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Alseddiqi, Mohamed, Mishra, Rakesh and Abdulrasool, Salah Mahdi

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Improving Teaching and Learning Effectiveness in
Engineering Education

Mohamed Alseddiqi, Rakesh Mishra and Salah Mahdi
Abdulrasool

Improving Teaching and Learning Effectiveness in Engineering Education

Mohamed Alseddiqi, University of Huddersfield, West Yorkshire, UK
Rakesh Mishra, University of Huddersfield, West Yorkshire, UK
Salah Mahdi Abdulrasool, University of Huddersfield, West Yorkshire, UK

Abstract: This paper presents the results from a study undertaken to improve the teaching and learning effectiveness in engineering education courses, specifically for Technical and Vocational Education (TVE) system in Bahrain. A teaching and learning assessment tool was developed for participants (existing TVE teachers in electrical and electronic engineering and a pilot group of TVE students). The purpose was to examine the existing approaches of teaching and learning practised in TVE educational environment as well as learning styles preferred by TVE students. The results confirmed that TVE teachers applied limited methods of teaching and learning. However, TVE students had widely varying learning preferences, as they are more motivated by using the experiential learning approach. The experiential learning model allowed students to make their own learning choices and relate what they were learning to the real-work applications (using diagrams, hyperlinked text, video, pictures, interactive examples, virtual reality simulations, and animations). Based on the drawn conclusions, a teaching and learning guideline for engineering education was originated specifically for the needs of the TVE system in Bahrain. The guideline is a potential tool for structuring and improving engineering learning courses in TVE. The guideline will also help in meeting modern industrial requirements by equipping students with better skills, abilities and attitude.

Keywords: Teaching and Learning, Experiential Learning, Curriculum Development, Guideline, Engineering Education, Electrical and Electronic Engineering, Learning Style

Introduction

THE TVE SYSTEM in Bahrain produces graduates in different engineering specialisations such as electronic and telecommunication engineering, building services, mechanical engineering, and computer technology. In the TVE system, the learning methodology consists of school-based learning (SBL) followed by work-based learning (WBL). It has been observed that TVE system is unable to satisfy the marketplace requirements (Alseddiqi et al., 2009). The industrial partners have repetitively indicated that the students coming through the SBL have limitations in knowledge and skills that are required for them to complete the industrial work placement and hence the WBL element satisfactorily (Mishra et al., 2009).

This study investigates the issues surrounding teaching and learning methodologies being used and proposes a guideline to improve the effectiveness of teaching and learning.

The guideline includes a framework which has been developed through investigation of various elements of teaching and learning processes involved through the benchmark studies

COMMON GROUND

available in literature. These elements include investigation on different teaching and learning styles (explained below) through the use of teaching and learning diagnostic assessment tools. Based on the investigation results, a guideline has been proposed for implementing an effective teaching and learning processes in engineering education courses.

Teaching and Learning Styles

This section presents the teaching and learning styles available in literature which can be used to benchmark existing teaching practices. A UNESCO report (2005) defined teaching and learning as the method of delivering knowledge and skills to students using various styles of learning including lectures, individual learning, group project, on-line learning, etc.

