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BRAIN-BASED LEARNING AS PERCEIVED BY SAUDI TEACHERS AND ITS EFFECT ON CHEMISTRY ACHIEVEMENT OF 7TH GRADERS

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Abstract. *This research explored science teachers' perceptions of BBL. Data was collected from 105 Saudi Arabian science teachers via a questionnaire survey, establishing how BBL is viewed and applied, and whether this interrelates with teachers' years of professional experience or qualification level. Furthermore, in a quasi-experiment comprising a single experimental group, a chemistry learning unit was designed using BBL methods and approaches and was delivered to 26 Saudi Arabian Grade 7 students. Pre- and post-lesson measurements of knowledge and achievement were conducted. The findings confirm the arguments in the BBL literature and show that BBL awareness is relatively high and BBL is viewed very positively. The results of the quasi-experimental component show that BBL methods are likely to improve student learning and outcomes. Teacher qualifications and years of experience were unrelated with BBL perceptions.*

Keywords: *brain-based learning, chemistry learning, chemistry teaching, grade 7, science teachers*

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Introduction

Brain-based learning (BBL) theory constitutes a core theory. BBL posits that the brain and its neurological faculties are central to the development of cognition and efficient knowledge acquisition (Shabatat & Al-Tarawneh, 2016). This theory is increasingly being applied in science learning environments, including chemistry education. The application of BBL theory to this field opens up new theoretical conjectures and new areas of empirical enquiry. A growing interest in BBL in science education contexts is emerging, based on the observation that the conceptual language of science is especially unique for students, and on the argument that engaging, stimulating and relevant ways of teaching such concepts for students require new theoretical approaches. Several studies have thus explored BBL in school settings; however, there is a dearth of research into how BBL takes place in the specific context of chemistry learning environments. Chemistry competency perceptions and Chemistry success of prospective science teachers can be enhanced through the use of innovative instructional methods and alternative assessment techniques (Alkan, 2013).

BBL pertains to the 'recognition of the brain's codes for a meaningful learning and adjusting the teaching process in relation to those codes' (Caine & Caine, 2002). By focusing on the ideal environmental conditions under which learning occurs most effectively in the brain, this theoretical approach seeks to identify the most precise and effective teaching methods and learning approaches. For children and young people with developing brains, the ensuing techniques and approaches can be extremely instrumental in effective learning. The theory emphasises how teaching and learning strategies can be best aligned with and informed by a scholarly comprehension of the ways in which the brain functions (Jensen, 2008). BBL theory derives its empirical foundation from neuroscience, neurological discoveries, knowledge of biochemical processes and the science of genetics (Jensen, 2008). The ultimate objective, from a practitioner perspective, is to incorporate this overall body of evidence in order to generate education, learning and teaching methods that use this evidence to create learning environments in which brains can best acquire new knowledge.

The last decade of the 21st century has been hallmarked as the 'brain decade' in many disciplines, because scientific discoveries and new findings pertaining to the nature and functions of the human brain blossomed dur-

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ing the 2010s. BBL theory is in no small measure the product of this decade-long innovation in disciplinary focus. There is a notable inclusivity inherent to BBL theory, in that the theory posits that, so long as proactive, stimulating, engaging and relaxing learning and teaching environments are fostered, with the aim of maximising the capability of the human brain to acquire and integrate new knowledge, all students can acquire new skills, knowledge and concepts (Al-Ruwaily, 2018). The emerging evidence that effective learning is best facilitated in enjoyable, non-stressful, strong-rapport situations has produced a set of opportunities in teaching and education. The body of evidence developed thus far in the 21st century invites educationalists to create innovative learning and teaching environments that are directly orientated to enable and empower BBL. It has also become apparent in multiple disciplinary bodies of literature that traditional modes of learning and teaching – those that have been developed thus far in classrooms – may in fact be failing to provide a widespread and holistic form of development for children and young people. The all-round development of an engaged and motivated personality may be an aspect that is too often overlooked. These nascent trends in academic thought are prompting practitioners and researchers alike to develop innovative approaches to learning and to create new curricula and teaching techniques that are capable of meeting the demands of a diverse plethora of learners (Varghse & Pandya, 2016).

