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Natural science and engineering instructors' knowledge and practice of brain-based instruction in Ethiopian higher education institutions

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ABSTRACT

Currently, the Brain-Based Instructional approach has become an alternative instructional method in the schooling system of different countries of the world. This study explored the current situation of natural science and engineering instructors' knowledge and practices of brain-based instruction in Ethiopian higher education institutions. A descriptive survey research design with concurrent mixed methods was employed. Data collection tools were developed based on the twelve principles of brain-based learning theory and confirmed their validity and reliability. Survey questions were used to gather quantitative data from 512 randomly selected instructors. Qualitative data were collected through interviews with 14 purposely selected instructors. Classroom observation was also conducted to triangulate data obtained through interviews and survey questions. Quantitative data were analyzed using descriptive statistics, whereas qualitative data were analyzed thematically. The findings of this study depict that most natural science and engineering instructors have good knowledge of brain-based instruction but not transferable knowledge and skills. There is a clear gap between instructors' knowledge and classroom practice of brain-based instruction. Thus, to improve instructional practices, higher education institutions need to work strongly to narrow the existing variation. Implications and further recommendations are also suggested.

1. Introduction

At this time, there are multiple studies about neuroscience and its implication for education. Most of the studies have focused on how the human brain executes different activities and makes memories using imaging technologies [1–6]. The rapid growth of new brain-imaging technologies (such as Magnetic Resonance Imaging-MRI, functional Magnetic Resonance Imaging-fMRI, Magneto-encephalography-MEG, etc.) has a significant role to comprehend the different parts of the human brain, how it performs multiple activities, and its influence on educational policy, particularly the classroom practices [6–8].

The increased research in neuroscience, cognitive neuroscience, behavioral neuroscience, computational neuroscience, psychology, medicine, etc. shed light on reforming the contemporary schooling system of many countries in the world [9–13]. The intersection of these varying fields was the foundation for the new discipline, Mind, Brain, and Education. Following this, Brain-based instruction (BBI) has emerged as an alternative teaching method and is rapidly growing to influence classroom practice in various countries [4,9,

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14–17]. As a result, in the past two decades, in many developed countries, BBI has started to become one of the alternative pedagogies in their school curriculum.

Various neuroscience scholars describe BBI in their words in connection to the research findings of neuroscience, and yet all focus on the human brain and its influence on learners' behavior, cognitive function, and effect on the actual classroom learning-teaching process. For example, some neuroscientists described it as a teaching method that focuses on how the various parts of the human brain learn in the way nature is designed to learn. It is also expressed as an active instructional method that enables learners to actively receive neural input from the environment, process information, make analyses, give meaning, make logical connections with previous knowledge, retain information, and redeem stored data [14,15,17,18]. BBI is a learning-teaching approach that deals with inquiries like "how do the learners' brain effectively learn?", "how do learners memorize?" and "how do learners make a meaningful connection?" [4,13,17,19]. These questions portray the strong association of BBI with learning and hence the teaching process. Likewise, Jensen [15] described BBI as an instructional method based on the twelve principles of brain-based learning theory that help learners to fully engage in meaningful learning.

The brain-based learning principles are the core foundation for the BBI [14,15,19]. These principles indicate that the human brain is capable of executing multiple activities simultaneously. Learning requires learners' entire bodies and emphasizes that learners learn uniquely. Learners' emotions are also key in triggering learners to make sound and logical meaning of the material/content through the pattern. Patterns have an indispensable role in making connections with learners' experiences and inputs from the environment and hence meaningful learning occurs. Besides, brain-based learning principles show how the learners brain analysis and synthesis (the wholes and parts) of different activities during the learning-teaching process. Learning also requires focusing on the mind and peripheral perception (i.e., conscious and unconscious processes). Learning is developmental under exposure to challenging activities and a safe learning-teaching environment. In a conducive learning environment, the learners' spatial and working memory certainly improve and hence their brain is ready for further learning [4,14,15,17,19,20].

Moreover, according to Caine and Caine [14], the twelve core brain-based learning principles are classified into three main brain-based instructional techniques. These are: 1) Relaxed Alertness: It is a way of eliminating students' learning threats or negative stress and engaging them in a challenging learning environment. This signifies that the learner's mind works to its maximum level and executes various activities without distraction by deterring the potential barriers that possibly exist in the learning-teaching environment. 2) Orchestrated Immersion: It creates a conducive [desirable] learning-teaching atmosphere that can fully immerse learners in rich and complex educational experiences. It is a means that engages the learner's brain to construct meaningful learning in connection with their prior experiences and natural environment. 3) Active processing: It is related to how learners consolidate and internalize the object (information) and make meaningful learning. It focuses on understanding rather than rote memory. These teaching techniques enable instructors to comprehend the complexity of the learner's brain and how it works effectively.

