration with colleagues, required textbook use, curriculum constraints, learner proficiency, classroom size, and pressure from parents, can substantially influence teachers and their TPL. Subsequently, researchers exploring the development of pedagogical competence must examine teachers' practices, cognitions, and personal/professional and contextual factors concurrently to attain an in-depth understanding of the complex TPL process.

In our research examining EFL teachers' engagement with brain-based principles, we also draw on the relatively recent neuroscientific understanding of the brain being a social organ (Cozolino, 2013). According to Lieberman (2013), social connections and relationships are not only fundamental to human survival, but they shape the brain and help humans thrive. As such, the social brain enables collaboration, and learning is enhanced in social environments. Many educators align with the benefits of social learning within a community of practice or inquiry (e.g., Garrison & Vaughan, 2008; Lave & Wenger, 1991; Majeski et al., 2018). Our study is, therefore, grounded in the belief that effective TPL must be situated within a social and collaborative environment to further grow and enhance teachers' knowledge, skills, and pedagogical practices.

4 Rationale for Present Study

Positioned within this theoretical framework and building on previous research with mainstream teachers, the objective of our Learning Study was an in-depth exploration of job-embedded TPL for EFL teachers. Our project intended to develop teachers' cognitions, engagement with, and application (i.e., practices) of brain-based principles in the English language classroom. While preliminary findings have suggested that taking part in our Learning Study impacted teachers' practices and cognitions (Burri et al., 2023a) and that the teachers felt positive about participating in this approach to TPL (Burri et al., 2023b), a more detailed examination of the qualitative data is needed to better understand the quality and long-term effects of these developments. As such, the current paper reports findings collected over the entirety of the 2.5 years. It provides new and valuable insights into the teachers' learning of brain-based principles and factors that contributed to or impeded their TPL process and subsequent translation into practice. This paper seeks answers to the following research questions:

- *Which practices and cognitions about brain-based principles developed as a result of taking part in a Learning Study designed for English as a foreign language teachers?*
- *What factors facilitated and/or impeded the teachers' developing practices and cognitions about brain-based principles?*

5 Methodology

5.1 Research context and teacher-participants

The learning study project was carried out in an undergraduate English program at a Japanese national university. First- and second-year students enrolled in Regional Design, International Studies, Education, Engineering, or Agriculture degrees were required to take language learning courses. First-year students were separated into five levels based on TOEIC score results, while second-year students were offered a range of academic English electives (e.g., language learning through media, and debate). The university program employed 23 English teachers: 10 full-time (FT) teachers from Japan, and 13 part-time (PT) foreign-born teachers. FT teachers taught reading and writing courses, while PT teachers taught speaking and listening courses within the program.

Resembling other EFL university programs in Japan, teachers were expected to maintain a fixed set of curricular outcomes but had relative autonomy regarding how they would deliver the content. Besides their regular teaching responsibilities, teachers were expected to conduct and disseminate research, and the program leaders expressed a keen interest in getting their teachers involved in TPL with the aim of improving teaching practices and students' English language learning experiences. Throughout the Learning Study project, the leaders were engaged in transitioning their program into an English for General Academic Purposes (EGAP) program. This was done with the goals of improving the curriculum, aligning the program with international standards, and better equipping students for the demands of high education in Japan and beyond.

Following ethics approval from the lead author's (i.e., Burri's) university, all teachers in the English program were invited to attend an initial project information session led by Burri in February 2022. This session provided an overview of the study and allowed teachers to ask questions. Following this session, four FTs and four PTs gave written consent and volunteered to participate in the project. One PT teacher did not complete all of the stages in the 2.5-year project; consequently, her incomplete data set was withheld from this paper. The seven teacher-participants were experienced English language teachers, with Table 1 providing relevant background information. All participant names used in this paper are pseudonymous.

Table 1

Teacher-participant Information

Teacher Names	Nationality; Gender	Age	Education	Teaching Experience (years)	Years in Current Program	Other Information
Full-time	Jun	Japanese; M	25-34	Master's in TESOL	5-9	1-4
	Mai	Japanese; F	35-44	Master's in TESOL	5-9	1-4
	Fujiko	Japanese; F	55-64	PhD in Education	20+	1-4
	Tim	New Zealand; M	45-54	Master's in Applied Linguistics	20+	10-19
Part-time	Martin	Australia; M	45-54	PhD in Applied Linguistics	20+	5-9
	Nathan	England; M	35-44	Master's in Multimedia Fine Art	10-19	10-19
	Mick	USA; M	45-54	Master's in Applied Linguistics	20+	1-4

