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Research article

What do faculties specializing in brain and neural sciences think about, and how do they approach, brain-friendly teaching-learning in Iran?

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Abstract

Objective: to investigate the perspectives and experiences of the faculties specializing in brain and neural sciences regarding brain-friendly teaching-learning in Iran.

Methods: 17 faculties from 5 universities were selected by purposive sampling (2018). In-depth semi-structured interviews with directed content analysis were used.

Results: 31 sub-subcategories, 10 subcategories, and 4 categories were formed according to the "General teaching model". "Mentorship" was a newly added category.

Conclusions: A neuro-educational approach that consider the roles of the learner's brain uniqueness, executive function facilitation, and the valence system are important to learning. Such learning can be facilitated through cognitive load considerations, repetition, deep questioning, visualization, feedback, and reflection. The contextualized, problem-oriented, social, multi-sensory, experiential, spaced learning, and brain-friendly evaluation must be considered. Mentorship is important for coaching and emotional facilitation.

Keywords : education, cognitive sciences, neuroscience, neuro-educational studies

Highlights :

- ✓ Faculty awareness about brain-friendly teaching-learning and special attention to neuro-education studies have been suggested.
- ✓ Executive function facilitation for the learners was considered, which included goal setting, educational planning, organization, study skills, self-monitoring, and evaluation skills.
- ✓ Careful contextualized learning, consideration of the role of sleep for information consolidation, cognitive load issues, problem-oriented learning, social learning, multi-sensory learning, experiential learning, spaced learning, brain-friendly evaluation, and some techniques such as repetition, deep questioning, visualization, reflection, faculty and learner's reflection were among the items considered in the brain-friendly teaching-learning process.
- ✓ Mentorship is an important process related to the professional and humanistic attitude transfer to learners, with special emphasis on coaching and the emotional facilitation of the teaching-learning process.

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Introduction

Learning is the formation of novel neural connections or the refinement of ineffective neural connections, which involves the formation of new dendrites and the reconstruction or reactivation of the previously formed connections (1). Therefore, the structure and function of the brain can change due to the property of neuroplasticity under the impact of experience and learning (2). In fact, faculties are designers of experiences that will eventually lead to an alteration in synapses and neural circuits in the brain irrespective of their form: formal or informal learning (3-5): thus, the reason teaching is defined as the "Art of brain changing" (6). The challenge is to design experiences that take full advantage of this capacity of "brain change." Thus, faculty awareness of evidence-based educational theories, strategies, and techniques could improve teaching quality and learning outcomes (7).

One of the topics highlighted in the 21st century is Brain-friendly teaching-learning (BfT-L). Brain-based learning studies have tried to bring variety into teaching strategies and maximize the learning process according to the natural learning process in the brain (8-10). Nowadays, the current science of BfT-L is based on the direct connection between neuroscience and education, as well as an indirect connection between the two through educational and cognitive psychology (11-14). The relationship between neurobiology and education was initially acknowledged in the 20th century. However, since the 1990s (Brain Decade), with the growing advancements in brain imaging technology, this connection has led to theoretical advancements in neuro-educational studies (13, 15-17), with ongoing development due to the new research findings in related fields (8).

Since learning is influenced by both formal and informal education, previous knowledge, contextual factors, attitude, and personality traits (9), BfT-L is designed in a way that consider the many factors affecting the teaching-learning process in order to achieve optimal learning outcomes (1, 9, 18, 19). Studies have revealed that, under intense states of emotion, the amygdala is metabolically overactive, and the information transfer to the hippocampus and the cerebral cortex is diminished in comparison with their natural state. Therefore, the new information will not enter the brain's memory storage due to the metabolic obstruction (2). It seems that molecular signals associated with appropriate stress levels can facilitate the synaptic potentiation of the brain circuits involved in learning and memory formation. However, high-level stress has the opposite effect (20). Problem-based, collaborative and active learning in small groups along with feedbacks provide a suitable level of stress for learning and would summon the pathways of the brain's reward system. Neural circuits related to the internal reward system are activated to calculate the relative value of a choice and evaluate the potential of immediate reward against a larger future reward. In real time, these estimations are often made at the subconscious level yet have a significant impact on decision making (18). Furthermore, learning by doing, successful task performance, and learning in different real environments would lead to the establishment of confidence (positive emotions), and thus, these experiences will be stored in episodic long-term memory. On the other hand, visualization activates real biological processes in the brain. The activation of related patterns from the sensory, motor, and executive neural circuits includes decision-making pathways and can enhance learning (18, 21). Learning can also be improved by repetition, i.e., faster information transfer occurring in neural circuits (18).

Furthermore, the cognitive sciences have documented that distributed learning (having rest periods during learning), retrieval practice (examining long-term memory for already-fathomed data over the course of studying), information interleaving (mixing past, present, and upcoming information), elaboration (variegating the manner, place, and time of the study or practice within and across sessions), providing challenges in accordance with the developmental level, providing a general overview before presenting the details, causal explanations and effective feedback to improve information storage, verbalizing learning stages, creating a similarity between learning and retrieval contexts, simulation-based mastery learning, stimulating interest and curiosity, creating a fun atmosphere in order to facilitate exploration, attracting conscious attention, and the faculty's own interest in the teaching-learning process can also help enhance learning (1, 5, 9, 22).

Coch has argued that "training teachers in the basics of neuroscience will be useful in developing teachers who can be informed and critical consumers of the so-called brain-based strategies and programs and the neuroscience research on which they are purportedly based". She further states that teachers trained in the basics of neuroscience are necessary in the field of neuro-educational studies, since they can empower this new science (16). Heeding this issue, faculties specializing in brain and neural sciences who teach theoretical, practical, and clinical courses at the university may reach a better understanding of BfT, especially if they develop competency in the science of "Education" (16). Such experiences can strengthen the use

of neuro-educational strategies to achieve effective teaching.

A comprehensive review of the literature on this topic has revealed that no qualitative studies thus far have described the experiences of faculties specializing in brain and neural sciences regarding BfT-L at universities. Therefore, the current study was carried to understand the lived experiences of these faculties related to BfT-L in the academic settings of Iran.