According to Akyürek & Afacan (2013), Brain Based Learning is a Learning approach that is based on the structure and function of the human brain. Distinct from current curriculum methods, brain-based learning emphasizes meaningful learning instead of memorization. It is further argued that brain-based learning activities had a statistically significant effect on improving the students' attitudes and motivation towards Science and Technology. Consequently, developed countries are now attempting to implement Brain Based Learning Approach owing to its closer relationship with Science attitude and Science motivation.

In such a newly formulated curriculum, scientific understanding of how the brain functions and in what environments it is most effectively stimulated will comprise the premise of curricular design. This approach will begin to diminish the use of educational theories and philosophies that have been developed in the fields of sociology, psychology and other social sciences, because such theories will be henceforth posited as being incongruent with our contemporary knowledge of the human brain. Based on this trend towards the use of a scientific understanding of the human brain to shape curricula, design teaching techniques and strategies, develop children's and young people's minds and drive effective knowledge acquisition, the present study investigates chemistry learning achievements among a sample of Grade 7 Saudi Arabian students and relates the empirical data acquired to the effectiveness of BBL methods and theories.

The Principles of Brain-Based Learning

The fundamental crux of this approach to learning is that the most learning-conducive conditions should be sought in teaching settings, with all aspects of such 'conditions' being centred around the brain and its ability to learn. Educational environments are accordingly built in which educators, tasks, assignments, curricula and classrooms optimise the brain's ability to acquire knowledge (Caine & Caine, 1991). BBL theory is underpinned by the basic tenets of neurology: that the brain is a parallel processor; that the full physiology of the brain is engaged in learning; and that generating and identifying patterns in perception, the external world, social reality and internal cognition is undertaken by the brain in a range of ways. The importance of how memory is enacted and how it functions in the brain is central to BBL, with effective learning environments being geared to what works best to facilitate the effective instalment and recall of information. Engagement in practical role play of real-life experiences is also seen as crucial in effective learning processes (Ozden & Gultekin, 2008). Learning is enabled by engaging learners in such experiences because, through such engagement, the learner is able to identify meanings and patterns of meaning. New evidence pertaining to brain functioning has influenced Ozden and Gultekin (2008) in arguing that it is vital for learners to be strongly personally engaged in classroom activities and processes, and that teaching materials and resources must be selected to satisfy this important principle.

Making and affirming generalised hypotheses based on prior observation of the world and ideas (in what is referred to as 'inductive reasoning') are central to BBL approaches, as is the identification of rules based on broad patterns of events or ideas ('deductive reasoning'). Problem-solving also takes centre stage, as it allows discrete problems to be scoped, conceptualised and resolved through analytical intellectual enquiry (Rehman, 2011). As Aydin and Yel (2011) argue, the fields of language learning, social science research, natural science research and knowledge creation, medical enquiry and mathematical advancement all rely on deductive, problem-solving and inductive forms of reasoning in their associated learning and teaching practices.

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Research Problem

The proposition that learning is a person-specific process links BBL to the wider paradigm of constructivist theories of learning. More conventional styles of teaching and models of learning, long since entrenched in our education systems, have been steadily modified in light of new evidence and theory in educational studies. Nevertheless, teaching is currently still rather teacher-centred, and inadequate attention is paid to the idiosyncratic personal learning-style differences that are highlighted by contemporary scholarship as crucial to effective teaching (Aziz, 2007, cited in Shabatat & Al-Tarawneh, 2016). A schism has emerged between our knowledge of best practices and our actual practices, with existing classroom practices unnecessarily inhibiting learning. As noted above, much of the research (e.g. Saleh, 2012; Oktay & Cakir, 2013) demonstrates the positive impacts of BBL approaches on cognition, conceptual understanding, motivation and affectation. Achievement and performance in chemistry and other natural sciences are often below nationally set targets, and science learning in the Kingdom of Saudi Arabia (KSA), for example, is currently facing challenges. In terms of international comparison, Saudi Arabia's Grade 8 students currently rank 43rd in mathematics and 39th in the sciences, out of a total of 50 countries, according to the 2015 Trends in International Mathematics and Science Study (TIMSS) (Barber, Mourshed & Whelan, 2007).