Proper knowledge and experience of the instructional methods lead to the effective use of instructional techniques in the learning-teaching process. Moreover, efficient use of these techniques allows learners to deep-learning and increase their cognitive, social, emotional, and practical skills [11,14,15,19]. Unlike the traditional methods, in BBI, learners can also demonstrate a high level of motivation, knowledge retention, and academic achievement [15,19,21,22]. Moreover, BBI is an effective instructional method that enables learners to develop metacognitive skills to critically think about how and what they learn by engaging the entire physiology of learners in a rich and attractive learning environment. It is also crucial in addressing learners' uniqueness (how learners learn in different ways) as they grow cognitively, emotionally, and socially [23]. The growth of these skills in turn provides learners with greater autonomy and independence in the learning-teaching process than traditional instruction. Learners certainly construct long-lasting memories and retain meaningful knowledge when instructors effectively use the core elements of BBI such as relaxed alertness, orchestrated immersion, and active processing [17,22,23].

Further, a thorough understanding of BBI has profound implications for the classroom learning-teaching process in higher education institutions (HEIs), especially in natural science and engineering fields. In this sense, instructors need to equip themselves with a firm knowledge of BBI techniques (relaxed alertness, orchestrated immersion, and active processing) to improve the quality of the classroom learning-teaching process.

Understanding the crucial role of natural science and engineering fields in the economic development of the country, the Ethiopian government has revised its education training policy and curriculum to improve the quality of the learning-teaching process in HEIs and thereby produce knowledgeable and skillful manpower to meet the demand for the labor market for the different economic sectors. Accordingly, the Education Sector Development Programme V (ESDP V) has given priorities on "Deliver quality education that meets the diverse learning needs of all children, youth, and adults; and Develop competent citizens who contribute to the social, economic, political, and cultural development of the country through creation and transfer of knowledge and technology [24]." Besides, the Ethiopian Higher Education Institutions (EHEIs) curriculum has emphasized on learning-teaching approach (such as discovery, critical thinking, memory-enhancing activities, diverse teaching and learning styles, individual differences, whole-body engagement, learners' emotions, cooperative learning, fieldwork, diverse forms of assessment, reflection, and feedback, etc.) to improve the overall quality of education [24,25]. A thorough look at the curriculum framework and the Education and Training Policy indicates the presence of the fundamental elements of BBI in its various forms, especially in the natural science and engineering fields.

Despite the emphasis given to BBI in the learning-teaching process at all levels, recent studies do not portray if natural science and engineering instructors acquire sufficient knowledge and skills of BBI which are crucial for effective learning-teaching. In addition, most studies on BBI used quasi-experimental research design and small sample sizes. And this might not show the complete nature of the core elements of BBI such as relaxed alertness, orchestrated immersion, and active processing [26–29]. Besides, most of the studies focused on private elementary schools, secondary schools, and very few colleges. In developing countries, research on how natural science and engineering instructors in HEIs apply BBI in the actual classroom is scanty [30–32]. Besides, some research findings indicated that BBI is haphazardly implemented at every school level and appeared to be unsuccessful [24,31,33,34]. Perhaps, such ineffectiveness might be associated with natural science and engineering instructors' knowledge and instructional practice of BBI is not clear [33]. Moreover, whether natural science and engineering instructors in EHEIs have a clear awareness of the fundamental elements of BBI (relaxed alertness, orchestrated immersion, and active processing) is poorly understood, as most studies have focused on the traditional methods of teaching. Therefore, the purpose of this study was to determine the extent to which natural science and engineering instructors in EHEIs know BBI as an instructional approach and utilize it in the classroom learning-teaching process.

2. Research questions

This study attempted to answer the following research questions.

(1) To what extent do natural science and engineering instructors in EHEIs know about BBI?
(2) To what extent do natural science and engineering instructors in EHEIs practice BBI in their actual classroom learning-teaching process?

3. Significance of the study

The current literature review shows that most studies on BBI were conducted in developed countries, with different contexts, cultures, and technology, and which do not reflect the situation of developing countries. This study reveals the real situation of the learning-teaching process of EHEIs, which could be another dimension and serve as an input to current literature, by investigating the knowledge and practice of natural science and engineering instructors about BBI. Moreover, this study has a methodological contribution to current literature because most studies carried out on BBI are either qualitative or quantitative (specifically quasi-experimental) research methods. However, this study applies mixed-approach (both qualitative and quantitative research methods) and has the advantage of obtaining an in-depth and wide understanding of the current study. The output of the study can also provide practical implications for national policymakers and institutional practitioners. Furthermore, the study may have a significant impact on learning-teaching practice in HEIs, help natural science and engineering instructors to integrate BBI in their lessons and engage students in the actual learning-teaching process and thereby increase their academic achievement.

4. Research methods and materials

This study applied a descriptive survey with concurrent mixed-methods research (MMR) design. Initially, targeted instructors were surveyed and then interviewed before the authors had the results of the survey. This is because, unlike a single research method, the MMR provides a better comprehension of research and more acceptance of study findings and makes inferences based on the study [35]. Besides, MMR resolves the weaknesses which could arise by applying only a single method [36]. And, hence both quantitative and qualitative data were collected in a single phase from the same participants (or similar target populations) to see the comprehensive nature of this study.