Materials and Methods

This research used a qualitative approach, as it described the lived experiences of faculties based on contextual relevance (23). Data were analyzed through directed content analysis. The purpose of this type of analysis is to validate or develop a conceptual framework or a previous theory or model. Operational definitions for each category are determined using the selected theory, framework, or model. So, the initial codes are extracted according to the predetermined conceptual framework and their categories. These codes are then reviewed carefully to identify if one or more categories or subcategories need to be added to the predetermined ones (24). The model-guided content analysis in this study was carried out based on the "General Teaching Model". This model was introduced by Gage and Berliner and includes the following stages: "Before the teaching activities", "Before and during the teaching activities", "During the teaching activities", and "After the teaching activities". Generally, activities related to the "Before the teaching activities" provide educational objectives and determine the learners' entrance conditions. Activities related to the "Before and during the teaching activities" refer to learning the psychological theories and experiences and to choosing the appropriate and motivational teaching-learning process. Activities related to the "During the teaching activities" choose and apply the appropriate and effectual educational strategies and techniques, and finally the activities related to the "After the teaching activities" choose and perform the appropriate educational assessment and evaluation (25).

The present study was conducted at the Medical Education Research Center of Isfahan University of Medical Sciences in 2018. The purposive snowball sampling was used in this study to select a number of participants among those who teach at the "Institute for Cognitive and Brain Sciences of Shahid Beheshti University (SBU)", the "Institute for Cognitive Science Studies (ICSS)", the "University of Isfahan", "Iran University of Medical sciences", "Shiraz University of Medical Sciences", and "Isfahan University of Medical Sciences" in a variety of disciplines related to brain and neural sciences, including neurophysiology, neuroscience, cognitive neuroscience, neuropsychology, neuro-psychiatry, neurology, neuro-education, neurosurgery and cognitive psychology. All the members of the faculties taught different theoretical, practical, and clinical courses at their universities and participated in advanced faculty development courses held by their universities with the objective of improving the participants' teaching-learning competencies. Two of them had a Master's degree in Medical Education in addition to their specialties, and one was a faculty member at the department of neuro-educational studies.

In this research, semi-structured in-depth interviews were used for the purpose of data collection. To this end, 17 individual interviews were conducted by the researcher, of which 13 were face-to-face in the participants' offices and 4 occurred via telephone. Participants' teaching experiences ranged from 5 to over 25 years, and involved theoretical, practical, or clinical courses depending on each faculty's specialty.

Each semi-structured interview began with the questions: "How do you make use of brain and neural sciences in your teaching-learning process? How do you base your instructional design on these sciences for before, during and after teaching session activities?" Participants' responses were followed by further questions until a deep understanding of the main themes and relative experiences was achieved. Interviews lasted from 30 to about 90 minutes.

The statements and comments made by the interviewees were audio recorded, with their consent, and transcribed word-for-word after each session. The statements provided by the participants were rewritten in a formal style with no loss of meaning. The transcriptions were reviewed by the researcher multiple times and computed into MAXQDA 12.3. Data were saturated after 17 interviews. In this regard, no new codes were identified in the last 3 interviews, and the researcher was convinced that further information would not lead to the emergence of a new theme.

In this study, rigor was presented in terms of dependability and confirmability, credibility and transferability. Accordingly, to increase data credibility, we used expert participants using purposive sampling, continuous reviewing of the data along with data collection, data analysis immediately after the interviews, and prolonged engagement with the data. For confirmability, the extracted codes and results were shared with some participants (member check). Any additions or omissions made by the participants were noticed in the final texts. Also, due to data dependability, researchers recorded all interviews and data very carefully and engaged more than one researcher in data analysis. To increase data

transferability, we tried to recruit participants with different demographic characteristics and specialties.

Ethical Considerations

The Ethics Committee of Isfahan University of Medical Sciences confirmed this study performance by ID (IR.MUI.MED.REC.1397.170). Also, written consent of the participants was obtained before carrying out and recording the interviews. The participants were guaranteed anonymity and were promised that the data would not be used for or against them and that no data manipulation would take place.

Results

17 subjects participated in this study. The expertise and experience of participants are represented in Table 1. Our data analysis led to the extraction of 1,036 initial codes which were classified into 31 sub-subcategories, 10 subcategories, and finally 4 categories according to the "General Teaching Model" which includes "Pre-Teaching activities", "Pre and During Teaching Activities", "During Teaching Activities", "Post-Teaching Activities" and one more category was formed, which was called "Mentorship". It works as an umbrella for all the other 4 stages, under the name of "General Teaching Model". The summary of the categories and subcategories are represented in Table 2.

Table 1. Expertise and Experience of the Participants

No.	17
Participants' specialty	3 Neurology (Participants No. 15, 16, 17) 1 Neuropsychology (Participant No.12) 3 Neurophysiology (Participants No. 9, 10, 11) 1 Neuropsychiatry (Participant No. 8) 2 Neurosurgery (Participants No. 13, 14) 1 Neuro-education (Participant No.1) 1 Cognitive psychology (Participant No.7) 2 Neuroscience (Participants No. 5, 6) 3 Cognitive Neuroscience (Participants No. 2, 3, 4)
Teaching Experience	5 participants with 5-10 years 4 participants with 10-20 years 8 participants with more than 20 years

Before the teaching activities

This category comprised the subcategories of "faculty's awareness regarding BfT-L", "Instructional design with respect to BfT-L" and "Teaching the neuroscience of learning to learners".

- "Faculty's awareness regarding BfT-L"

This subcategory was specified due to the importance and necessity of the faculty's training about the best evidence in the field of the teaching-learning process. It was related to new learning science, which was extracted from the mind and brain sciences. The 2 related sub-subcategories were "BfT-L importance" and "Awareness of Neuro-educational studies".

- "*BfT-L importance*"

Some participants believed that the faculty`s training about cognitive sciences and neurosciences' findings applicable in educational settings was necessary, in the form of faculty development workshops which can enhance their knowledge related to the new best evidence in educational improvement. Participant No. 10 stated that *"… When we are talking about learning, we must realize that this learning happens in the brain, and know the mechanisms involved in learning are like someone driving a car and understanding the mechanics and the engineering of the car at the same time with the need to be educated…"* Further, he added *"… if we lack scientific information on how plasticity occurs, how information is stored, how it is recalled, or how consolidation happens, not only will we not reach our goal, but sometimes even misconception occurs, hidden bad education occurs, the new information deletes the previous information, or the information is learned but never retrieved…"*

Participant No. 3: *"… If the medical education development center (EDC) were to teach faculties the methods related to the best evidence in medical education, especially the implications of neuroscience and cognitive sciences in medical education, in the form of training courses and workshops, a faculty in the university would lean toward brain-friendly education…"*

- *"Awareness of Neuro-educational studies"*

One of the participants in the field of neuro-educational studies emphasized that although it is necessary to make faculties aware of cognitive sciences, neuroscience, and cognitive psychology findings in education, it is also necessary to introduce new study fields that should deal with some misunderstandings of using basic sciences in education.