The present research is based on the argument that acquiring knowledge and applied skill in new and stimulating teaching and learning methods will empower Saudi Arabian teachers to improve student performance. New policies have emerged in the KSA that aim to imbue science teachers with new skills; these policies include the KSA Ministry of Education's creation of an elementary curricular component that involves problem-solving and critical thinking in scientific studies, and programmes targeting schools and run by the King Abdullah-bin-Abdul-Aziz Public Education Project. The bulk of teaching and learning strategies practised in Saudi Arabia continue to be based on memory and recall, and on passive learners who are taught – or instructed – by a teacher who is unquestioned in his/her logic and thinking. Thus, students are not fully engaged as interested and interactive partners in learning and teaching; instead, they are seen as the recipients of information and as uncritical receivers of top-down teaching. '[Saudi Arabia] is still using traditional teaching methods which do not take students' participation and views into account and are mainly based on teachers and textbooks' (Alhammad, 2015, p. 121).

Full conceptual clarity on an item of knowledge and/or genuine acquisition of a skill do not *de facto* result from effective memorisation and the recall of stated facts. Being able to verbally express a scientific law, for example, does necessarily mean that a student truly understands it. In addition, cultural values, norms and ideas can perturb the effective acquisition of scientific knowledge, further hindering learning. BBL is a potential way for Saudi Arabian teachers to bridge the gap between true conceptual understanding and the ability to state facts. The first precondition of this inculcation of BBL into teaching and learning practices is that teachers must become aware of BBL and its role in and potential for improving science learning. Therefore, this study poses the first primary research question: *what is the level of awareness of BBL among teachers?*

Although conventional modes of teaching and learning are coming under criticism, there is limited support for or awareness of other strategies, such as thematic instruction, cooperative learning, meaning-centred curricula design and so forth, in the KSA. The emerging BBL and brain-based teaching approaches incorporate a wide array of developmental scales into a coherent system (Thomas & Swamy, 2014), and these approaches seem promising as a means of enhancing teaching; however, there is a paucity of literature pertaining to BBL being practised or researched in Saudi Arabia. A considerable number of studies have taken place internationally, but this broader interest is absent in Saudi Arabia. Given this clear gap in the literature, coupled with the growing importance of BBL and the relative lack of awareness of it, this study posits the second primary research question: *what is the impact of using a teaching-learning programme based on BBL on the achievement of Grade 7 Saudi chemistry students?*

Research Focus

By using learning tools, including instruction plans and pre-learning and post-learning examinations, to assess the effects of a BBL approach in a chemistry programme targeted at Grade 9 female students, Shabatat and Al-Tarawneh (2016) found that there was statistically significant differentiation between the impacts of BBL and the effects of traditional modes of learning, as executed in the control group. Based on a sample of 64 students, T-tests, standard deviations and ANOVA processes were run on a quantitative dataset compiled through pre- and post-hoc exams. The authors claimed that the findings indicated that BBL in chemistry is a practicable, effective and generalisable method of enhancing learning outcomes.

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Varghese and Pandya (2016) have provided several recommendations to both academics and educational practitioners pertaining to the implementation of BBL approaches via specific and novel methods of teaching. The researchers claim that these methods can be used to create highly engaging and innovatively designed learning environments. Deploying a quasi-experimental factorial research design involving both pre-learning and post-learning tests, they explored how BBL affected achievement, and how this interacted with student stress and behaviours in a secondary education context. All the proposed methods deployed a neurocognitive model of BBL; as a result, the learning became an enjoyable process. The researchers argued that BBL approaches must be promoted in educational settings around the world, and that information should be disseminated that conveys the effectiveness of these approaches.

The evidence to date indicates that the variable of gender does not affect the positive benefits of BBL. Using a sample of Grade 5 students studying the natural sciences in Jordan, Altiti (2014) conducted a quantitative study to evaluate the effects of a brain-based teaching programme. The findings clearly indicated that all of the students in the experimental group – those subjected to BBL – showed better learning outcomes than the control group, and that both boys and girls experienced this to the same degree.

Some studies have focused on pure physics. Investigating student understandings of Newtonian physics as part of form-four physics sessions while examining the effectiveness of brain-based teaching methods, Saleh (2012) reported that the BBL methods unequivocally facilitated learning. Saleh applied a series of methods outlined by Caine and Caine (2003), including seven core aspects: (1) the activation stage; (2) clarification of the core learning outcomes and an overview of the whole session; (3) a focus on making connections between different aspects of the lesson; (4) interactive engagement in learning activities; (5) an exercise to show that students had comprehended the lesson; (6) a recall exercise; and, finally, (7) a prelude to lead up to the next lesson's contents. Working with a sample of 100 Malaysian secondary-level students, Saleh (2012) used a questionnaire survey designed to identify qualitative patterns that were identified by students through their learning about Newtonian physics. When compared with the learning of the students who were subjected to more traditional modes of teaching, the results showed that the BBL and teaching methods Saleh experimented with were highly effective, and resulted in great improvement in students' pattern making and recall.