5.2 Research project structure and data collection

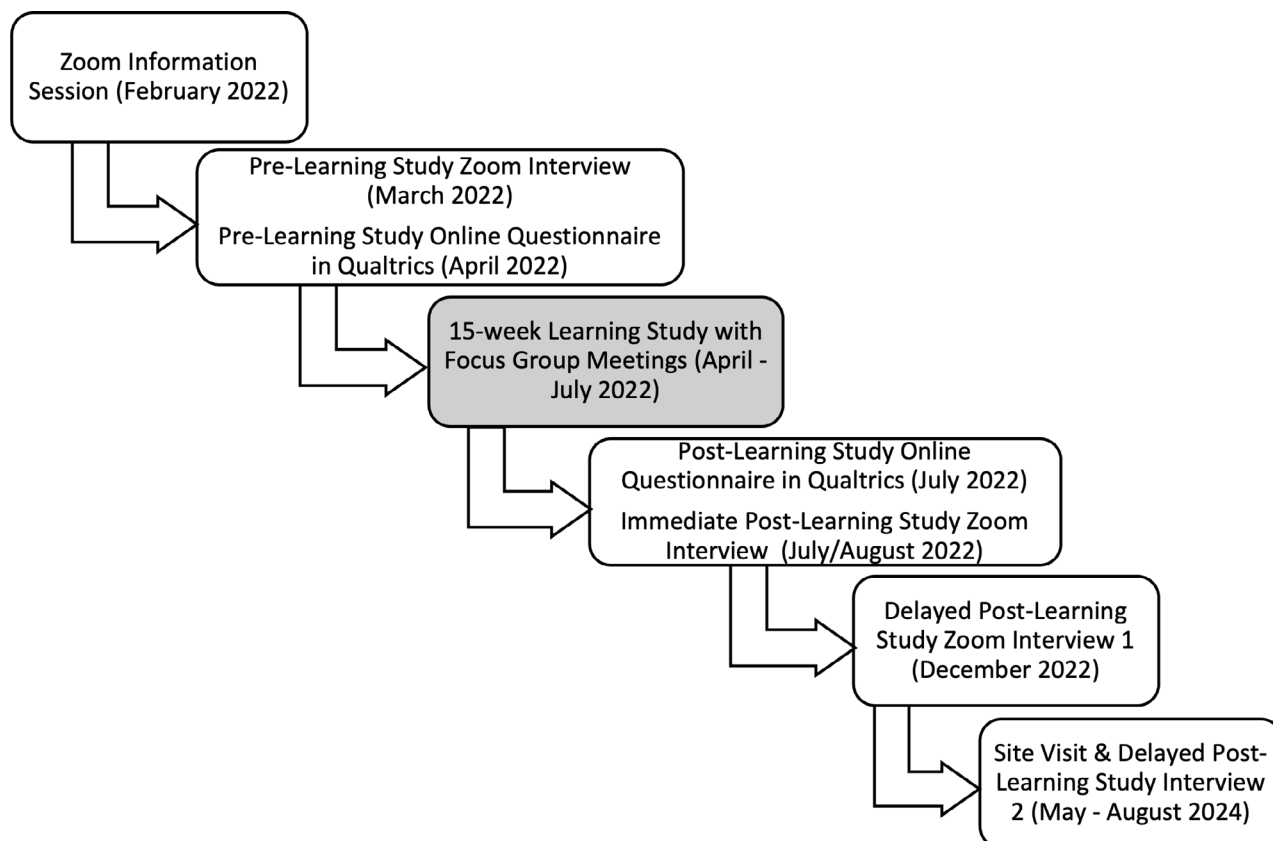
The research project covered a period of 2.5 years. All data reported in this paper were gathered between February 2022 to August 2024. Initially, the project was scheduled to end in December 2022. However, Burri was visiting Japan in the second half of 2024 and therefore the research team decided to extend the study and add another interview round and site visit to strengthen the data triangulation and thus gain additional insights into the participating teachers' TPL.

Irrespective of the project's extension, the objective of carrying out a longitudinal study was twofold: (1) to better understand the long-term TPL process of EFL teachers, and (2) to obtain an in-depth perspective of the potential long-term EFL classroom application of teachers' newly acquired neuroscience knowledge. Meeting the two objectives was believed to make a valuable contribution to the TPL literature.

Figure 1 shows the progress of the project and related data-gathering activities. Data sampling across the entire project aimed to collect information on participant experiences and their developing practices and cognitions about brain-based principles.

Figure 1

Overview of Project and Data Collection



Each participant was initially interviewed via Zoom. The 30-minute pre-Learning Study interviews (PLSIs) sought information about the participating teachers' backgrounds and general understandings and cognitions about the brain. The interview also allowed Burri to build rapport with the teacher-participants, as he was the project's main contact and developer.

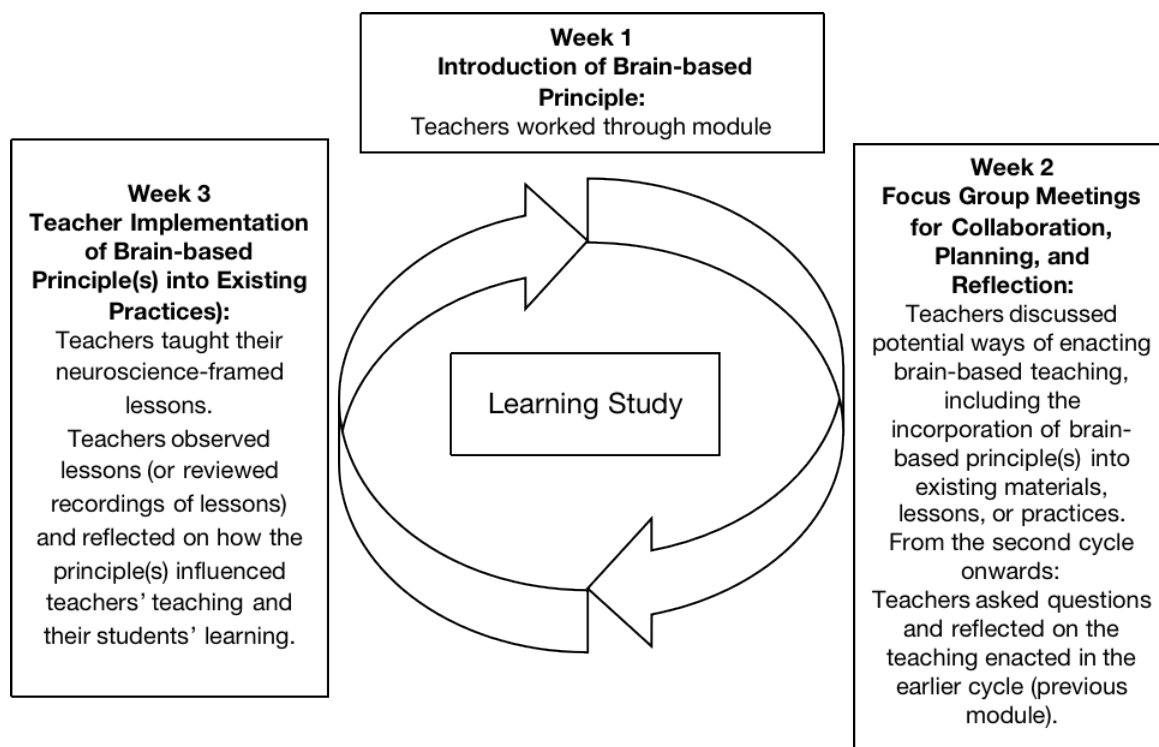
Following the PLSIs, Burri sent participants a pre-Learning Study questionnaire administered through Qualtrics. This questionnaire gathered information on the teachers' backgrounds, including age, gender, nationality, education, and teaching experiences, as well as assessed their knowledge of the brain and its functions. In the development of the questionnaire, we used Betts et al.'s (2019) survey tool which investigated the knowledge about the brain of close to one thousand instructors, instructional designers, and higher education administrators (n=929). To ensure that the questionnaire aligned with content covered during our Learning Study project, we modified Betts' survey and included only items that were covered in the five modules (see below). The final pre-Learning Study questionnaire "consisted of 15 demographic items and 36 statements about the brain (e.g., *We use our brain 24 hours a day*) in which participants could select "correct," "incorrect" or "I don't know," taking an average of 15 minutes to complete" (Burri et al., 2023a, p. 169). The participating teachers completed the questionnaire one week before the commencement of the Japanese academic year in early April 2022, when the 15-week Learning Study began.