Participant No.1: *"… Neuro-education is a novel science… Although Neuro-education`s father and mother*

are neuroscience and psychology, it is a science of its own… It's like cooking; you might use various ingredients, such as tomatoes, meat, etc., but the resulting food is no longer any of those ingredients, it has a new taste… We must beware of neuro-myths… there are certain things being said about VAK (visual-auditory-kinesthetic) learning styles that are completely false…"

- "Instructional design with respect to BfT-L"

This subcategory explains the importance of designing learning objectives, contents and strategies by faculties based on the mind and brain findings, especially the ones related to higher cortical executive functions. The sub-subcategories related to that are: "Learning objectives, contents, and strategies", "Input behavior evaluation" and "Restorative education".

- *"Learning objectives, contents, and strategies"*

Most of the participants believed that complex or novel tasks require the skills related to the higher-order executive functions such as initiation, planning, decision making, organizing, monitoring and termination. These higher level functions can be especially utilized by the faculty's mental imagination before starting the teaching-learning process.

Participant No. 4*: "… I believe that it is needed to apply very complex mental processes which are called executive functions when we are trying to get to know our audience, their needs, their strength and weakness, and also when we are planning a course, its contents, conveying strategies and student evaluation. The first thing I do is try to acquire all the necessary information related to planning a course, then I start planning it…"*

Another participant used a special strategy to determine objectives, contents and strategies, i.e., visualization.

Participant No. 3: *"… First, I have already created a pattern of the class in my mind. I customize the objectives of my class based on my imagination (visualization), and I determine the size of those objectives…When I have 1-h teaching, I ask myself what I want to say in that session. I know how to utilize each second optimally by visualization…"*

- *"Input behavior evaluation"*

Participants had evaluated the student's entrance behavior related to the knowledge level and procedural skills as a baseline for educational goal setting, planning and goal attainment.

Participant No. 9: *"… At the beginning of the classes, I have always written 10-12 questions on the materials before teaching and I have asked the learners to answer them in order to evaluate the scientific knowledge of the students. Since we are aware of the mind`s capability, we can set the learning objectives realistically for them. This is similar to a map which says where you are, where you go, and in which way you can go… of course this is a complex higher order brain cortical function which is needed for the new modern life planning…"*

- *"Restorative education"*

Participants tried to provide compensatory opportunities for the learners` deficiencies, as they believed that starting to learn new tasks may overload non-mastered learners both mentally and physically.

Participant No. 17: "*… For individuals at lower levels, I would provide further explanations along with more examples, I would also ask them to participate actively in the case-based discussion sessions at the hospital … not enough knowledge and skills before entering a new course may result in cognitive and physical overloading which is against learning…"*

Participant No. 14 added statements related to procedural learning. Participant No. 14: "*… If there is any deficiency in the learner's knowledge and procedural skills before starting new ones in the operating room, then they must practice. Practice in skill-lab can be helpful with different simulators… Procedural learning can be facilitated by practicing in settings so similar to the real ones. Hence, restorative education is essential to knowledge and skill acquisition…"*

- "Teaching the neuroscience of learning to learners"

This subcategory refers to the awareness of the students related to the basic neuroscience of learning which consists of "Teaching brain-friendly learning principles to learners" and "Teaching learning optimization techniques".

- *"Teaching brain-friendly learning principles to learners"*

Participants believed that if they teach the topics related to how their brain learns naturally, learners can take some responsibility for their own learning.

Participant No. 3: *"… If learners know that their brain's structure and function can change during life through their experience due to the brain's neuroplasticity, and they know the topics related to brain sensory processing, cognitive-emotional-motor system relationships, motivation and reward system, brain-body relationship, implicit and explicit learnings, memory architecture and memory optimization techniques, the role of sleep and nutrition in learning, their learning would be optimized by finding the right experience and avoid disruptive experiences …"*

Another participant organized some workshops for the learners related to the brain-friendly teaching-learning

process. He stated: *"... one of the essential issues for learners is to know how their brain receives, processes, percepts environmental information and learns naturally… I have always hold workshops on study skills and time management for my students …"*

- *"Teaching-learning optimization techniques"*

Participants mentioned that teaching brain-based techniques such as mindfulness, relaxation, effective studying techniques, and thinking about their own thinking can enhance learning due to mental and emotional regulation.

Participant No. 1: *"... I try to present the methods of meditation and relaxation for anxiety management… and I teach the students how to use metacognitive techniques to have insight related to their learning process… I practice such techniques with my students during the class …"*

Before and During the Teaching activities

Subcategories include "Attention to individuality and brain uniqueness" and "Learner`s orientation heeding BfT-L".

- "Attention to individuality and brain uniqueness"

This subcategory points out the individual differences according to the difference in the brain's function and structure. They stated that since everybody has his own genetic factors, contexts and previous experience, neural circuits form differently. Participants mentioned that by respecting these differences in human brains and minds and by providing special learning opportunities for their special needs can result in better achievement. The sub-subcategory includes "*Brain structural and functional differences*".

Participant No. 3: *"... Human brains are wiring differently, similar to their own fingerprints. Therefore, it is not fair to have the same education for all students even in the same class. Not enough attention to brain's developmental stages, individual sensory processing style, cognitive-emotional needs, etc. can decrease educational efficacy …"*

- "Learner's orientation with respect to BfT-L"

Participants mentioned that the facilitation of the learner`s executive functions is the main goal of most educational systems which include educational planning, organization, study skills, self-monitoring and evaluation skills. Hence, this subcategory refers to the learner's orientation with special attention to BfT-L. The sub-subcategories comprise "Objectives and program explanation" and "Rules and expectation explanation".

- *"Objectives and program explanation"*

Participants mostly valued the explanations of educational goals and objectives during the first sessions to facilitate the student's learning planning through a course. Participant No. 10 stated: *"... I do believe that the main goal of medical educational systems must be the facilitation of some abilities which are necessary to the complicated medical service provisions. Students need the higher order functions which are the requirements of modern societies ... In order to accomplish this, I have always paid a lot of attention to the preliminaries of the class to teach the students about goal setting, planning and decision making. I present the framework of educational objectives and programs to facilitate their own educational goal settings…"*

- *"Rule and expectation explanation"*

Some participants commented on the importance of rule and expectation explanations during the initial stages of the teaching-learning process. Most of them emphasized the need of providing some chances for learners to participate in rule settings.