In an exploration of whether misunderstandings and incorrect conceptualisations of electricity by Grade 8 Jordanian students could be redressed using brain-based teaching, Bawaneh et al. (2012) drew from a large sample of 357 students at the Bani Kenanah Directorate of Education. Of these, 183 students were instructed and engaged in accordance with the principles and methods of BBL approaches to teaching (roughly equal in male/female proportions), and 174 students were taught in learning environments using traditional teaching methods (again, roughly evenly distributed between males and females). A multiple-choice exam was issued to capture the misunderstandings present in the students' comprehension of electricity at the outset, and student learning was assessed post-hoc via an inventory of participant learning. The results, when aggregated according to conventional teaching/brain-based teaching, did indeed highlight that brain-based teaching was more effective on average. They also indicated, however, that the learners who learned via more intense meaning making and rigorous abstraction showed higher learning levels than those who learned by rote or those in between, regardless of which group they were in. This finding indicates that when designing curricula intended to utilise the techniques and principles of BBL, policy makers and teachers should consider different forms of learning and different types of learner, in order to ensure that the brain-based methods are equally applicable to and beneficial for rote learners, 'meaning' learners and those in between.

In an effort to link the wider body of knowledge on BBL and brain-based teaching with the formation of attitudes and motivation regarding learning, Akyurek and Afacan (2013) conducted an experimental research project with Grade 8 science students, comprised of a single experimental group and two distinct control groups. The three groups comprised 19 students each, with students in the experimental group learning about cell division and heredity as part of the contemporary science and technology curriculum. Students in the two control groups were taught according to older curricula that were less orientated to BBL. The experimental group had better scores than the two control groups, and these differences in achievement had statistical significance.

In an exploration of teacher-training staff's perceptions of, knowledge and beliefs regarding, and practical application of BBL in their classrooms, Klinek (2009) developed a multidisciplinary learning framework covering the theories of multiple intelligences, cognitive learning and planned behavioural acts. Drawing from the results of a survey issued to respondents in a American university, Klinek (2009) found that the respondents had a good working knowledge of the role of brain functions in learning and the link between this and the other theories

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of learning listed above. The majority of the participants claimed that using a variety of learning methods was valuable, and some showed willingness to use BBL approaches in their teaching, pending the acquisition of more knowledge about them.

Research Questions

1. What is the level of awareness of BBL among teachers?
2. Does BBL awareness differ according to the number of years of experience?
3. Is there a significant difference in BBL awareness between teachers holding bachelor's degrees and teachers holding masters-level degrees?
4. What is the impact of using a BBL-Based teaching-learning programme on the learning and achievement of grade 7 Saudi chemistry students?

Research Methodology

General Background

This is a descriptive research in answering the first question while experimental research method with one group design was utilized to answer the fourth research question. The study took place during the first semester of 2019/2020. Perceptions of Science teachers were elicited through a 5- point Likert questionnaire. The study sample consists of 7th grade students in Saudi Arabia. A consent form was used to ensure the participants' willingness to share in data collection process. The present researcher explained the aims of the research to the participants and they were given the choice and freedom to withdraw at any time. Sampling and application of measurement surveys were administered in accordance with the ethical standards of Jouf University.

To explore the perceptions of Saudi Arabian science teachers pertaining to the use of BBL in science lessons, a BBL survey was deployed. Furthermore, a quasi-experimental research project was designed and carried out in order to gauge the effectiveness of BBL in boosting the performance of Grade 7 chemistry students.

Sample

The research sample for the first part of this research comprised 105 Saudi science teachers, and the research sample for the quasi-experimental component of this study comprised 26 Saudi chemistry students from the Al-Imam Al-Bukhari Middle School. They represent one class, so it was decided to use the whole class in order to enable the researcher to deal with them all as a treatment group.

Instrument and Procedures

Adapting and building on Klinek's (2009) BBL survey, in order to answer the first research question, this research used a modified and translated (into Arabic) version of Klinek's survey consisting of 35 questions and issued it to 105 Saudi science teachers. The reliability of the Arabic version of the survey was verified by means of a preliminary review conducted by two experienced science teachers.