Quantitative research is crucial to examine objective theories in connection with defined variables that can be expressed through numerical data [36]. Cognizant of these facts, survey questions were utilized to collect numeric data about the level of natural science and engineering instructors' knowledge of and classroom practices of BBI in EHEIs. Besides, qualitative data were collected through deep semi-structured interviews to substantiate the information obtained through the survey questions. This study also harnessed classroom observations to triangulate the data obtained through survey and interview questions.

4.1. Participants

The population of this study was the entire natural science and engineering instructors in EHEIs in the Tigray region. Initially, a sample of 564 randomly selected natural science and engineering instructors were involved in the survey questions. After the survey questions were distributed to the subjects, only 512 of them were valid and filled appropriately, and used for the final analysis of this study. Furthermore, 14 purposely selected instructors (7 from natural science and 7 from engineering) were interviewed to gather relevant data regarding the research questions. And, to observe how the natural science and engineering instructors practice BBI in their actual classes, 12 (6 from natural science and 6 from engineering) volunteers of the interviewed instructors were observed for three instructional periods each.

4.2. Instruments and Procedures

This study used survey questions, deep interviews, and classroom observation to collect valid and reliable data. The survey questionnaire was prepared based on the twelve principles of Brain-based learning theory developed by Caine and Caine in 2005. A pilot study was conducted to confirm the reliability and validity of the collected data. The coefficient of Cronbach's alpha (α) value was used to compute the internal consistency of the items in the survey questionnaire. The survey questionnaire consists of 21 Likert scale items (with "1" implying "strongly disagree" to "5" being "strongly agree") on instructors' knowledge of BBI and 20 Likert scale items (with "1" implying "never" and "5" being "always") referring to their practice of BBI in the classroom learning-teaching process. These items were categorized into three subscales (such as relaxed alertness, orchestrated immersion, and active processing). Table 1 depicts the Cronbach alpha (α) value of the subscale and the overall items. The reliability analysis results for all the variables depicted an acceptable level of internal consistency [37].

Concerning the interview, semi-structured interviews with guiding questions were designed in line with the research questions based on the principles of Brain-based learning theory to obtain relevant information from key informants. The interviewees were selected based on their teaching, work, and research experience. Besides, the researchers discussed with the interviewees to see their awareness of BBI side by side with the survey data. After identifying the instructors who are familiar with BBI, the researchers expressed clearly the purpose of the interview. To make the interview smooth, the interview questions were designed using the English language. During the interview, interviewees were free to use their local language to sense freedom of expression and describe their ideas smoothly. The interview was guided by providing some probing questions such as "give an example", "elaborate on it", etc.

To substantiate the data obtained through survey and interview questions, this study used actual classroom observation. Classroom observation is useful to comprehend what is really happening in the actual classroom and is required to gate easily communicable data that inform the classroom practice. Thus, for classroom observation, the researchers prepared an observation checklist based on Caine and Cane's twelve brain/mind principles and Eric Jensen's teaching with the brain in mind. The observation checklist has twelve items with a focus on the three fundamental components of BBI (relaxed alertness, orchestrated immersion, and active processing). The scores of the 12 items for the classroom observations were rated based on 0 to 4 points with "0" implying "never" and "4" indicating "instructors frequently apply BBI".

4.3. Validity of the instruments

Validity is an indispensable metric for assessing the quality and adequacy of research and computing what it is supposed to measure [38]. The content validity of the instruments (survey, interview, and classroom observation) was confirmed by the judgment of five-panel experts. The experts rated every item on a 1 to 5 score based on their accuracy, relevance, simplicity, and applicability. The average content validity index (CVI) was 0.953 for survey questions, 0.902 for interview questions, and 0.931 for classroom observation. The CVI for each tool revealed an acceptable level of validity [37].

4.4. Ethical Considerations

The study was done with the full approval of the study site. The universities wrote a letter of consent to their respective colleges and departments to facilitate the data collection process. In addition, all potential respondents were provided informed consent before they participated in the study. The study also protects the confidentiality of anonymous respondents. Special attention was also made to the culture, beliefs, and opinions of participants.

4.5. Data analysis methods

The quantitative data were analyzed employing descriptive statistics (cumulative frequency, mean, and standard deviation) using SPSS version 24. Thematic analysis was applied to analyze the qualitative data. Data gathered from the interview and field notes were analyzed critically by forming essential categories, sub-themes, and main themes related to the research questions. Moreover, the classroom observations were analyzed through cumulative frequency based on the lens of the twelve principles of Brain-based learning theory [18].

5. Results

This study aimed to examine the natural science and engineering instructors' knowledge of BBI and its influence on applying the principles of BBI in the classroom learning-teaching process at EHEIs. To this end, the first research question determined the extent to which the current natural science and engineering instructors in EHEIs know about BBI.

The outcomes of the study were explained based on the fundamental elements of BBI (such as knowledge of relaxed alertness, orchestrated immersion, and active processing). Accordingly, Table 2 depicts the descriptive statistics of responses of natural science

Table 1
Reliability statistics.