Participant No. 5: *"... First, I set the educational rules with the participation of my learners and then I talk about my expectations in the clinical field in order to facilitate their goal setting and planning …"*

Participant No. 10: *"... I make introductions about my own expectations… This way, the brain allocates the space, the time and the energy required for the task …"*

During the Teaching activities

This category comprises the subcategories of "Facilitation of cognitive-emotional learning" and "Facilitation of cognitive and procedural learning".

- "Facilitation of cognitive-emotional learning"

This subcategory states the importance of emotions in the teaching-learning process. Participant No. 3 reflected: *"... Emotion is not the actor in the scene of learning, it is in fact the director…"*

Another participant, No. 8, reflected: *"... As soon as the information processing starts in the nervous system, the evaluation of the data occurs in order to make it valuable and this is the exact work of the emotional system and it can facilitate valuable data for higher order processing or discard them ... So, if we want to have effective brain-based teaching, we must pay attention to the process of cognitive-emotional learning …"*

The related sub-subcategories include: "Emotional atmosphere", "Utilizing art potentials" and "Curiosity triggering".

- *"Emotional atmosphere*"

This sub-subcategory includes an anxiety-free and a happy atmosphere, which heeds the human needs to rewards. Participant No. 2 stated: *"… One of the important issues is that learners should not have to enter the clinical setting with anxiety, because their performance speed and attention would be diminished and this would lead to a lot of errors…"*

Participant No. 8: *"… Every once in a while, at the theoretical classes for medical learners, I throw in an ice-breaker… a joke wrapped in a riddle… and I leave the ending open to interpretation … this engages higher cognitive functions…"*

Participant No. 8*: "… All humans need rewards. The human limbic system needs to be boosted every few minutes. The human reward system needs to go from the ventral tegmental area to the limbic system once in a while, to inject some dopamine into the prefrontal lobe and keep us focused… If we use rewards, individuals would do their absolute best to receive the rewards, but if we use punishment, they would only do the minimum required…"*

Participant No. 8 also added that Wisdom-related rewards according to higher cortical functions are more in line with the brain-friendly teaching-learning process. He mentioned*: "… The more the rewards are at the level of higher cortical functions, the higher the quality of the work. It means that if the rewards are only based on the quantity of the tasks, they might not be performed very well. But if we involve quality, for example, say patients and their families will pray for you and you will receive blessings, we are now treading in areas of wisdom which work best…"*

- *"Utilizing art potentials"*

Participants expressed the potential of arts for ultimate cognitive learning. Painting, storytelling, poetry, and music were emphasized by them.

Participant No. 12: *"… If one member of a faculty has an artistic taste such as painting, he/she can use drawing and colors in the process of teaching and it would be better for the learners if an image were drawn step by step, as opposed to suddenly confronting them with a complex image from a book … artistic teaching engages positive valence systems which can facilitate cognitive learning …"*

Participant No. 3: *"… When I am telling a story … for instance, I like the interlocking that is made in the brain for specific diseases to angry people who are creating garbage, and this garbage needs to be thrown in the apartment's garbage system … learning is facilitated by the mind`s comparing and contrasting analogy …"*

Participant No. 5: *"… For instance, in order for my students to remember how to start the relaxation process, I teach them the steps rhythmically. Rhythm means music and poetry; it means creating harmony. Any kind of harmony in the brain helps learning…"*

- *"Curiosity triggering"*

Some participants believed that learning can be facilitated by triggering the creativity and curiosity of the learners. Participant No. 10 explained: *"… During the course of my teaching, I must be able to keep the learners' minds curious and creative. This is how they become thirsty for knowledge. All learning pathways in the brain are facilitated in order to better process the information …"*

- "Facilitation of cognitive and procedural learning"

This subcategory refers to the facilitation of learning through various strategies and techniques during the teaching-learning process. This subcategory includes the sub-subcategories named "Learning in a variety of contexts", "Task repetition", "Cognitive load considerations", "Learning by problem-solving", "Socratic questioning methods", "Experiential learning", "Multimodal teaching", "Visualization", "Spaced learning", "Sleep role", "Observational learning", "Peer group learning".

- *"Learning in a variety of contexts"*

This category refers to the necessity of providing opportunities for doing tasks within different social, physical, cultural, personal, and spiritual contexts until deep learning occurs. Participant No. 8: "… *Students must learn by visiting a large number of variant patients of different ages and genders to facilitate deep learning, which is exactly what is happening in the computer's deep learning … Deep learning means that I have practiced a given task in multiple contexts to the degree that I can proceed on my own from here on … Contextualized learning helps the brain activate objective and spatial perceptual circuits, sidelong emotional circuits according to the setting's requirements …"*

- *"Task repetition"*

Participants valued task repetition for enhanced learning as it can strengthen the previous effective neuronal circuits. Participant No. 8: "*… Deep learning happens by practicing and repeating a given task as neural circuits can be empowered by their consecutive activation …"*

- *"Cognitive load considerations"*

Participants believed that the student`s cognitive overloading works against the ultimate learning process. They suggested cognitive load management techniques

such as information categorization, maintaining information coherence, making the information meaningful, and taking notes to discharge extra data from the memory.

Participant No. 1: *"... The brain tends to associate meaning to a phenomenon, and this meaning is only formed when a coherent and meaningful picture is presented as a whole. That's why, in the first sessions, I draw a conceptual map of all topics that are going to be discussed during the term, and the same plans are repeated in the subsequent weeks, each time expanding and going deeper ... These are my management techniques for cognitive loads ..."* (Optimization of germane load)

Participant No. 10*: "... I sometimes tell my students to write a given question; this way, their minds calm down, because we've given them the opportunity to reflect later, and this way, we do not overload the minds ..."* (Decreasing extraneous load)

Participant No. 7: *"... When I teach a topic in the class, I also state where these data are going and to which previous or future data they will be connected. I try to put different separate parts of information together to facilitate learning without cognitive overloading ..."* (Optimization of germane load)

Participant No. 17: *"... Sometimes, a resident asks a question, and I say this question is 3 steps ahead, you should not think about this matter until the categorization is complete and a mental pattern is formed ... I think categorization and teaching from simple to complex and creating a mental pattern can help the minds be formatted without being overloaded ..."* (Intrinsic load management and optimization of germane load)

Participant No. 13: *"... I tell my students to dig deeper and refer to basic sciences and bring these together with applied sciences and present them in a single package. We provide a piece of integrative information into mental schemas to facilitate learning ..."* (Optimization of germane load)

- *"Learning by problem-solving"*

Participants stated that teaching about a special problem in life can result in a better perspective for learning. Participant No. 8 reflected: *"... We encounter a complex package of problems such as schizophrenia in our life. As the brain works in parallel and not in serial, the best way is teaching around a problem with providing opportunities to integrate anatomy, physiology, pathophysiology, behavioral sciences, etc. around that problem to facilitate a complete overview ..."*