To answer the fourth research question, a quasi-experimental research project was carried out, involving a single experimental group. The experiment covered just one unit of the overall chemistry programme – namely, *Material and Its Changes* – which was taught using BBL techniques and strategies. This unit is a key part of Grade 7 curricular science book for 2018/19. All students in the sample were from the Al-Imam Al-Bukhari Middle School. Students from the Ain Albaidha Institution were intentionally sampled because the researcher had ready access and there were two Grade 7 classes in the school.

The two classes were designated as the experimental group and control group, respectively. The modules that were taught for the chemistry programme during the 2018/19 school year were from the core science syllabus for first-year middle schools. The *Material and Its Changes* unit is part of the fourth chapter of the syllabus book (covering material structures, elements, composites and mixtures), and this particular unit involves various BBL techniques and approaches. The researcher developed a Teachers' Guide for the unit that covered methods

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for deploying BBL theory to help students conceptualise chemistry. The aim of the guide was to enable teachers to identify the core tenets of BBL theory and apply BBL methods accordingly when teaching science. The Teachers' Guide was discussed and critiqued by a panel of judges to confirm that it was relevant to BBL, scientifically informed, suitable for the sample of students and clear on the respective roles of teacher and learner. The judges made a series of modifications to the guide prior to its distribution to the teachers.

The key parts of the lesson and the intended learning outcomes of the lesson were established in the lesson plan. This plan also covered the core concepts to be discussed, the tools and resources used, and the interactions with and between students, all in accordance with BBL theory. To evaluate the learning that occurred during the unit, students' experiences of the process of learning, the questions raised, and scientific experiments engaged in (as mapped out in the Student Guide) were all observed and recorded. The Student Guide was intended to help the students conceptualise and explore the unit. The guide included clear instructions on health and safety protocol and mapped out the core activities of the lesson in ways that aligned with BBL theory. The guide was also subjected to scrutiny by a panel of judges (experts in science pedagogy) to assess its pedagogy and its congruence with the Teachers' Guide. Some alterations were made to improve the relevance of the activities after the judges' review.

The researcher's supervisor then assessed the three documents – the Teachers' Guide, the Study Tool and the Student Guide – and gave supervisory approval to conduct the study. The three documents were then submitted to the Department and to the General Directorate of Education of the Al-Jouf region. The study was granted formal approval to proceed, and the *Material and Its Changes* unit was delivered to the students by the teachers in full accordance with the key principles and practices of BBL over a four-week period.

A 25-item multiple choice test was used to assess learning in the chemistry unit. When preparing this test, the researcher analysed the core topics covered, ascertained that the core topics pertained to acids, bases and minerals, their interaction, and electrochemical cells, established the objectives for each topic and developed the questions accordingly.

Data Analysis

Different statistical techniques were used to analyse the data. Frequencies and percentages were computed to detect teacher responses towards brain-based learning. ANOVA was used to compute the difference in teachers' responses concerning brain-based learning according to years of experience, t-test was utilized to detect the difference between the pre- and post-lesson measurements and finally regression analysis was adopted to assess the capability of immediate achievement to predict subsequent achievement.

Validity and Reliability of Data Collection Methods

To determine the degree to which the BBL survey was understandable and completable, the researcher sampled 20 faculty members of Jouf University and 10 science teachers as part of a pilot study. The participants of the pilot study were asked to comment on and suggest amendments for the questions. To assess the validity and reliability of the test used to evaluate student learning in the science classes at the school, the researcher recruited several members of the university working in science education, and asked them to act as judges to appraise the test, its relevance and its analytical practicability as a research tool for data collection. The researcher invited comments and recommendations on the fit between the study research questions and the survey/test, the scope of the test/survey contents and whether this had covered everything adequately, and any other unprompted areas of interest. To affirm the learning test's reliability, the researcher issued the initial test version to a pilot group of 30 students external to the final sample. A split-half method was deployed to determine the coefficient of test reliability. The correlation coefficient between the scores for the overall sample pertaining to the test was halved. The reliability score was high (0.79), so the test was confirmed for dissemination in the study.

Research Results

Following are the findings of questions of the research.

Table 1 provides the frequencies and percentages for the teachers who were queried about their perceptions of the use of BBL in teaching science. Most teachers agreed or strongly agreed with the positive statements. The values listed represent the highest values in each response category.