Scale	Number of items	Cronbach's alpha (α) Value
K-RA	8	.812
K-OI	7	.703
K-AP	6	.782
Overall Knowledge of BBI	21	.814
P-RA	9	.831
P-OI	6	.758
P-AP	5	.765
Overall Practice of BBI	20	.847

Note: K-RA, K-OI, and K-AP refer to Knowledge of Relaxed Alertness, Orchestrated Immersion, and Active Processing. Likewise, P-RA, P-OI, and P-AP refer to the Practice of Relaxed Alertness, Orchestrated Immersion, and Active Processing.

and engineering instructors' knowledge of BBI.

The descriptive analysis of quantitative data in Table 2 shows that the mean score of instructors' knowledge of relaxed alertness was 3.68 (SD = 0.55). The mean score of instructors' knowledge of orchestrated immersion was 3.78 (SD = 0.49). Likewise, the instructors' mean score of active processing knowledge was 3.97 (SD = 0.58). And, the aggregate mean score value was 3.79 (SD = 0.45) which revealed that most natural science and engineering instructors in EHEIs possess good knowledge of the basic principles of BBI.

In agreement with the quantitative results, the qualitative data showed that most of the natural science and engineering instructors were familiar with BBI. The data obtained from the interviews about the instructors' awareness of BBI lie on major themes such as instructional approach, meaningful learning, classroom environment, neuroscience, emotional connections, and learning interaction. For example, about the instructional approach, a biology instructor described BBI as:

> […] an effective instructional method that engages learners in deep learning and assists to make meaningful connections with prior knowledge and experiences. It also enables learners to retain the knowledge gained for a long time.

Similarly, a mathematics instructor expressed it as "a teaching strategy that requires learners' critical thinking ability. And thereby enables learners' brain to internalize and integrate the various information they received and restore for further use."

Most of the interviewed instructors also articulated BBI as a new instructional method that could be effective in a positive and safe classroom environment. Supporting this, a civil engineering instructor described BBI as:

> …, a learning-teaching strategy that requires a rich and attractive classroom environment that engages the entire physiology of learners. It fully engages learners to be active with their learning and is proactive in reflecting on their ideas. A well-designed learning-teaching environment for BBI, be it in an actual classroom or laboratory room, or fieldwork, always attract and maintain learners' full attention.

Some of the interviewed instructors also described BBI as a neuroscience research finding. A Mechanical Engineering instructor described it as "a new teaching method based on scientific findings of neuroscience study." Congruent with this, a biology instructor said:

> It is a newly emerged instruction from the blended fields of biology and neuroscience and mainly deals with how the learners' varying parts of the brain learn effectively. Under the BBI, learning-teaching is related to the development of neurons or dendrites in the learner's brain. It is all about how the learner's brain acquires, processes, analyzes, and interprets information and retains it in long memory.

Consistent with the above facts, some of the interviewed instructors described BBI in terms of "new neural connections" and elaborated it as "learning that occurs whenever neurons of the learner's brain make new connections. That is, the more a memory possesses new connections, the better durable it is."

They also described it with emotional associations and connections. Most of the interviewed instructors believed that keeping the emotional mind of a learner during the learning-teaching process is critical. Thus, BBI helps learners to manage their intrinsic emotions

Table 2
Descriptive statistics of the responses of natural science and engineering instructors' knowledge of BBI (N = 512).

Item	Statement	Mean	SD
K1	Possess enough knowledge of how to use one-to-one, small group, and/or whole group discussions in my class.	3.83	.68
K2	Possess enough understanding of how to do practical work.	3.73	.69
K3	Know how to pre-expose learners to new content and the context of a topic.	3.79	.67
K4	Familiar with how learners interact with one another in class.	3.75	.82
K5	Possess enough understanding of how learners assess their learning.	3.68	.80
K6	Familiar with how to maintain learners' interest in the class.	3.47	.83
K7	Understand how to maintain learners' attention.	3.60	.80
K8	Familiar with how learners construct their learning.	3.57	.86
	Knowledge of Relaxed Alertness	**3.68**	**.55**
K15	Familiar with the multi-sensory environment.	3.72	.71
K16	Know how to prepare for challenging activities.	3.91	.61
K17	Familiar with multiple forms of assessment.	3.62	.70
K18	Familiar with how to incorporate learners' experiences in class.	3.85	.82
K19	Know how to offer reflection time during instruction.	3.80	.78
K20	Know how to evaluate learners uniquely.	3.75	.76
K21	Understand how to provide ongoing instant feedback.	3.80	.67
	Knowledge of Orchestrated Immersion	**3.78**	**.49**
K9	Possess enough understanding of how learners consolidate information.	3.97	.73
K10	Know how learners contemplate concepts and make essential connections.	3.94	.89
K11	Know how to encourage learners to develop higher-order thinking skills.	3.99	.78
K12	Know how to consider learners' learning styles and uniqueness.	3.90	.83
K13	Familiar with how to make meaningful learning.	3.92	.79
K14	Familiar with how learners make situation analyses.	4.09	.69
	Knowledge of Active Processing	**3.97**	**.58**
	Instructors' overall Knowledge of BBI	**3.79**	**.45**

Note: SD refers to the Standard Deviation.

and raise their interest in learning. In line with this, a Chemistry instructor expressed it as:

> A teaching strategy that focuses on learners' readiness for learning. Having a good understanding of BBI could assist to manage distracting factors in the learning process. And, instructors can keep the interest or attention of learners during the learning-teaching process.