- *"Socratic questioning methods"*

This sub-subcategory is related to asking deep questions for concept clarification which result in deep learning. Participant No. 4 stated: *"... I ask deep questions with why, what, what if, to make students aware of the multi-aspects of patient management. I use their answers to trigger another clarification question continuously to shape a good mental schema..."*

- *"Experiential learning"*

Some faculties expressed their experience related to providing opportunities for the learner`s educational experience and especially those opportunities with safe trial and error. Participant No. 5 reflected*: "... I provide the chances to the learners that they can discover about how to work with medical tools such as ophthalmoscopes ... trial and error through an experiment facilitates learning by both long-term potentiation and long-term depression in the brain..."*

- *"Multimodal teaching"*

This sub-subcategory elucidates the use of some techniques to facilitate multi-sensory learning such as utilizing multimedia, teaching in the skill labs, and some other techniques which can engage different senses together, to address the same information. Further, participants stated that using the appropriate body language when teaching can have multi-sensory potentiation as it uses visual-auditory-tactile senses to enhance learning.

Participant No. 3: *"...We can use multimedia as a powerful tool in learning and also test its educational effect on the brain through neuroimaging techniques ... Further, as working memory has limitations in its capacity, our information presentation can be done by auditory-visual senses altogether to use two input channels of working memory which result in better learning if we notice cognitive loads ..."*

Participant No. 3: *"... Non-verbal communication can be extremely effective in education ... using verbal and nonverbal cues can provide a better multi-sensory learning opportunity for the learners ..."*

- *"Visualization"*

This sub-subcategory is formed to mention the participant's experience related to the strength of mental rehearsal by imagination. Participant No. 3 expressed: *"... Words come, Words go, but images have a greater impact ... imagination can facilitate learning more than just speaking ... We know that when you imagine a certain thing in your mind, not only the visual system is activated, but also circuits in other regions, such as the superior part of the temporal lobe, the basal ganglia, the prefrontal*

region, and the auditory cortex are also activated and this improves learning …"

- *"Spaced learning"*

This sub-subcategory refers to providing learners with resting during the teaching session. One of our participants explained about a neurocognitive brain network which was linked to various modes of self-generated thought and can throw the person in his/her thought from time to time.

Participant No. 8: *"… The default mode network is a brain network which starts activation from time to time and, because of that, the person immerses in his or her own self and can be distracted from the outside … if a faculty does not know this fact, he/she teaches for a long time and then complains that students are falling into their thoughts and they are no longer listening to the lesson …"*

- *"Sleep role"*

This sub-subcategory points out the important role of sleep in learning. Participant No. 1 stated: *"… Neuro-educational research has shown that young people usually sleep late at night and their level of awareness is not so high in the morning. Hence, I try to avoid compressed and uninterrupted teaching in the early morning hours … Furthermore, research revealed that sleep helps the consolidation of memory and keeps the information in long-term memory…"*

- *"Observational learning"*

Participants emphasized learning by observation, especially in medical sciences. It was mentioned that mirror neurons fire during observational learning and it can result in a better reproduction of the target behavior for future endeavors.

Participant No. 4*: "… The main part of our teaching-learning process is based on observation and imitation, which can be facilitated by mirror neuron`s firing in the brain and it can facilitate the repetition of the task in the next efforts by his/her own…"*

- *"Peer group learning"*

Social learning was valued in the interviews as it explained that social interaction can provide a positive emotional atmosphere, added knowledge and more feedback.

Participant No. 10: *"… I told the students that you can have a group of 3 of your friends and have a discussion about the texts … We do believe collective wisdom elevates the mind`s capability progressively. They can provide feedback to one other and correct their mistakes …"*

"After the Teaching activities"

This category covered the subcategories of "Brain-friendly evaluation", "Facilitation of the learner's self-reflection" and "Faculty's self-reflection".

- "Brain-friendly evaluation"

This subcategory states the power of assessment and evaluation for learning enhancement and the best circumstances for brain-friendly student evaluation. It has 2 sub-subcategories named "Frequent assessments" and "Test-enhanced learning".

- *"Frequent assessments"*

It was mentioned that since personal and environmental factors can affect mental functions, they must be approached through educational assessment.

Participant No. 11: "… *I take some quizzes randomly during the semester to understand the exact knowledge level and decrease personal or environmental effects on assessments … Personal mood or environmental disturbing factors can influence the single assessment of the semester…"*

Another participant pointed to the attention variation during a day. Participant No. 1 mentioned: *"… The findings of Neuro-educational studies have revealed that, at a given time of taking a test, a given learner might not be at his or her top attention threshold ... Attention varies during the different times of the day. There are also individual differences ... Assessments must be frequent during the course of a term at different times of a day…"*

- *"Test-enhanced learning"*

The exams' potential to improve cognitive learning was considered. Participant No. 7*: "… I provide chances to retrieve information from long-term memory through repeated quizzes, then I discuss the answers with the learners interactively to refine their mental models …"*

- "Facilitation of the learner's self-reflection"

This subcategory was considered to mention the importance of the students` introspection related to their own competencies and empower these competencies to some extent, to be life-long learners without external supervision. Participants stated that they try to facilitate the student`s self-monitoring and self-assessment. The 2 related sub-subcategories include: "Persuasion to self-assessment and reflection" and "Self-directed learning by reflection".

- *"Persuasion to self-assessment and reflection"*

Learners have been asked to undergo self-reflection and self-assessment. Participant No. 5: *"…as soon as a medical procedure was performed, I often ask the learners what*

score they would give themselves out of 3 ... I want them to learn about self-assessment and in this case, they can prepare their minds for a better modification …".

Another participant added that self-reflection can decrease errors, especially in the medical fields. Participant No. 17: *"… Most of the clinical errors are the results of habitual reasoning and I try to facilitate self-reflection in order to decrease them…"*

- *"Self-directed learning by reflection"*

It was believed that self-reflection is one of the main skills which is required to convert a novice learner into an advanced life-long learner.

Participant No. 14*: "… I ask my residents to always try self-reflection related to their knowledge and skill acquisition. In this case, they can improve their cognitive and procedural abilities even without direct supervision after graduation …"*

- "Faculty`s self-reflection"

This subcategory is related to the importance of the faculty`s self-reflection in both areas of his/her expertise and educational competencies in order to improve their educational and specialty-related mental models. The 2 related sub-subcategories are "Learning by teaching" and "Self-reflection on educational competencies".