A typical Learning Study involves several in-person meetings where new content and theoretical perspectives are presented and discussed (Tan & Amiel, 2022; Tan et al., 2019). However, we implemented an online Learning Study (see Burri et al., 2023a, 2023b) and delivered TPL modules via a digital platform (i.e., a Weebly website). Each module covered a key neuroscience principle within a three-week cycle (see also Figure 2):

- Module 1: The Brain – The brain’s functions and how it works as a social organ
- Module 2: Emotions & Stress –The role of emotions and stress on learning
- Module 3: Language – Connecting language teaching, learning, and the brain, including multimodal learning and debunking several neuromyths
- Module 4: Memory – Memory formation, storage, and retrieval in L2 teaching and learning
- Module 5: Embodiment – The brain-body connection

Figure 2

Three-week Cycle of Each Module with Five Cycles Being Implemented



During Week 1 of each cycle, participants were introduced to and worked through new brain-based principles presented via the website designed by Burri and Wotring. The module content was presented in a rich learning environment, including YouTube videos, links to articles and external materials, research summaries, online podcasts, recorded conference presentations, coloured-coded text, images, and reflective prompts. The content aimed to facilitate teacher-participants' learning about the brain and provided space to reflect on this newly gained knowledge before classroom application.

In the second week of each three-week cycle, the FT and PT groups met in separate focus groups (FGs) with Burri via Zoom to discuss specific brain-based principles and the incorporation of this learning into the following week's lessons. The researchers recognised that due to teacher workloads, collaboration could not focus on re-designing entire lessons but rather exploring teachers' modification of current teaching practices. Our Learning Study allowed teachers to work through different aspects of newly acquired knowledge instead of collectively targeting identical teaching practices. The FG meetings also

afforded the groups opportunities to ask questions and reflect on the teaching done in the implementation week (i.e., Week 3) of the previous module. All FG meetings were recorded through Zoom and lasted 30 minutes on average.

In the third week of each module, the teachers taught their lessons featuring the brain-based principles discussed in the second week. A common feature of the Learning Study approach, and utilised in this project, is lesson observation (Tan & Amiel, 2022). The FT teachers observed each other, while PT teachers video-recorded their classrooms. PT teachers would review these recordings enabling self-reflection. Arranging peer observations for the PT teachers was not possible due to scheduling conflicts and teaching responsibilities at other institutions. Following the Week 3 lessons, teacher-participants were asked to reflect on how specific brain-based principles may have influenced their practices and students' learning. Once a 3-week cycle was completed, the next module was released for participants to work through new neuroscience content.

Immediately following the 15-week Learning Study, Burri sent the participants a post-Learning Study questionnaire. This questionnaire was administered via Qualtrics, containing the same brain statements as the pre-study questionnaire, plus five additional questions for participant feedback (Burri et al., 2023a).

A week after completing the post-Learning Study questionnaire, Burri interviewed each participant. This immediate post-Learning Study interview (IPLSI) examined whether any changes occurred in the participants' teaching practices and explored whether perceptions of their roles as English language teachers and their students' roles had changed following the Learning Study. Teacher-participants also gave feedback on the content's presentation and organization, often with the post-Learning Study questionnaire responses initiating this reflection. The participants were then asked to discuss any memorable (i.e., critical) incidents (Richards & Farrell, 2005) from the project.

Four months following the IPLSI, Burri met the teachers for the first delayed post-Learning Study interview (DPLSI1). The DPLSI1 explored the sustainability of the participants' learning several months after completing the 15-week Learning Study. The IPLSI and DPLSI1 were both conducted and recorded via Zoom and lasted about 15-30 minutes.

Five months after the DPLSI1, Burri visited the university's English language program to meet the teacher-participants in person and visit their classes. Although no formal observations were conducted, informal class visits and chats with several participants were deemed sufficient to triangulate insights gained from previous interviews. During the visit, Burri also conducted another interview round (hereafter DPLSI2) with three of the teachers (Jun, Mai, and Tim). Due to scheduling difficulties, the remaining four teachers (Fujiko, Martin, Nathan, and Mick) were interviewed on Zoom between June and August. DPLSI2 aimed to further explore the extent to which neuroscience-informed pedagogical principles had filtered into the teachers' classroom practices over 2.5 years. Examining this long-term application was targeted as previous research suggests that teachers' developing practices and cognitions often stagnate, or even taper off, after the completion of a TPL program (Burri & Baker, 2020; Kang & Cheng, 2014; Webster, 2019). The DPLSI2s lasted about 17 minutes on average.

For this paper, the pre-, immediate post-, and both delayed post-Learning Study interviews, as well as the focus group interviews (n=15) were drawn upon as data sources. The pre- and post-Learning Study questionnaire and IPLSI data provided preliminary insights into the occurrence of TPL during the 15-week Learning Study and are reported elsewhere (see Burri et al., 2023a). However, to gain a more comprehensive understanding of the participating teachers' developing practices and cognitions about brain-based principles, the analysis of all interview and focus group data was required.

5.3 Data analysis

Data collection and analysis occurred concurrently in our project. Analysing data was a shared responsibility between Burri and Wotring, with findings from the analyses iteratively feeding into FG

meetings and all interviews conducted over 2.5 years. Zoom initially transcribed the FG meetings and interviews (conducted in English), followed by a more accurate verbatim revision by Wotring, who noted preliminary findings and key quotes. Burri then independently coded these transcripts in NVivo. Transcripts were read and re-read multiple times, and then coded inductively (Xu & Zammit, 2020). That is, nodes (i.e., identified themes) were created in NVivo that were believed to help answer the research questions.