In support of this, an Electrical Engineering instructor also said that "BBI is highly connected with learners' sensory functions to recognize the various learning conditions and knowledge about how to react and then how to carry out actions."

Supplementing the findings, among the four evaluation measurements shown in Fig. 1, the cumulative percentage is a relatively good evaluation criterion to scrutinize the extent of natural science and engineering instructors' knowledge about BBI. The result shows that the majority (71 %) of the instructors possess good knowledge and about 10 % have excellent knowledge of BBI. On the other hand, about 19 % of them possess poor knowledge of BBI (see Fig. 1).

The quantitative, as well as qualitative results, signifies that natural science and engineering instructors in EHEIs have good knowledge of the fundamental elements of BBI (relaxed alertness, orchestrated immersion, and active processing).

The question that can be raised here is: Does it always mean that acquiring good knowledge implies the good practice of BBI in the actual classroom learning-teaching process? To see this, consider the second research question which deals with the extent to which natural science and engineering instructors practice the core elements of BBI in their classroom learning-teaching process. The descriptive statistics in Table 3 depict responses of natural science and engineering instructors' classroom practice of BBI.

From Table 3, the mean score value of instructors' practice of relaxed alertness was (M = 2.94, SD = 0.60). The mean score on the practice of the orchestrated immersion was (M = 3.37, SD = 0.52) and that of active processing was (M = 3.43, SD = 0.53). The overall mean score of instructors' practices of BBI was (M = 3.25, SD = 0.43). These results depict that natural science and engineering instructors' practice of BBI appears to be more than average. Nevertheless, this score does not mean that the instructors effectively utilize BBI in their classroom as the requirement of the principles of Brain-based learning theory. This is because most of the scores of instructors' responses were concentrated around the middle score value (3 points). This indicates that most instructors [sometimes] use BBI in their classes. In support of this, the responses of the interview indicated that: core activities of BBI such as the provision of enough time for learners to process information, do practical activities, keep attention, construct their learning, apply multiple forms of assessment, provide chances to consolidate and internalize information, seem to be not usually practiced in the learning-teaching process.

Consistent with these results, considering cumulative percentage as evaluating criteria for overall instructors' practice of BBI, out of 512 natural science and engineering instructors, only 10 % of them had shown effective usage of BBI in their actual class. And 25 % of them had acceptable/good practices of BBI. On the contrary, the largest proportion (65 %) of instructors had a poor practice of BBI in learning-teaching processes (see Fig. 2) that need further improvement.

In support of the quantitative results, most interviewed instructors agreed that "BBI is highly applicable to create meaningful learning and is a means for knowledge retention and transfer. However, the trend showed that learners are not usually actively engaged in the learning-teaching process." This signifies that there is a gap in utilizing the fundamental elements of the BBI in the classroom learning-teaching process.

To see the big picture of instructors' classroom practice of BBI, instructors were asked the guiding question: "How often do you use fundamental elements of BBI in your class?" In response to this inquiry, most of the interviewed instructors replied that "they sometimes apply BBI in their learning-teaching process." For instance, a mathematics instructor suggested that:

> …, most mathematics instructors commonly use elements of BBI such as brainstorming, think-pair-share, and reflection in their class, especially when they introduce definitions of new terms, theorems, and corollaries. This is because BBI allows the learner's brain to primarily think about the material/object, make a discussion with their partner, and reflect on the whole class. This method assists to break the content into its parts so that learners can easily process it effectively. Despite its significance, it is not effectively utilized in the actual classroom due to the large class size (usually an average of 70 students per class),

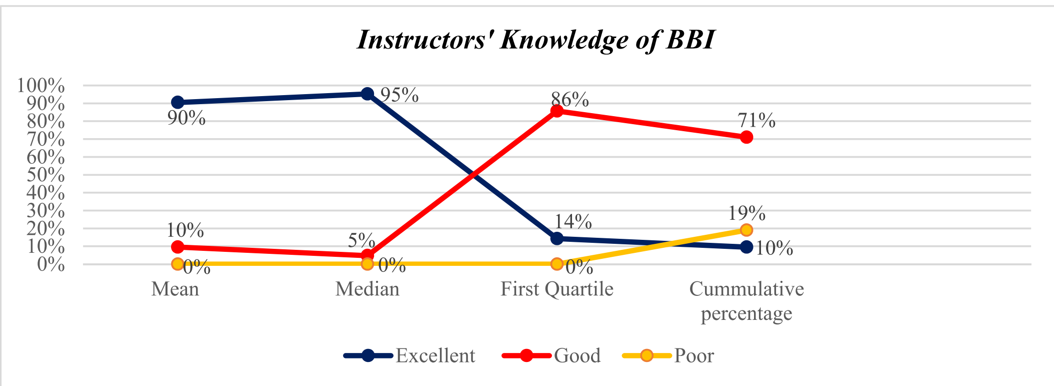

Fig. 1. The extent of the overall natural science and engineering instructors' knowledge of BBI.