Kolb (1984) formulated an experiential learning theory and learning styles model from the empirical work of Dewey, Lewin and Piaget. The experiential learning theory combined Dewey's philosophical expediency, Lewin's social psychology and Piaget's cognitive model. Kolb's experiential learning theory explains in a structured manner the exchange of knowledge between the students and the teachers. Baker et al. (2002) confirmed that the students' experiential learning uses conversation as a mode to transform knowledge into experiences. The experiential learning theory includes pedagogic activities that include both academic and practical activities. Figure 1 illustrates that the functioning of the model is based on the idea that the students' learning preferences can be represented in two dimensions: dimension one represents the transformation from (concrete experience) to (abstract conceptualisation) along vertical axis as the approach to acquire knowledge; and dimension two represents the transformation from (reflective observation) to (active experimentation) along horizontal axis as the process of acquire knowledge.
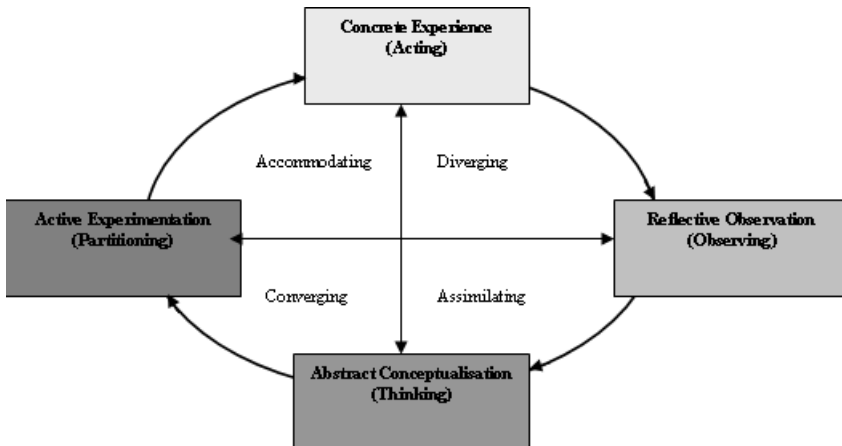
Figure 1: Experiential Learning Model and Learning Styles Cycle (Kolb, 1984)

The structured knowledge transformation has four typical stages within the learning cycle, these are diverging, assimilating, converging, and accommodating.

Figure 1 also clearly shows that the students with a preferred converging learning style (thinking and partitioning) helps them to understand the theoretical information in-depth through active experimentation thereby allowing them to develop finer details of the theor-

etical concepts. In accommodating learning style, the students may gain new knowledge by working in groups, solving problems relying on others' information, and learning from other peoples' technical work. After that, the students prefer to watch and gather information rather than practical applications in diverging learning style. The divergers add different experiences to the learning processes from the concentrate experience and process those experiences through reflective observation. During the learning processes, divergers perform better in reviewing existing circumstances, listen openly to others' opinions, generate new ideas, conduct brainstorming sessions, and gather information. After the students gathered the information, they focus on analysing the information in the assimilating learning style. Furthermore, the assimilators are theorist students who have a preference for approaching knowledge acquisition through abstract conceptualisation and complete things through reflective observation. Assimilators prefer the theoretical learning approach as they are best at reading, thinking, analysing situations, and putting information into a logical sequence. The conclusion is that the student should have a balance of learning styles for effective learning output (McCarthy, 2010).

A recent study in TVE system in Bahrain emphasised the existing problems in TVE teaching and learning processes (Alseddiqi et al., 2010). The results stated that the existing teaching and learning strategy is not suitable for modern industrial requirements. The affective domain skills, which are so important in industrial setup, have not found to be integrated with teaching and learning processes. The study recommended the need for embedding affective domain skills in both curriculum development and teaching and learning processes. In addition, more solutions were recommended, such as integrating new information technology techniques in traditional teaching and learning processes and ensuring that the quality of teachers' knowledge and experience are appropriate.

It has been suggested by several researchers that the teaching and learning process should be designed to accommodate students preferred learning styles and teaching styles should reflect that preference (Hillier, 2009). Keeping that in view, investigation on teaching and learning styles being used in TVE Bahrain was considered important to improve overall effectiveness.

Based on the above literature, the next section presents the teaching and learning diagnostic assessment tools that have been used to identify the teaching styles that teachers prefer for delivering the learning activities and the learning styles preferred by TVE students.

Teaching and Learning Diagnostic Assessment Tools

As mentioned above, the learning style inventory was employed as an instrument to produce typical learning activities for both; teachers' diagnostic assessment tool for the teaching styles being preferred by the teachers during the knowledge transfer process and the students' diagnostic assessment tool for the learning styles preferred by the students. (Refer to appendix 1 and appendix 2).

Teachers' Diagnostic Assessment Tool

This section explains the diagnostic assessment tool that has been developed to assess preferred teaching styles employed by teachers. This assessment tool consists of 20 typical learning activities as shown in appendix 1. The assessment tool was distributed to 20 TVE

teachers with electrical and electronic engineering specialisation. Each learning activity has four possible modes of delivery.