- *"Learning by teaching"*

Faculties stated that they can improve their specialty-related competencies by teaching. *Participant No. 3: "… As I teach, it's like having my hands open to others to use my knowledge, deficiencies are still observable for myself in this scene of the show. Now, as this hand is open, I can improve my knowledge by observing weaknesses… My mental models are still changing by new learning opportunities..."*

- *"Self-reflection on educational competencies"*

Participants talked about their reflection on educational competencies besides their own expertise. *Participant No. 9: "…I always try to get my students' comments to improve my teaching by the end of the semester. Brain-friendly teaching should be redesigned according to student`s learning needs…"*

Mentorship

One more category called "Mentorship" appeared after data analysis, which refers to the subcategories of "Coaching" and "Professionalism consideration". It may comprise all 4 stages under the heading of "General Teaching Model". Emphasis was given to these activities because of the importance of professional and humanistic attitude transfer, in addition to teaching knowledge and skills, and also due to the emotional aspects of education. As the participants have mentioned, it is their responsibility to provide support and guidance to enhance learning, paying special attention to the student`s needs, interests, strengths and weakness.

- "Coaching"

This subcategory refers to the coaching and role modeling activities related to mentorship besides providing motivation and feedback. The related sub-subcategories are called "Coaching steps", "Role modeling activities", "Feedback provision" and "Motive provision".

- *"Coaching steps"*

Participants mentioned that there are some steps in guiding the learners. Participant No. 3 mentioned 6 coaching steps*: "… The first step of coaching is to sell the value of a thing to the learner (stating the value of information). For instance, I have a painting to sell, what a thing! This means that I should show the value of my painting… The second step is that I would obviously have to explain the situation to the learners (explanation)… Then imagine a flight attendant saying there are two doors in the front, two doors in the back; so this means guiding the learners (guiding)…, the next step is that I must let learners train with providing them the opportunity to practice (giving opportunity to practice)… and then follow up with the learners (following with the learners)… of course, we should follow the teaching-learning process along with the learners, and ask them in what ways we can find the objectives… and, at last, providing feedback can be helpful (giving feedback)… In this case, the repetition of the steps can facilitate learning with the help of a coach…"*

- *"Role modeling activities"*

Mostly, faculties explained about implicit and explicit learning which can be acquired during learning activities in different settings, especially from a role model's performance.

Participant No. 4: *"…One of my responsibilities is to represent professional behaviors to my students, for example, I can be a good role model to teach what is appropriate in patient-doctor communication beyond procedural skills… The brain can reproduce what it has seen before as we have implicit and explicit learning…"*

- *"Feedback provision"*

This sub-subcategory is about the importance of feedback in BfT-L and its conditions which should be considered.

Participant No. 3 mentioned*: "… Feedback is the spotlight of the teaching-learning process. I stimulate the learner`s mind by providing the chances of being aware of the weakness and strengths and modify their mental and procedural activities as I believe in the facilitation of the brain`s long-term potentiation and long-term depression by teachers…"*

Participant No. 11*: "… When I provide productive feedback in a friendly manner far from imposing anxiety with respect to the learner`s strong points, and with the objective of compensating for his weakness, then there is no resistance in modifying their performance, since their feedback is valuable…"*

- *"Motive provision"*

Participants insisted on the importance of the learner`s motivation to learn by presenting meaningful, valuable, and right challenging activities, which is one of their main responsibilities. Moreover, they stated that having an interest in teaching and conveying this interest to the learners can motivate them to improve their learning.

Participant No. 10 stated: "…*When I only try to pass my knowledge to the learners in my classes, the best faculties in the world cannot hold their audience's full attention for even one hour. Attention diminishes and people get distracted… No attention leads to no memory nor learning, since attention is the doorway to memory; when it is lost, memories will no longer form… It is compulsory to convey knowledge and practice with the right attitude towards those values. Right then, knowledge and practice would be meaningful and motivating…"*

Another participant explained that if she balances between her supervision and the learner`s autonomy, learners are more motivated to upgrade their learning. In this regard, participant No. 4 stated her experience as follows: "*… I try to decrease my help and give them autonomy, similar to a kid who is going to walk independently step by step…The learners' mind must have a chance to use their previous supervised experience and feedback to modify their performance gradually… In this case, they are motivated to increase the quality of their performance without extra supervision…"*

Participant No. 16 talked about teaching with love and its potential to motivate the learners. He stated: *"…Teaching with love can transfer this love to the learners and motivate them to learn more and more… Teaching is making your best effort to transfer with love what you have learned with love to the learners… This is similar to using emotional potentiation for the ultimate teaching-learning process…"*

- "Professionalism consideration"

This subcategory explains the importance of having a humanistic, professional attitude and persuading learners to respect these in their professional life. Participants mentioned that as a teacher, one can influence the learner`s valence system through their own humanistic and professional attitude and behavior. The 4 related sub-subcategories are "Humanistic and empathetic attitude transfer", "Responsiveness providing", "Trustworthiness" and "Emotional regulation".

- *"Humanistic and empathetic attitude transfer"*

Transferring humanistic and empathetic attitude to the learners was also mentioned by the participants. Participant No. 4 related: "… *A humanistic perspective which takes respect to the other`s personality triggers positive emotions in the learners and facilitates the student`s learning towards improved patient care… I try to encourage the learners to consider this issue in all parts of their life beyond the educational environment…"*

- *"Responsiveness providing"*

Showing responsiveness to the learner`s learning was also considered by some of the participants. In this regard, Participant No. 17 debated: *"… I think being responsive to the student`s learning can encourage them to develop more knowledge and skills. In this case, I try to guide them with every step in the hospital…"*

- *"Trustworthiness"*

Trusting the manner of thinking was stated as an important item in facilitating learning. Participant No. 16 explained: "…*Trusting the educator is an important item which can facilitate learning. This trust is beyond the specialty-related abilities; it is related to the manner of thinking about the world… having no trust means that there is not enough motivation to follow the educator…"*

- *"Emotional regulation"*

Participants emphasized the balance between cognitive and emotional functions for faculties which can improve the teaching-learning quality. Participant No. 6 mentioned: *"If I can regulate my emotions and balance between cognitive and emotional functions in order to use the positive potentiation of emotions in educational settings, the quality of the teaching-learning process would be improved and I could still protect myself from working burn-out…"*