Table 3
Descriptive statistics of the responses of natural science and engineering instructors' classroom practice of BBI (N = 512).

Components of BBI	Mean	SD
Relaxed Alertness	2.94	.60
Orchestrated Immersion	3.37	.52
Active Processing	3.43	.53
Overall Instructors' Practice of BBI	**3.25**	**.43**

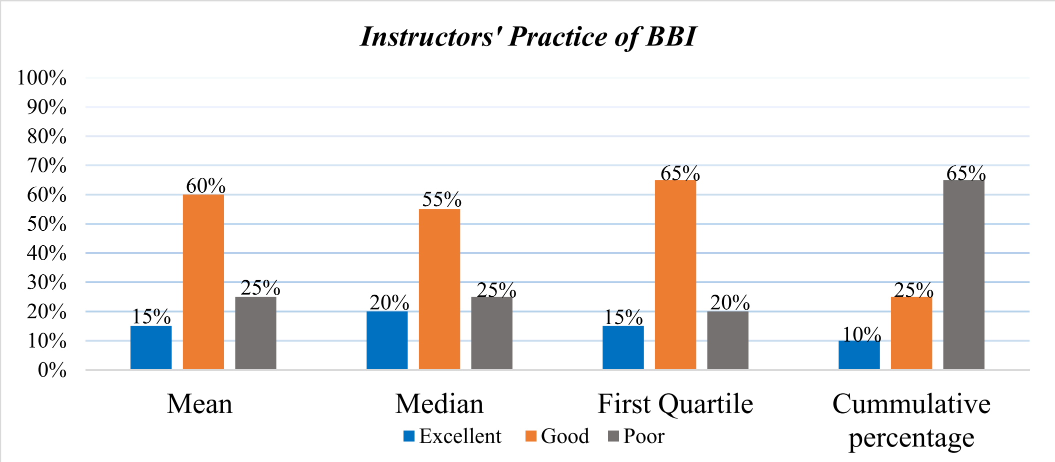

Fig. 2. The extent of the overall natural science and engineering instructors' practice of BBI.

especially in the College of Engineering. To see proper discussion and reflection of such a large number of students is difficult and time-consuming.

Besides the above reality, some interviewed instructors relate their ineffective interaction with course content and classroom setting. Due to the vast course content, most instructors are imposed to cover course content. They usually used the traditional lecture method and PowerPoint presentation which of course restrict learners to make effective interactions. Moreover, the fixed-row armchair seating arrangement and the large class size make group interaction difficult.

Further, when instructors asked about "what BBI activities are easily applicable in class?", most of the responses were inquiry-type activities, hands-on activities, puzzles, and project work. However, a look at the classroom observation indicated that their practices were not satisfactory. Supporting this, a Mechanical engineering instructor described the trend in his university as:

Table 4
Instructors' classroom observation on the practices of BBI.

No.	Descriptions	Often		Sometimes		Rarely	
		f	%	*f*	%	*f*	%
	1. Relaxed Alertness						
1	2. Create a conducive classroom environment.	3	25	8	66.7	1	8.3
2	3. Maintain learners' attention.	4	33.3	7	58.3	1	8.3
3	4. Allow learners to have downtime to process information.	2	16.7	8	66.7	2	16.7
4	5. Keep learners pursuing their interests.	3	25	7	58.3	2	16.7
	1. Orchestrated Immersion						
5	Provide students with a multi-sensory environment.	1	8.3	8	66.7	3	25
6	Engage learners in challenging activities.	2	16.7	8	66.7	2	16.7
7	Utilize multiple forms of assessment.	1	8.3	7	58.3	4	33.3
8	2. Provide ongoing instant feedback.	1	8.3	9	75	2	16.7
	Active processing						
9	Engage learners to consolidate and internalize information.	1	8.3	8	66.7	3	25
10	Assist learners to make meaningful learning.	1	8.3	5	41.7	6	50
11	Engage learners to construct their learning.	1	8.3	7	58.3	4	33.3
12	Encourage learners to develop critical thinking skills.	1	8.3	8	66.7	3	25

Note: f refers to the frequency of natural science and engineering instructors' practice of BBI in their classes.

…, Instructors have got different training aimed at enriching their pedagogical knowledge, skills, and appropriate activities for BBI. However, most of them are not seen applying their knowledge and skills in their class. In this way, it is unlikely to think that every learner can construct meaningful learning.