The questionnaire data (not included in the present paper) were analysed immediately after the completion of the 15-week Learning Study. Percentages were calculated for the 36 brain statements included in the two questionnaires, enabling the examination of any potential change in the teachers' cognitions about brain-based principles due to their participation in the Learning Study.

The data analysis was, however, not without its difficulties. For example, coding the large amount of qualitative data that was collected over the 2.5-year period was not only a subjective undertaking, but a time-consuming and labour-intensive process. Also, at times it was challenging to discern whether an identified theme belonged to particular node in NVivo or whether a new node needed to be created. To mitigate these challenges, the nodes were continuously refined, merged, or renamed during several rounds of coding, eventually resulting in an extensive coding framework that consisted of 37 nodes. Burri and Wotring also met regularly to discuss, review, and refine the coding framework, with the other authors providing feedback during regular team meetings. This recursive and collaborative analysis with the resultant coding framework allowed for an in-depth understanding of the participants' developing practices and cognitions about brain-based principles as well as the identification of factors that were believed to facilitate and/or impede the developmental process.

Following the data analysis, the coding framework in NVivo was used to create a profile for each teacher-participant to illustrate their developing practices and cognitions about brain-based principles.

6 Findings

Teacher profiles – derived from our analysis of the interview and focus group data – are used in the first part of the Findings to highlight the significant teacher learning that occurred over the course of the 2.5-year research project. As evidenced in these profiles, each teacher focused on different aspects of neuroscience content introduced during the Learning Study; content that was immediately relevant to them as practitioners. To illustrate the teachers' developing practices and cognitions about brain-based principles, the seven profiles are thematically sequenced as follows:

- Focusing on emotions (Jun, Martin, Mick),
- focusing on brain plasticity (i.e., how neural networks in the brain can change) (Mai),
- centering on the social brain (Tim),
- focusing on multimodality and embodiment (Nathan), and
- thriving on group work (Fujiko).

Presenting the profiles of individual teachers is believed to be an effective means to showcase the nuances in the teacher participants' learning and application of brain-based principles in the EFL classroom.

6.1 Teachers' developing practices and cognitions about brain-based principles

Learning about emotions and embodiment (brain-based principles covered in Modules 2 and 5 of the 15-week Learning Study) fostered Jun's desire to increase his students' engagement in his classroom.

Before the research project, Jun felt “successful [as a teacher] when students [were] engaged in [his] class positively and actively” (PLSI), but the second module focusing on emotions and stress notably raised his interest in “emotion[s] and what stress factors can affect students’ engagement” (IPLSI). As he explained, he began to have “students stand up and move around the class, to chat with their ... peers. And then before the class I ... try my best to create a comfortable atmosphere ... for students by playing music before beginning the class” (DPLSI1). Jun believed that this added “positive ... emotions towards coming [to] class and participating [in] activities and tasks” (DPLSI1).

Jun’s translation of neuroscience principles into practice appeared to have been further enriched by his subsequent engagement with classroom research. At the outset of the Learning Study, he expressed interest “to do some research” (PLSI) and taking part in the study helped him solidify this idea. He began to plan and conduct classroom research on his students’ speaking task engagement. Crucially, learning about the brain and engaging in subsequent research appeared to improve his confidence and it was “good to know, what I’m doing right now ... is kind of meaningful” (DPLSI1). 1.5 years after the DPLSI1, Jun was still researching but expanded his focus to include brain plasticity, which he now thought was the most memorable aspect of the Learning Study. That particular concept was important to him because many of his university students believed that it was too late for them to learn an additional language. Drawing on what he had learned during the Learning Study, he tells his students that “learning never stops” (DPLS2) and therefore they “can become fluent in the future if [they] try hard” (DPLSI2).

Similar to Jun’s initial interest in the roles of emotions and stress on learning (included in Module 2), Martin derived several insights for classroom applications drawing from the same brain-based principles. In the project’s early stages, he was somewhat surprised about “the actual physical reduction in the size of the brain as a result of stress” (FGM2). Subsequently, in an attempt to reduce his students’ stress, he began to give them “buffer time” (FGM2) (i.e., additional thinking time) when answering questions. Three weeks later, he said that he “found it [worked] pretty well” (FGM3) and that he was “pleasantly surprised” (FGM3). His interest in stress, “sort of carried on from this professional development to [his] professional life; beyond that to [his] private life” (DPLSI1).

In the second half of the Learning Study, Martin began to express interest in using multimodality (incorporated into Module 3) in his listening classes, which he then connected with memory because he believed that “it all sort of fits together nicely” (FGM4). The practical implications of helping students transition vocabulary from working to long-term memory became a key focus for Martin. After completing the Learning Study, he took “a more multimodal approach to [teaching] in terms of introducing vocabulary” (DPLSI1). For example, Martin began using flashcards in combination with listening, reading, and writing activities to facilitate learner autonomy and modify his students’ vocabulary learning practices. His participation also gave him “a deeper sort of sense ... of thinking about the structure of [their own] programs” (DPLSI1) and the fundamental purposes of assessment and learning. Two years after the Learning Study, he reported being “more aware of producing material that does offer a variety of modes in terms of content, but also in terms of assessment” (DPLSI2). Looking back, he “really appreciate[s] learning something new, but there’s [still] a lot of things” (DPLSI2) he doesn’t know.

Learning about the importance of stress and emotions in the second module of the Learning Study increased Mick’s desire to create a safe classroom environment. According to Mick, Module 2 on stress and emotions was thought to be “fairly intuitive” (FGM2), but “this [was] kind of the first time [he’s] really understood what making a safe space meant from a cognitive point of view” (FGM2). He realised that he needed to create “the space for [students] to actually have emotions” (FGM2). The following week he “wanted to be very conscious of students’ emotional states” (FGM3), which was realised by giving “them more space to ask questions in the lead up to the test” (FGM3). However, Mick recognised that “remembering to actually take that time [was] going to be an ongoing challenge” (FGM3).