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Table 1
Means and Standard Deviations of BBL Survey Items (N = 105)

Item	*M*	*SD*
1	3.49	1.18
2	1.05	.21
3	2.88	1.08
4	3.55	.71
5	4.53	.65
6	4.23	.71
7	4.18	.60
8	3.96	.62
9	2.87	.92
10	3.17	1.01
11	4.01	.94
12	2.78	1.13
13	3.38	.70
14	4.00	.72
15	4.12	.76
16	3.54	.75
17	3.73	.67
18	4.10	.65
19	3.96	.66
20	3.94	.73
21	3.37	.93
22	3.75	.77
23	2.70	1.03
24	3.70	.92
25	3.78	.92
26	3.69	.85
27	3.82	.95
28	3.79	.99
29	3.06	1.03
30	3.41	.80
31	3.70	.87
32	3.86	.86
33	3.38	1.78
34	4.07	1.35
35	3.33	.80
36	3.74	.76
37	3.63	.97

Table 2
ANOVA Results for Difference in BBL in Light of Years of Experience (N = 105)

Source of variance	Sum of squares	*df*	Mean squares	*F*	*p*
Between groups	745.206	3	248.402	2.04	.113
Within groups	12300.642	101	121.789		
Total	13045.848	103			

As shown in Table 2, years of experience did not appear to determine BBL awareness levels and the *F*-value was not significant, indicating that BBL awareness is not influenced by the extent of experience teachers have.

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Table 3
t-test Results for Differences in BBL Awareness between Teachers Holding Bachelor's Degrees and those Holding Masters-level Degrees (N = 105 science teachers).

Group	Mean	*SD*	*df*	*t*	*p*
Teachers with Bachelor's degree	127.6	11.26	103	0.468	.641
Teachers with Master's degree	130,0	10.70			

No statistically significant difference was detected in the BBL awareness of teachers with bachelor's degrees versus teachers with master's degrees. The t-value was not significant.

In the quasi-experimental research design, which comprised only an experimental group, this study measured knowledge and proficiency both pre- and post-lesson. A statistically significant difference was identified between pre- and post-lesson measurements, as shown in Table 4. This finding indicates that the programme, in deploying BBL theory and practice, was effective in improving the learning and achievement of the students.

Table 4
t-test Results for the Difference between the Pre- and Post- Measurements (N = 26)

Measurement	*M*	*SD*	*N*	*t*	*df*	*p*	η
Pre	9.00	1.95	26	37.83	25	0.01	0.982
Post	21.12	2.02					

As shown in Table 5, immediate achievement was a slight predictor of subsequent achievement, with a total variance of the model standing at 8%; despite being relatively low, this result is suggestive of a link.

Table 5
Regression Analysis of Immediate Achievement as Predictor of Subsequent Achievement (N = 26)

Predictor	*B*	*R*	ΔR^2	*β*	*t*	*p*
Immediate Achievement	0.080	0.086	0.034	0.086	7.38	.001

Discussion

Two core findings emerge from this study. Firstly, the majority of teachers surveyed about their perceptions regarding and awareness of BBL in science teaching agree or strongly agree with a series of positive statements supporting the role and effectiveness of BBL in teaching chemistry. The results of the teacher survey suggest that BBL is positively viewed and its application in science teaching is looked on favourably. A paucity of awareness and understanding of BBL among teachers may inhibit the application of this approach in classrooms, and – as Klinek (2009) found in an exploration of the knowledge, beliefs and practices of state educators in the USA – awareness and understanding regarding BBL was a key determinant of the degree to which BBL strategies are practised. Similarly, among a sample of 52 teachers, Kayalar and Ari (2016) found that teacher attitudes and levels of motivation in deploying BBL methods and their actual practice were positively correlated. (see also Duman (2010). The findings of the present study support the present finding.

In line with the present findings, Ramakrishnan and Annakodi (2013) explored the perceptions of BBL among teachers and teachers' levels of knowledge regarding BBL. They found that teachers perceived BBL in positive ways, considering it as a valuable learning and teaching approach. Type of school, gender and number of years of experience in teaching were found to have no significant effect on BBL awareness. Similarly, the present study identified no significant difference in BBL awareness between more experienced teachers and less experienced

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ones. Additionally, no significant difference was detected between teachers with bachelor's degrees and teachers with master's degree in their awareness of BBL. This finding is consistent with findings presented by DiTullio (2018) who found that the general perception of BBL was positive, regardless of teachers' professional standing in terms of years of experience or qualification level.