When asked about how they create meaningful learning, the most common replies were analyzing learning situations, making real connections, identifying characteristics, seeing relationships, and making critical thinking. In this regard, a biology instructor said:

…, most instructors in the natural science fields are familiar with how to make meaningful learning. But, the situation at the university is not conducive. Most instructors rarely apply BBI to make meaningful learning, because most of the courses are designed without laboratory experiments, fieldwork, and apprenticeship. In this case, learners do not get real exposure and experience to relate the theory to a real environment. Hence, learning might not be concrete and last for a long time.

Similarly, the classroom observation showed that most natural science and engineering instructors were seen poorly practicing the fundamental elements of BBI in classes (see Table 4) which strongly supports the data obtained through survey questions and interviews.

The result in Table 4 shows most instructors "sometimes" applied the basic elements of BBI (relaxed alertness, orchestrated immersion, and active processing) in the learning-teaching process. Concerning relaxed alertness, the classroom observation indicated that most instructors have poor practice. Most of the instructors did not usually create a conducive learning-teaching atmosphere, keep learners' emotions (attention and interest), and allow learners to have downtime to process information at their disposal. With a focus on the use of orchestrated immersion, classroom observations showed that most instructors did not effectively use it in their classes. For example, a multi-sensory environment, challenging activities, multiple forms of assessment, and ongoing instant feedback were not given regularly. A similar scenario was observed regarding the indicators of active processing. The majority of the instructors rarely provided opportunities for learners to internalize the concept, make meaningful learning, and encourage critical thinking skills. All in all, the results of the study indicate that natural science and engineering instructors' practice of BBI is not as per the principles of the brain-based learning theory and hence needs serious follow-up and further improvement.

6. Discussion

This study intended to examine the extent to which natural science and engineering instructors in EHEIs know the fundamental principles of BBI (relaxed alertness, orchestrated immersion, and active processing) and the effect on applying the core principles in their classroom learning-teaching process. The results of this study are explained and interpreted in connection with the principles of brain-based learning theory.

The quantitative and qualitative results of this study show that most natural science and engineering instructors acquire basic knowledge of BBI (relaxed alertness, orchestrated immersion, and active processing). Instructors are aware of how to create a safe learning environment, learning interactions, emotional and neural connections, and meaningful learning. This signifies that proper knowledge of BBI enables the instructors to realize how the different parts of the learner's brain learn effectively. It could also assist the instructors in designing and developing workable lessons that can immerse learners in varying learning experiences and emotional connections in the learning-teaching process. Supporting this, prior research work has shown that proper comprehension of the key elements of BBI is crucial to creating meaningful learning, retaining knowledge, and improving long-lasting memory [16,19,22].

Furthermore, an awareness of the brain-based learning principles enables instructors to make an effort to impair learners' stress and create a conducive learning environment that maximizes learners' learning potential [11,15,22]. Under a challenging classroom environment and minimal stress, learners are fully immersed in multiple learning experiences. This in turn helps learners actively process, internalize and retain available information [concept] to continue their learning [15,18,19]. Supporting this, Morgan [32] suggested that instructors that understand neuroscience and BBI easily engage learners in a practical learning environment [in or outdoor] that can allow learners to completely immerse, produce, interact, and process meaningful information and retain it as a long memory. Likewise, unlike the traditional instructional method, Jensen and McConchie [39] suggested that BBI is a good instructional method that incorporates psychology, cognitive science, and neuroscience research findings to direct the classroom process. And thus when instructors acquire a proper knowledge of the core elements of BBI and how the learners' brain executes varying activities could improve the learning-teaching process of natural science and engineering fields at HEIs. In addition, instructors could recognize what students are learning and how they are learning effectively based on the principles of neuroscience and brain-based learning theory, and, consequently, improve the quality of the global learning-teaching process.

In fact, what instructors apply in the actual learning-teaching process relates to what they know and understand about BBI. The issue is whether this always means that a good knowledge of BBI implies good practice in the classroom. In this study, although most natural science and engineering instructors have a good knowledge of BBI, the results of their BBI practice indicate the opposite. Surprisingly, all the surveys, interviews, and classroom observations depict that most natural science and engineering instructors are poor at utilizing the core elements of BBI (relaxed alertness, orchestrated immersion, and active processing) in their classrooms. Most instructors did not frequently create a conducive learning-teaching atmosphere, engage learners to construct their learning, make good interactions, maintain learners' emotions, immerse them in a multi-sensory environment, make logical connections, assess their learning, and meaningful learning. Furthermore, most courses in natural sciences and engineering are not supplemented by practical work (laboratory and field work). Instead, most instructors typically use the traditional instructional approach [lecturing and PowerPoint methods] aimed at covering the course content. This clearly shows that irrespective of their good knowledge, most instructors do not apply the crucial elements of BBI correctly. This means that learners may not have an opportunity to interact with each other, ask questions, process information, think, internalize, and create meaningful learning. In line with this finding, prior related works depicted that whenever instructors inconsistently practice certain BBI skills, learners find it difficult over time to improve their essential learning abilities and skills [22,40]. Strengthening these findings, Jensen and McConchie [39] suggested that mere knowledge without proper practice could not rewire a learner's brain and strengthen neural connections to make meaningful learning. This is because only the appropriate use of BBI techniques engages learners in deep learning with full attention and helps them improve their cognitive, social, emotional, and practical skills [8,11,14,15,19,22].