Mick’s attempts to create a conducive learning environment were supported by his learning about multimodality in Module 3, which gave him ideas for “how [to form a] bridge from the novelty to the

repetition” in the classroom. In fact, after completing the Learning Study, he believed that “the biggest takeaway ... for [him] was multimodality” (DPLSI1). Mick’s aim was now to “make the classroom a safe space” (DPLSI1) by “bring[ing] that multimodal aspect into this peer-to-peer situation” (DPLSI1) in his classes. For example, he “got rid of a lot of the homework” (DPLSI1) and was now more interested in the process of learning vocabulary rather than how well his students performed on quizzes and tests, and thus he provided students with opportunities to discuss “the words, rather than just [give] a translation” (DPLSI1). Additionally, in his essay writing class, he “g[a]ve each group a big box of crayons” (DPLSI1) to collaboratively plan their essays, and he noted that the mind maps “were much more detailed, much more dynamic” (DPLSI1) than in previous semesters. 1.5 years later, he also included “multimodality in the basic classes, [and] embodiment in the advanced classes” (DPLSI2) by making the students “stand up and ... move around, kind of like a Ted talk” (DPLSI2).

For Mai, learning about brain plasticity in the first Module shaped her cognitions about classroom practices. Early in the Learning Study, Mai viewed herself as a facilitator in that she “tried to communicate with [her students] in English and tr[ie]d to encourage them to speak English” (PLSI). However, at the end of the 15-week Learning Study, Mai was fascinated by the idea of “educators [being] brain changers” (DPLSI1) because she “didn’t have that kind of idea, when [she] was teaching before” (DPLSI1). Learning about brain plasticity provided her with confidence that “you’re not too old for learning” (DPLSI1). Mai thought that plasticity was “one thing that I want to focus [on]; like I want to tell my students that you can still learn other things” (IPPI). She also explained she would try “to change [her] teaching style” (DPLSI1) to “activate students’ neural networks” (DPLSI1) when returning to the classroom after her maternity leave.

Learning about the brain and findings from neuroscience research reaffirmed Mai’s current teaching practices and cognitions, particularly regarding multimodality and classroom instruction. 1.5 years later, Mai reported an adjusted teaching style. As a result of learning about the connection between emotions and memory in Module 4 of the 15-week Learning Study, she now “uses more Japanese” (DPLSI2) to reduce her students’ stress level for working with an additional language and “for them to fully participate in the classroom” (DPLSI2).

Tim was interested in the perception of the brain as a social organ (see [Cozolino, 2013](#)) and reflected on his approach to fostering a social classroom and learning environment (discussed in Module 1). Initially, Tim said that he viewed “language [as] a social connection” (PLSI) and therefore he aimed at creating “an environment where [students] feel comfortable” (PLSI) and “to kind of break that [traditional learning] culture, get them into a different mindset, and facilitate [their] learning in the classroom” (PLSI). Even though Tim’s perspective remained the same during the 2.5-year research project, taking part in the Learning Study provided him with “detailed background knowledge” (DPLSI1) and it “[r]eaffirmed a lot of things and then made [him] think about a lot of things that [they] do in the classroom and why [they] do it” (DPLSI1). Storytelling, stress, emotions, empathy, memory, and multimodality are brain-based principles and important aspects of ELT that were explored during the Learning Study, and Tim situated this knowledge within the conception of the brain as a social organ (i.e., how the brain requires social interaction to thrive and survive). This learning was particularly useful for Tim’s understanding of “how we need group work, and everything like that, kind of resonated with [him]” (DPLSI1).

Two years after completing the Learning Study, Tim included some of the key brain-based principles that were covered in the five modules, such as plasticity, multimodality, and embodiment, in an elective pre-service teacher education course he taught at a different university. The “university students that want to go on and become English teachers” (DPLSI2) did not “get that kind of information from other professors there” (DPLSI2) and so covering these principles “affected [his] teaching quite a bit” (DPLSI2).

For Nathan, his key learning experience concerned how learning about several brain-based principles reaffirmed his teaching practices, while his cognitions began to shift towards multimodality and the embodied classroom. Learning about the social brain in Module 1, for example, “reinforced, or helped

to explain, or helped to give me a basis on what I've already done" (FGM1) in the classroom. He also appreciated "the memory storage and retrieval page" (FGM4) in the fourth module because it reaffirmed "how ... anxiety and stress negatively affect our abilities to recall, concentrate, and focus on the activities" (FGM4).

During the Learning Study, the brain-based principles of multimodality and embodiment – introduced in Modules 3 and 5 – began to have an impression on Nathan, with multimodality particularly leaving "a kernel in there that's cooking and popping away" (DPLSI1) with a "prolonged impact, I think. Yeah, on how I teach" (DPLSI1). He was planning to "flesh out" (DPLSI1) the connection between multimodality and embodiment in a future media and speaking course. He was unsure how to bring those two together but was planning to eventually "step back ... [and] let the students take over" (DPLSI1) their learning. He also thought that learning about the brain made him now "double guess a lot of things" (IPLSI) and he would "maybe look at more of the construct behind ... the teaching task" (IPLSI). In the later stages of the project, Nathan reported on his sustained interest in multimodality and embodiment by combining gestures, body movement, and spoken language in group activities. Nathan aimed for student interaction to "be as spontaneous and as smooth as possible" (DPLSI2), and it "seem[ed] to work pretty well" (DPLSI2).

As the project progressed, Fujiko's cognitions and reported practices shifted notably towards social learning (presented in the first module), particularly the use of group work in the EFL classroom. At the study's outset, she was "not 100% convinced about [group work]" (FGM1) as this type of classroom organization significantly differed from her own language learning experiences. She also expressed her reservations about creating a fun classroom environment: "[I]f I make [a] relaxing atmosphere, the students don't do homework and don't study well" (FGM2). However, as the project progressed, her perspective began to change dramatically: "During participation in your study, I completely changed my idea about group study ... Before ... honestly, I didn't find the real significance of ... group work, pair work" (DPPI), but to her surprise, "students actually liked group work. I didn't think so. I thought that the students were reluctant ... but it's not the case" (DPLSI1).

By observing Tim several times during the Learning Study, she was "always impressed by" (FGM4) his social approach to teaching and learning. Based on this new understanding, she "tried to include at least one time of group work, pair work in ... every class" (DPLSI1) in the intervening semester. She came to realise that she did not "have to be always the center of the class" (DPLSI1) and that her students should be given "the chance to learn by themselves" (DPLSI1). Fujiko's appreciation of group work persisted following the Learning Study. She now includes group work in every class, and she can "see the students actually enjoy[ing] it" and as a result, she thought "[her] teaching has become more comfortable" (DPLSI2).