Table 2. Categories, subcategories, sub-subcategories

Category	Subcategory	Sub-subcategory
Before the teaching activities	Faculty's awareness regarding BfT-L	BfT-L importance
		Awareness of Neuro-educational studies
	Instructional design with respect to BfT-L	Learning objectives, contents and strategies
		Input behavior evaluation
		Restorative education
	Teaching the neuroscience of learning to learners	Teaching brain-friendly learning principles to learners
		Teaching-learning optimization techniques
Before and during the teaching activities	Attention to individuality and brain uniqueness	Brain structure and function differences
	Learner`s orientation with respect to BfT-L	Objectives and program explanation
		Rule and expectation explanation
During the teaching activities	Facilitation of cognitive-emotional learning	Emotional atmosphere
		Utilizing art potentials
		Curiosity triggering
	Facilitation of cognitive and procedural learning	Learning in a variety of contexts
		Task repetition
		Cognitive load considerations
		Learning by problem solving
		Socratic questioning methods
		Experiential learning
		Multimodal teaching
		Visualization
		Spaced learning
		Sleep role
		Observational learning
		Peer group learning
After the teaching activities	Brain-friendly evaluation	Frequent assessments
		Test enhanced learning
	Facilitation of the learner's self-reflection	Persuasion to self-assessment and reflection
		Self-directed learning by self-reflection
	Faculty`s self-reflection	Learning by teaching
		Self-reflection on educational competencies
Mentorship	Coaching	Coaching steps
		Role modeling activities
		Feedback provision
		Motive provision
	Professionalism consideration	Humanistic and empathetic attitude transfer
		Responsiveness provision
		Trustworthiness
		Emotional regulation

Discussions

This study explained the perspective and experiences of faculties specializing in brain and neural sciences regarding the brain-friendly teaching-learning process in Iranian universities. The participants' perspectives and experiences were categorized based on the "General Teaching Model," with one new category on "Mentorship" recently emerging.

In this study, participants insisted on the faculties' role in changing the learner`s brain. Participant No. 3 mentioned: "… Teaching means having a pencil in the right hand and an eraser in the left and making an impact on the brain with these two tools; it means that you succeed in forming certain synapses and eliminating others which are called Long-Term Potentiation and Long-Term Depression.

Furthermore, participants emphasized the need for considering the "Faculty`s awareness regarding BfT-L", "Instructional design with respect to BfT-L", and "Teaching the neuroscience of learning to learners" for before-the-teaching activities, "Attention to individuality and brain uniqueness" and "Learner`s orientation with respect to BfT-L" for before-and-during-the-teaching activities, "Facilitation of cognitive-emotional learning" and "Facilitation of cognitive and procedural learning" for during-the-teaching activities, "Brain-friendly evaluation", "Facilitation of the learner`s self-reflection" and "Faculty`s self-reflection" for after-the-teaching activities. They also suggested the mentoring role of the faculty as it can facilitate emotional issues related to cognitive learning.

They emphasized faculty development related to BfT-L. They mostly emphasized paying attention to the learners` brain uniqueness, executive function facilitation and valence system. Research revealed that explaining topics in well-designed training courses about brain neuroplasticity, brain development, learning and memory, cognitive-emotional learning, mirror neurons` function and such related topics can improve the teaching-learning process (26, 27). The importance of neuro-myths in neuro-educational studies was also emphasized by three of the participants. Neuro-myths originate from a crude relationship between neuroscience and education resulting from the different epistemic natures of the two sciences, so the neuroscientific findings must be interpreted in education with great caution (13, 17, 28, 29).

Instructional designing with respect to BfT-L was considered an important item for pre-teaching activities. Participants used the potential of visualization besides collecting information for a course designing. They explained the important role of higher-order cortical functions such as planning, decision making, self-regulation (goal-directed modulation of thought, action and emotion), initiation of goal-directed behaviors, and behavioral inhibition called by executive functions in a successful teaching-learning process for both faculties and learners. As previous studies have revealed, executive functions are important for the appropriate adaptation and performance in life situations. They allow people to initiate and complete tasks and to encounter challenges. Since most of the environments and their requirements are unpredictable, executive functions are vital to humans in order to recognize unexpected situations and to quickly make alternative plans when unusual events arise and interfere with normal routine. In this way, the executive function contributes to success at work and at school and allows people to deal with the challenges of daily life effectively. Executive functions also enable people to inhibit non-proportional behaviors (30). On the other hand, restorative educational programs were a matter of interest as participants mentioned that starting to learn new tasks may overload non-mastered learners both mentally and physically. Mc Sparron et al. have also pointed out that asking questions before teaching allows the faculty and the learner to identify gaps and create curiosity for more learning (31).

Some faculties insisted on the importance of informing students about the BfL. Blackwell et al. found that educating about the basic neuroscience of learning can be effective in the improvement of self-understanding, self-efficacy, metacognition, and motivation (32). Moreover, Mahan et al. discussed that presenting the students with the logic of educational processes and the methods of teaching would activate the internal reward system in the learner`s brain towards ultimate learning (33).

The importance of the learner`s orientation was expressed by some participants in this study with the aim of persuading learners to plan their learning during the course. Previous studies have also revealed that executive functions can be facilitated or inhibited by educational contexts which influence the student`s learning and achievement (34, 35). Moreover, Delany (2015) pointed out that work and study schedules are among the stressful challenges for medical students, which need to be addressed by the educators in instructional designing (36).

Participants considered the important role of emotions in learning. They suggested that providing happy, anxiety-free teaching-learning environments and strategies that encourage curiosity and creativity, using the potential of arts and utilizing especially wisdom-related rewards which trigger higher cortical functions are among the most

effective brain-friendly teaching-learning processes. Taylor et al. (2016) mentioned that emotion contributes to forming or elaborating more complex pathways for interpretation of experience (37). Lauria (2017) explained that novel, understandable, and integrated information presentation can result in positive emotion due to dopamine release in the reward system of the brain and thus increases learning. Furthermore, the multisensory information contained in a story can increase attention and retention and strengthens the schema generated by the brain (38). Feili (2018) mentioned that medical movies persuade active engagement and learning by medical students and increase the learner's curiosity and attention through its realistic medical scenarios, thereby reinforcing the original learning process (39).

Facilitation of cognitive and procedural learning, heeding learning in multi-contexts, task repetition, cognitive load management, learning by problem solving, deep exploratory questioning, learning by experience and trial and error, multimodal teaching, imagination, distributive learning, sleep role, learning by observation, and participative learning were indicated as important items for the "during the teaching activities". Although none of the participants referred to special kinds of cognitive loads, they considered them in their teaching-learning process. Studies propose that learning tasks ranging from easy to difficult, educational environments varying from low to high fidelity, pre-training in the features of important concepts, and principles that reduce the lessons into learner-controlled segments can result in intrinsic load management (15, 40-45). Moreover, preserving the concepts' incoherence and essential content delivering without redundancy are among the extraneous load reducing strategies. The illustration of the tasks or problems by using multiple examples, deep questioning, alternating tasks to prevent students from concentrating on only one aspect of the task, and practicing it in different contexts close to realistic ones, learner`s self-explanation, thinking out loud, and comparing and contrasting learned contents are among the strategies that help optimize germane loads (15, 31, 40, 41).