Furthermore, the findings of this study show that EHEIs are characterized by a traditional classroom setting, large class sizes, and less furnished classrooms. This condition might hinder instructors' effective implementation of the key principles of BBI in the learning-teaching process. Supporting this, Jensen [15] suggested that a classroom that is not practical for free movement undermines meaningful learner learning. When the classroom setting is not conducive, instructors remain ineffective and unable to use strategies that address the key components of BBI (relaxed alertness, orchestrated immersion, and active processing), and the learning-teaching process does not give real sense to learners [18,31,39,41] and hence learners face the problem of constructing meaningful learning. That is, BBI demands learners' proper physical movement (such as walking, talking, writing, tapping out, etc.) to fully engage in the learning-teaching process and create neural networks that enhance learners' emotions and long-lasting memories [15,16,18,42]. Supporting this, Gage [29] and Jensen [15] suggested that proper movement and classroom setting increase the release of brain chemicals (endorphins) which are essential for making emotional connections and permission for improving on-task behaviors [15, 29]. It also helps learners develop an interest in interacting, working in groups, and making sound reflections. This in turn enables them to maximize their collaborative, social, practical, and critical thinking skills [11,15,19]. This signifies that whenever instructors properly apply the BBI techniques in the classroom, learners could demonstrate a high level of motivation, and improve their knowledge retention, and academic achievement [15,19,21,22].

The classroom environment needs to engage learners with challenging activities to make emotional connections and create meaningful learning. Related studies also suggested that classrooms that allow learners free movement while doing activities help to increase learners' neurons that enhance their cognition [30,43] and reduce learners' depression. They also argued that a classroom environment that allows free movement helps learners to develop new brain cells that improve learners' motivation, alertness, and attention in the learning-teaching process. Adding to this, the study by DiTullio [31] suggested that a classroom environment full of kinesthetic activities is essential for learners to develop their brain learning capacity. Therefore, classroom settings and resources in HEIs need to be improved in a way that enables natural science and engineering instructors effectively implement the core elements of BBI to improve the quality of the learning-teaching process.

7. Conclusion

BBI is one of the effective pedagogical approaches and is becoming popular at all levels of the education system. Cognizant of its use, it is inculcated in the EHEIs curriculum to improve the quality of the learning-teaching process. This study aims to investigate whether natural science and engineering instructors in EHEIs are aware of the fundamental elements of BBI (relaxed alertness, orchestrated immersion, and active processing) and practice effectively in relation to Caine and Caine's twelve principles of brain-based learning theory. The overall findings of this study show that most natural science and engineering instructors at EHEIs consider themselves familiar with BBI. On the contrary, the finding depicts that the majority of the instructors were less effective in implementing the core elements of BBI (relaxed alertness, orchestrated immersion, and active processing) in the actual learning-teaching process. Therefore, it is most important to conclude that irrespective of the instructor's awareness of BBI, most of the instructors lack transferable knowledge and skills that can positively affect the practice of BBI in the actual learning-teaching process in HEIs. Indeed, the classroom setting and resources have also impaired the effectiveness of natural science and engineering instructors to implement the core elements of BBI in the actual learning-teaching process. This signifies that BBI is not properly exercised in the EHEIs as per the principles of Brain-based learning theory and the intended curriculum. Therefore, it is imperative to reduce the existing gap in the classroom practice of BBI to improve the quality of the learning-teaching process in HEIs with conscious handling of the factors that negatively account for the practice gap.

Limitations and further research

This study was delimited by two variables. It was merely focused on the investigation of the current status of natural science and engineering instructors' knowledge and their practice of BBI, assuming that it will create a context for other variables that affect BBI in the HEIs learning-teaching process. Moreover, cross-sectional (one-shot) data were applied and this might not show the improvisation of instructors' classroom practice of BBI. The researchers also discussed with the interviewed instructors side-by-side with the survey questions to see their awareness of BBI. This might have biased the result as the instructors feel confident and *would already have some knowledge of BBI.* Besides, the subjects of the study were only natural science and engineering instructors and hence the collected data might not portray the big picture of the learning-teaching process using BBI in HEIs. Thus, further research might need to include additional subjects (students, curriculum expertise, pedagogies, etc.) and variables (beliefs, demographic and work-related variables, administration support, etc.) to come up with a comprehensive nature of the learning-teaching process with BBI in the EHEIs.

Data availability statement

This study was directed by the fundamental principles of research integrity and research conduct with human respondents, as stated in several documents. Respondents were informed that their anonymity and the confidentiality of data pertaining to them would be retained. Therefore, the authors abided by this agreement with the respondents not to share and deposit data for public use.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Luo Siming: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ataklti Abraha:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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