There is no definition of what constitutes an adequate level of knowledge of BBL to apply BBL theory effectively in the classroom (see Dubinsky et al., 2013); such a definition would be a helpful objective of future studies because its lack makes it difficult to connect high awareness levels to the prospect of students benefitting from teacher awareness. Overall, however, BBL was viewed by the sample herein as a positive set of principles and tools that was valuable in supporting effective learning, and, as in other studies, the teachers felt that BBL served students' interests and preferences in the learning process (Klinek, 2009).

In the second component of this study, pre- and post-lesson tests were executed among a sample of Grade 7 chemistry students who partook in a curricular unit designed by the researcher to accord with the theory and practice of BBL. The second important finding of this study comes from this component. The BBL programme was found to be effective in enhancing the learning and achievement of the students. This finding is greatly supported by the findings of Shabatat and Al-Tarawneh (2016), Varghese and Pandya (2016), Akyurek and Afacan (2013) and Bawaneh et al. (2012). BBL is evidently helpful in improving students' knowledge acquisition, conceptualisation, memorisation and recall of the overall learning process.

These studies have generally posited that applying BBL facilitates improvements to brain functioning. The broad thesis states that brain function and power are enhanced via the application of BBL (and brain-based teaching) methods. The associated theory surrounding BBL claims that the 12 core principles underpinning BBL can be used to generate new curricula for highly effective teaching and learning. This overall approach is extremely inclusive and universalist, as it is based on the proposition that all students – regardless of capability and intelligence level – can benefit from BBL methods so long as an appropriately motivational and relaxing learning environment is created (Al-Ruwaily, 2018).

Emerging evidence in the fields of neurology, neurosciences more generally, and psychology is increasingly influencing teaching and learning theories and practices, propounding a new approach that is centred on brain functions and how knowledge of the brain can be harnessed for effective learning. These methods also link emotions, cognition and learning into a matrix of brain-orientated understanding of the mind (Al-ruwaily, 2018).

The BBL-based teaching and learning programme that was designed and applied in the quasi-experimental component of this study was found to have positive impacts on student learning and achievement. No baseline was captured in this study, with control groups being absent, but the results are nonetheless consistent with the findings of other scholars. Obeidat and Abu Al-Sameed (2007) highlight the role of cooperation and engagement during lessons as drivers of learning, and report that BBL practices of interactive engagement are capable of stimulating the student's brain more effectively than conventional teaching methods. The researchers claim that by deliberating and communicating, students benefit from a fulfilling and effective learning environment (Obeidat & Abu Al Sameed, 2007).

Conclusions

This research adds to the body of literature new insights into the possible benefits of teachers' use of BBL in improving students' understanding of Chemistry concepts. This study was pioneer in the Kingdom of Saudi Arabia to use both samples of teachers and students in the one research. The findings related to years of experience and education level are similar to the previous results which were indecisive in this aspect. One of the main practical implications of these findings is that teachers might better explain Science lessons in accordance with the BBL principles since it was found that they improved understanding of Chemistry concepts. Previous studies suggested that using BBL approach in teaching Science enhanced Science motivation and attitudes towards Science while the present study found that BBL approach improved Chemistry achievement, taken together those findings provided evidence-based findings that BBL was a useful instructional approach and should be adopted in Science education.

The findings of this study, in conjunction with those of prior studies, have certain practical ramifications. Firstly, policy makers and researchers involved in designing curricula need to create curricular content and text-book and other resources that fully harness BBL methods and principles in order to improve learning. This may be especially relevant and important in science teaching, which lags behind international benchmarks in several

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nations, including Saudi Arabia. Educators – both managerial-level staff and junior-level teachers – should be formally trained in the theory of BBL and in specific BBL practices. This training should be ongoing, with further professional development ensuing as new studies of the brain produce new pertinent evidence relevant to teaching and learning. Detailed and comprehensive training, consisting of evidence reviews relating to brain functioning as well as updates on the latest methods of applying BBL in classrooms, will enable teachers to utilise BBL to the best effect for students. This research is limited by the small number of students' sample. Further research might replicate the present one recruiting a larger sample. The impact of BBL awareness on assessment practices still represents a question unresolved, accordingly, future study may tackle this point from a cross-cultural perspective. The study tool represents a viable limitation. Using mixed methods in data collection instead of just a survey will be a source of deeper insight into BBL approach.

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