Collectively, these profiles demonstrate that participants' practices and cognitions about several brain-based principles developed notably during the 15-week Learning Study. While each participating teacher focused on somewhat different neuroscience content (i.e., brain-based principles) covered during the 15-week Learning Study, the above profiles also reveal some common patterns across the seven teachers. Jun, Fujiko, and Tim seemed to concentrate mostly on the social aspect of L2 learning, whereas multimodality was of prime interest to Martin, Nathan, and Mick. More importantly, however, the participants' engagement with Learning Study content appeared to continue for the following two years with all seven participants focusing on different aspects of neuroscience that were relevant to them as teachers. However, the analysis also revealed evidence of brain-based principles with which some of the participants potentially struggled during the Learning Study, namely one specific neuromyth: learning styles.

Although the teacher-participants did not directly link the neuromyths to their practices and cognitions about brain-based principles, references to learning styles made in the focus group discussions allude to the participants' attempts to make sense of the newly presented content and theories. Tim, for

example, found it interesting “that learning styles are a myth” (FGM3) because he “didn’t know that” (FGM3). Martin also expressed his interest in the non-existence of learning styles: “There was something that ... I found surprising. I think it was about having a best learning style that sort of stood out to me because ... a lot of people think that they do have a best learning style” (FGM3).

For two other participants, however, changing their perception of learning styles appeared to be an area of potential difficulties. Jun expressed his uncertainty about “the kind of main difference[s]” (FGM3) between learning styles and learning strategies, suggesting that he may still base the differentiation of teaching strategies based on the existence of learning styles. Similarly, Fujiko’s persistent belief in learning styles was evident when she commented on students’ different learning styles after having observed Tim’s class (FGM4). Yet, further exploration is needed as to whether Jun or Fujiko continued to retain their beliefs about these particular neuromyths past the Learning Study.

6.2 Factors contributing to teachers’ developing practices and cognitions

Our analysis of the interview and focus group data revealed a range of factors that contributed to the teachers’ developing practices and cognitions about brain-based principles. These included (1) connections of participants’ personal/pedagogical experiences with brain-specific content; (2) focus group meetings; (3) classroom observations; and (4) content delivery through videos, and readings and summaries (see Table 2).

Table 2

Factors Contributing to Participants’ Professional Learning

Facilitating Factors	Number and Names of Participants
1. Connections of personal and pedagogical experiences with brain-based principles	All 7 participants
2. Focus group meetings	4 (Jun, Fujiko, Tim, Martin)
3. Classroom observations	4 (Jun, Fujiko, Tim, Nathan)
4. Content delivery	
4a. Videos	6 (Jun, Mai, Fujiko, Tim, Nathan, Mick)
4b. Readings and summaries	5 (Fujiko, Tim, Martin, Nathan, Mick)

Connecting personal and pedagogical experiences with brain-based principles contributed to all seven participants’ TPL. That is, the continuity between previous and current learning experiences was alluded to by the participants. Nathan’s background in multimedia, for example, stimulated his interest in multimodality: “I guess, [multimodal learning] speaks to me in some ways. My background is in multimedia; you tend to use different ... collection[s] of media in order to put over an idea or a concept ... and I guess ... yeah, it makes a connection” (DPLSI1).

Making these connections was intertwined with two specific Learning Study features and further enhanced the participants’ TPL process: (1) focus group meetings, and (2) classroom observations. Jun, Fujiko, Tim, and Martin, for instance, found the opportunity to discuss content and ask questions during FG meetings to be beneficial. Tim mentioned that the expectation of having to join an FG meeting prompted him to work through content presented in the online platform, as the meetings worked as “a wee bit of a kick up the bum, you know. Meeting’s tomorrow. I have to get into [the Weebly content]” (IPLSI). For Jun, the FG discussions facilitated his learning: “I especially liked the way we discussed in the group through the, you know, Zoom ... If it were only me, I think it might have been kind of difficult, because I don’t usually learn anything through online platform. So, you know, thanks to the opportunities

to have like, actual interaction with you and other [teacher-participants]. It was really meaningful to me” (DPLSI1). The teachers appeared to value the opportunities for discussion and collaborative learning of brain-based principles afforded by the focus group meetings..

Furthermore, classroom observations contributed to four participants’ TPL (Jun, Fujiko, Tim, Nathan) by prompting further discussion and reflection on the teachers’ current cognitions and practices, including their personal and professional experiences with brain-based principles. For instance, the observations contributed to Jun’s desire to increase his students’ engagement: “[the] observation, that made me feel like, you know, I need to engage my students more [in] my class” (IPLSI). As the following statement illustrates, the observations had a particularly notable impact on Fujiko in that watching her colleagues’ classes and being watched enabled her to gain a new understanding of the value of group work in the classroom: “[T]he most memorable thing is that I had a really strong reaction about class observation ... because I tried to do things that I don’t usually do. So that’s makes me really uncomfortable, and that was really a bad experience. But, but after this, five or 15 weeks, I realised that, you know, group work, pair work; it’s very important. Yeah, [it] totally changed my idea” (IPLSI).

Fujiko’s initial negative association with trying something new in the classroom while being observed turned into a positive learning experience because of the peer observations. Particularly, observing Tim enabled her to witness the benefits of a collaborative classroom environment, connect these insights with Learning Study content and her personal and professional experiences, and eventually overcome previously held preconceptions of group work. This suggests that observing and being observed had a profound impact on her cognitions about the importance of language learning in a collaborative classroom environment. Fujiko’s case also aligns with previous research demonstrating the importance of classroom observations in transforming teachers’ cognitions and facilitating TPL (Burri, et al., 2017).

Lastly, the delivery of Learning Study content facilitated the development of six of the seven participants’ practices and cognitions about brain-based principles. Mai’s comment on the content design is representative of the participants’ reflections: “The platform, I think, it was very easy to go through. The text and the videos, that combinations were good for me because I can read it; at the same time, I can watch some videos” (IPLSI). In addition to the mode of delivery, five of the participants (Fujiko, Tim, Martin, Nathan, Mick) reported that some of the referenced readings, or summaries of recommended articles and video clips included in the Weebly platform, contributed to their understanding of brain-based principles. Martin, for instance, viewed the video and module summaries as beneficial to his learning of new content: “The summaries for me, like after the videos or at the end of the modules, where you actually tie it up ... I found [those] particularly useful” (IPLSI).