Multimodal teaching as a learning enhanced technique was also mentioned. Friedlander (2011) has shown that multisensory processing by simultaneous visual-auditory teaching without information redundancy is used for searching, encoding, and analyzing external information, as well as the internal representation of information in order to learn and consolidate the data. It is mentioned that different learning opportunities can be provided to different individuals through reading, lecturing, visualization, and the interactive use of the teaching equipment according to their needs. So, different teaching approaches that provide the information through multisensory processing may facilitate the learning process (18). Moreover, utilizing the appropriate body language was also emphasized by the participants since it can facilitate multi-sensory learning. A well-recognized study reported the significance of nonverbal communication, which leads to the "7/38/55" rule, where 7% of communication originates from spoken words, while 38% comes from the tone of the voice and 55% from our body language. So, educators can benefit from body language which engages the audience, grabs attention, controls challenging learners and conveys passion for a topic (46).

Visualization was also an important technique to enhance learning from the participants` point of view. Evidence showed that learning improves, following both learning by doing and the mental training, but they are based on distinct neuroplasticity changes in the brain. The cerebellum is more strongly associated with the first one and visual association cortex is related to the latter (18, 21, 47). Mirror neuron networks in the brain (the premotor cortex, the posterior parietal lobe, the superior temporal sulcus and the insula (48)) also participate in the process of visualization (18).

Spaced learning was another issue expressed in this research. Faculties provided rest time during their teaching and considered sleep as an important factor in the teaching-learning process, especially for information consolidation and decrease of cognitive errors. Lauria (2017) indicated that during a presentation, the peak of attention and concentration is between 10 to 15 minutes and after that, it decreases. Although the perfect presentation time is not clear, it is suggested to be between 20 to 30 minutes (38). Cellini (2016) also reported that sleep leads to the stabilization, strengthening and efficacy of neural patterns and it can strengthen learning during daily events (49).

The brain-friendly evaluation consists of frequent assessments, and test-enhanced learning was suggested by faculties as part of the post-teaching activities. Learning by testing or testing effect was another learning strategy suggested by the participants. Reuiter (2013), Cecillio-Fernandez (2016), Van Hoof (2018) mentioned that repetitive tests during learning facilitate retrieval from long-term memory. This strategy modifies the information based on the new knowledge and improves learning by the reconstruction of schemas (5, 28, 50).

The faculty's and the student`s self-reflections were asserted as important "after teaching activities" to enhance the teaching-learning process. Taylor et al. (2016)

explained that self-reflection is similar to a bridge between tacit and explicit aspects of knowledge (7). Van Hoof (2018) and Gozuyesil (2014) suggested that faculties should ask questions to promote self-reflection and also specify the time to practice it by learners. This way, faculties create a safe atmosphere to integrate the learner`s thinking, connection establishment and gap identification needed to be filled for enhanced learning (5, 51).

Mentorship was an emerging category which was formed to demonstrate the faculties` viewpoint related to the importance of transferring professional and humanistic attitudes besides transferring knowledge and skills and considering the emotional aspects of the teaching-learning process. Mentorship comprised the subcategories of "coaching" and "professionalism consideration". Rencic (2011) mentioned that coaching can include feedback, motivation facilitation, and role modeling (52). Boud (2015) pointed out feedback from faculty is very important as it can open up or close down learning possibilities. The main purpose of feedback is the learner's capacity of improvement by using the information to picture themselves in similar situations. Students always need to be placed as pro-active learners who can initiate feedback seeking behavior (53). The importance of the valence system was mentioned by the interviewees, related to motivating students and providing an appropriate emotional environment for ultimate learning. Research states that the basis of the positive valence systems is to approach motivation, which can be explained as regulating the process to direct and maintain the approach behavior (54). So, behavior can be controlled through the valence a learner associated with the entering data. Furthermore, role modeling activities were stated as an important mentorship process in this study, since learners often learn by observing and imitating a role model. Evidence revealed that learning by observing and imitating others can be facilitated by mirror neuron`s activities in social contexts (55). Ramani (2003, 2008) and Carter (2016) explained that a clinical medical educator has the opportunity to be a role model to his learners and teach professional ethics and professionalism, performing procedures and conducting physical examinations without lecturing in a purely theoretical mode (56-58).

Limitations

In terms of the limitations of this study, we note that we had access to select specialties in the brain and neural sciences, while other emerging fields such as behavioral neuroscience, social neuroscience, cultural neuroscience, and developmental neuroscience had not been considered. However, we tried to create diversity among the participants in terms of common brain and neural specialties in Iran. It is also recommended to investigate the opinions and experiences of faculties regarding the challenges and facilitators of BbT-L in a multidisciplinary expert panel so that by reaching a deep understanding of such experiences, we can make progress towards neuro-educational studies in higher education.

Conclusions

We organized the faculty`s perspective and experience about brain-friendly teaching-learning into 4 categories of general teaching models and one additional category labeled "Mentorship", similar to an umbrella for all 4 categories. It seems that higher education faculties could facilitate the teaching-learning process if they were educated about neuro-educational studies as new learning sciences, in terms of the brain's structure and functional uniqueness in instructional designing, executive function facilitation related to the learner`s educational contexts, attention to the importance of valence system for learning optimization, contextualized learning, considering the role of sleep for information consolidation, cognitive load issues, problem-oriented learning, social learning, multi-sensory learning, spaced learning, brain-friendly evaluation, and some techniques such as repetition, deep questioning, opportunity to trial and error, visualization, feedback and reflection. Furthermore, the learner's development related to the basic neuroscience of learning can improve their learning skills in universities. Mentorship can facilitate brain-friendly teaching-learning processes, mostly because of the professional and humanistic attitude transfer and also the emotional facilitation for learning optimization. We hope that our findings strengthen the emerging field of neuro-educational science and application according to the perspective and experience of faculties specializing in brain and neural sciences in Iran regarding BfT-L.

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Acronyms and abbreviations

BfT-L: Brain-friendly Teaching-Learning

BfL: Brain-friendly Learning

Conflict of interest disclosure

There are no known conflicts of interest in the publication of this article. The manuscript was read and approved by all authors.

Compliance with ethical standards

Any aspect of the work covered in this manuscript has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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