6.3 Factors impeding teachers’ developing practices and cognitions

Besides the four contributing factors, physical space as well as time and curricular constraints hindered the implementation of brain-based principles in the classroom, thus potentially impeding six of the seven participating teachers’ TPL process.

Four teacher-participants (Jun, Martin, Nathan, Mick) felt that the university’s classrooms (i.e., physical space constraints) prevented them from incorporating some of the teaching techniques and activities discussed in the Learning Study. For example, Mick said that they “[didn’t] have much control over [their] physical spaces” (DPLSI2) and so “in a classroom where you can barely walk through the aisle” (FGM5), “the large physicality [of movement and touch discussed in the fifth module] might be difficult” (FGM5) to implement. This is notable because the classroom size seemed to somewhat constrain Mick’s intention of creating a multimodal and safe classroom for his students over the course of the 2.5-year study. Martin echoed Mick’s sentiment in that the implementation of embodied (i.e., brain-body connected) activities proved challenging: “But the reality of our situation is ... we’re sitting in ... relatively small classrooms ... it’s impossible to walk to the back of the classroom; so, we’re sort of confined by the physical space” (FGM5).

Time and curricular constraints also limited six of the seven participants' (Jun, Martin, Nathan, Mick, Tim, Fujiko) engagement with and application of brain-based principles. The English language program's requirements (e.g., assessments) limited, for instance, Martin's ability to spend time exploring his area of interest (i.e., vocabulary learning): "And there hasn't really been the opportunity to explore [working memory and the transition to long-term memory] in terms of timing. We're sort of faced with mounting evaluations ... that really, really take up the majority of the class time" (FGM5). Concerns about these constraints were regularly mentioned by most participants throughout the research project, supporting the proposition that teaching demands can hinder the TPL process (Burri & Baker, 2021; Avalos, 2011).

7 Discussion

This longitudinal study investigated EFL teachers learning about neuroscience (i.e., brain-based principles), centered around a 15-week Learning Study and exploring its impacts two years on. To the best of our knowledge, this is the first study of its kind in ELT. Therefore, this research offers an important contribution by demonstrating the considerable and durable learning that occurred with each participant focusing on different areas of neuroscience relevant to them as EFL teachers. Findings support the notion that teachers' practices and cognitions – and thus their TPL – are intertwined (Borg, 2006) and shaped by contributing and impeding factors (Burri & Baker, 2021). Teachers focusing on different aspects also suggests that practitioners' TPL is not uniform nor linear, but rather a process unique to each teacher.

As mentioned above, however, some teachers shared areas of focus and interests during the Learning Study. Three of the four FT teachers (Jun, Fujiko, and Tim) were concerned with aspects related to the social nature of the classroom, whereas the three PT teachers (Martin, Nathan, and Mick) tended to focus on the application of multimodal teaching and learning. Each PT teacher concentrated on a specific aspect of multimodality: vocabulary memorization (Martin), embodied (Nathan), and safe classroom environments (Mick). The Learning Study approach, with its collaborative cycles of reflection and discussion (Tan & Amiel, 2022; Tan et al, 2019), may have led the two groups to focus on a specific and shared area immediately relevant to the courses they taught. Even though Tim was a foreign-born teacher who taught an advanced second-year English honours course, the other three teachers in the FT group were Japanese teachers who taught the, typically perceived, less interactive skills of reading and writing. As such, in consideration of the theory suggesting that the brain requires social connections and relationships to learn (Cozolino, 2013; Lieberman, 2013), it is reasonable to speculate that the focus group discussion might have steered this group in the direction of creating a more social classroom environment to facilitate their students' language learning process.

This contrasts with the PT teachers' focus on teaching more collaborative oral and aural skills. Their priorities might have gravitated towards the enhancement of their skills-specific practices to maximise their students' EFL learning in the classroom. Although the FT teachers occasionally mentioned multimodal learning, multimodality was most often seen by the PT teachers as an effective means to improve their speaking and listening classes (see, for example, Diamantopoulou & Ørevik, 2022). The findings, therefore, suggest that the teachers were not just developing practices and cognitions on an individual basis, but they were also collaboratively adapting their learning to specific course and student demands. Our findings thus support previous TPL and Learning Study research that suggests the benefits of collaborative learning for teachers' developing skills, cognitions, and practices (e.g., Banegas & Glatigny, 2021; Lefstein et al., 2020; Jian & Gu, 2022; Tan & Amiel, 2022; Tan & Nashon, 2013).

Equally important are the findings showing that learning about neuroscience can have a lasting impact on teachers' views about EFL teaching. This sustained engagement is important considering that previous research has demonstrated that L2 teacher learning can taper off (Burri & Baker, 2020; Kang & Cheng, 2014; Webster, 2019) or that teachers may revert to previously held beliefs and pedagogical

practices (Lortie, 1975; Tang et al., 2012). As such, the goal of engaging teachers with sustained learning rather than one-off TPL opportunities (Pang & Runesson, 2019; Tan & Nashon, 2013) appears to have been realised via our modified Learning Study approach. These findings provide a valuable platform for future studies investigating whether this continuing impact can prove effective in facilitating the integration of neuroscience content through the Learning Study approach.

7.1 Implications

The findings in this paper hold implications for providers of effective and sustainable TPL programs. Although the university English program was just beginning to transition into an EGAP program (see research context above), we believe that the findings also have implications for EFL teaching and learning in academic contexts, similar to the one in which this study was conducted.

Firstly, the individualised nature of TPL suggests that an individual's personal, historical, and lived experiences must be considered in teacher learning programs (Johnson & Golombek, 2020). While not necessarily a new finding, the different directions of our participants' TPL and individuated impacts on EFL teaching practices reinforce the call for job-embedded learning opportunities (Crandall & Christison, 2016). In the same vein, EFL teachers in EGAP programs would be well-advised to personalize their students' language learning endeavours. As such, academic resources and learning activities should be closely tailored to the learners' own experiences and backgrounds to meet student interests, needs, and goals. Helping students link previously and newly presented content to their own lived experiences would most certainly optimize their EFL learning. As suggested by Herawati (2023), helping teachers personalize their students' EFL learning should be incorporated into TPL (Herawati, 2023).

Our project also afforded teachers opportunities to personalise their connections to newly learned content. These connections, in combination with focus group discussions and classroom observations, contributed to the participants' learning about brain-based principles, fostered TPL, and facilitated teachers' adaptation of their learning to course demands and student needs. This suggests that teachers should be given opportunities to collaborate, discuss, and reflect on theory and practice in a social learning environment (Lieberman, 2013) for them to connect newly presented content meaningfully with current courses and students' needs. Such opportunities could include regular, informal gatherings in the staffroom or more formal meetings organised by a lead teacher. The point is that for TPL programs to be effective, they should include outlets for teachers to reflect collaboratively on their present practices (Benson et al., 2018; Lefstein et al., 2020) in conjunction with classroom observations (Elliott, 2015) and personalised learning opportunities. To this end, our Learning Study approach provides a viable and sustained TPL option that mirrors practices found within communities of practice and inquiry (Garrison & Vaughan, 2008; Lave & Wenger, 1991; Majeski et al., 2018).

Along the same lines, EGAP classrooms should be social learning environments, despite the curriculum constraints, time pressure, and limited classroom configurations the teachers experienced in this study. As our findings showed, a social learning environment augments learning, and therefore EFL teachers in academic English programs should strive to create learning opportunities for students to collaborate, discuss, and explore issues of relevance. Working together aligns with Cozolino's (2013) and Lieberman's (2013) proposition that humans require social interaction and a collaborative environment to learn and thrive.

Nonetheless, future research should further explore our emergent findings on the nexus between TPL, EFL teaching, and neuroscience principles. Our recommendation for such investigations would be to address explicitly and with depth the issue of neuromyths. Neuromyths are often deeply entrenched in teachers' minds, persisting even after teacher-training programs aimed to dispel them (see Coch, 2018; Im et al., 2018; McMahon et al., 2019; Newton & Miah, 2017; Rousseau, 2024; Tan & Amiel, 2022). The EFL teachers in this research project appear to be no exception. Future Learning Studies could include purposefully planned opportunities for teachers to discuss and reflect on various neuromyths, such as

learning styles. Betts et al.'s (2019) report can serve as an excellent resource for these discussions, as it contains concise refutations of many neuromyths.

Research has established that changes in teacher beliefs are a gradual process that occurs over time (Burri & Baker, 2020; Woodward et al., 2018). Opportunities for teachers to collaboratively consult and reflect on resources, such as the Betts et al. (2019) report, may assist in refuting misconceptions about the brain (Grospietsch & Mayer, 2018). Such informed teacher discussion and reflection could lead to more effective teaching practices and students' learning experiences.

8 Conclusion

This present study has provided insights into the TPL process of EFL teachers' learning about brain-based principles. More research in different contexts is needed to understand better the effects of teachers learning about neuroscience. As the EFL teachers participating in our research project were experienced practitioners, future research will need to include novice teachers. Inexperienced teachers may find connecting theory and research with practice more challenging than the teachers in the current study but may also be less susceptible to neuromyths. Nevertheless, the present paper has demonstrated that a Learning Study centered on neuroscience holds great potential for facilitating teacher learning over a prolonged period. The teacher-participants are now conducting classroom-based research projects informed by some of the brain-based principles covered in the 15-week Learning Study (see McKinley, 2019; Rose, 2019; Sato & Loewen, 2019, for recent discussions about teacher research). In addition to the profiles derived from the data sources, the teachers' continued classroom research provides further evidence that our initial Learning Study on neuroscience served as an effective platform for lasting and sustainable professional learning.

Endnote

1. Following Burri et al.'s (2017) work, we use the term 'cognitions' in our study rather than 'cognition' in order to capture the different beliefs, knowledge, attitudes, and perceptions held by an L2 teacher.

Appendix A

Overview and Definition of Brain-based Principles

Learning styles imply that people possess different strengths, such as being visual learners, auditory learners, kinaesthetic learners, and reading/writing learners. Research (see, e.g., Betts et al., 2019) has provided compelling evidence of the existence of learning preferences rather than learning styles.

Multimodality is the way information is conveyed, used, and learned in different modes (e.g., written text, oral explanations, and visual images).

Neuromyths are commonly held misunderstandings about the brain (e.g., learning styles).

Long-term memory refers to memories that comprise both facts and knowledge (explicit memory) as well as procedures (implicit memory). These memories are held indefinitely and can be retrieved as explicit memories, such as remembering a birthday party that took place at a specific time and place in the past, or as implicit memories, such as remembering how to ride a bike after a long time of not riding one.

Brain plasticity – also known as ‘neuroplasticity’ or ‘neural plasticity’ – is the brain’s capacity to change the connections between neurons and neural networks in response to new stimuli and information being learned. Brain plasticity means that the brain changes and adapts over time, rather than information, responses, or processes being hard-wired into our brain.

Embodiment emphasizes the connection between the body, the brain, and the mind in teaching and learning.

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Michael Burri is a Senior Lecturer in TESOL at the University of Wollongong, with his professional interests focusing on teacher education/learning, Mind Brain Education, pronunciation instruction, and the ethical use of GenAI. Michael will be leaving for Wenzhou-Kean University to take up a professorial position in August 2025. Having worked and researched in Australia, Canada, and Japan, he's looking forward to continuing his academic journey in China.

Anthony Wotring works within the School of Education at the University of Wollongong. Previously teaching English in South Korea, he currently supports emerging teachers' TESOL pedagogy, literacy, and research skills. His recent research explores the impact of an explicit focus on disciplinary literacy on teacher practice and student learning.

Yuen Sze Michelle Tan is an Associate Professor in science education at the University of British Columbia. Her overarching research program is characterized by an emphasis on theorizing teaching practice in K-12 settings and equipping teachers with tools to support learning. She takes special interest in the Learning Study approach.

Wendy Nielsen is a retired Associate Professor from the School of Education at the University of Wollongong. Her research interests include teacher knowledge, using technology in science learning and teacher education.

Joshua Amiel is a science teacher and academic researcher. Currently, he is studying teachers' use of neuroscience principles to strengthen pedagogical decisions and create powerful learning experiences for students. Joshua has a keen interest in science education and building professional learning communities.