The teachers were asked to rank the preferred modes of delivery for each learning activity using the scale as shown below:

1. The most-used approach to teaching and learning
2. Good approach to teaching and learning
3. An adequate approach to teaching and learning
4. The least-used approach to teaching and learning

The emphasis of this tool is to critically analyse the existing teaching and learning mechanisms practised by TVE teachers during the delivery of engineering education courses.

Student's Diagnostic Assessment Tool

This section explains the diagnostic assessment tool for students. The student's diagnostic assessment tool incorporates 24 typical different learning activities as shown in the appendix 2. The tool indicated the preferred learning styles by the students.

The tool was distributed to a pilot group of 30 students in the field of electrical and electronic engineering. Each learning activity has four possible learning styles. The students were asked to rank the styles according to their preferred way of learning.

1. The most-preferred approach to learning
2. Good approach to learning
3. An adequate approach to learning
4. The least-used approach to learning

It was obvious that both diagnostic assessment tools (teacher and student) were designed in such a manner that it would interest the respondents to rank the teaching and learning activities according to the learning style inventory instrument. The assessment tools were reviewed and validated by the TVE specialists.

Findings

Figure 2 compares between the average results from all the teachers' responses to the identified learning activities (see appendix 1). The x-axis represents the learning styles of Kolb's model: accommodating, diverging, assimilating, and converging. The y-axis represents the respondents' average percentage to the learning styles for each learning activity.

For example, figure 2 indicates that 40% of the respondents used that the converging learning style for the delivery of learning activity 2. Almost half of the respondents used the assimilating and diverging learning styles equally. However, only 10% of the respondents used the accommodating learning style to deliver this learning activity.
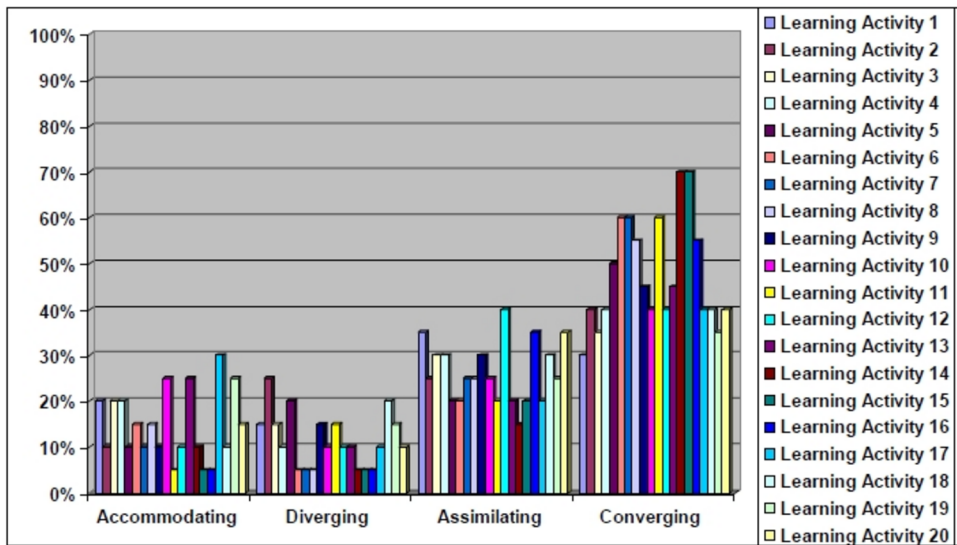
Figure 2: The Learning Styles Practices by TVE Teachers

The respondents justified the nature of the existing learning materials; the content and time allowed for each module forced them to be limited in their ways for delivering the learning activities. In total, figure 2 shows that:

- Converging was the most-used approach to teaching and learning
- Assimilating was a good approach to teaching and learning
- accommodating was an adequate approach to teaching and learning
- Diverging was the least-used approach to teaching and learning

Figure 3 indicates the results from the student's diagnostic assessment tool. The respondents were asked to rank different learning activities (refer to appendix 2). The x-axis represents the identified learning styles by Kolb and the y-axis represents the average percentage of students' preferred learning styles.

For example, in learning activity 1, 30% of the respondents preferred the converging learning style. Regarding the assimilating learning style, 27% of the respondents preferred this approach of learning. In addition, 23% of the respondents preferred the diverging learning styles, and the remaining 20% preferred accommodating learning style. The example has indicated that different learning styles interest different students.
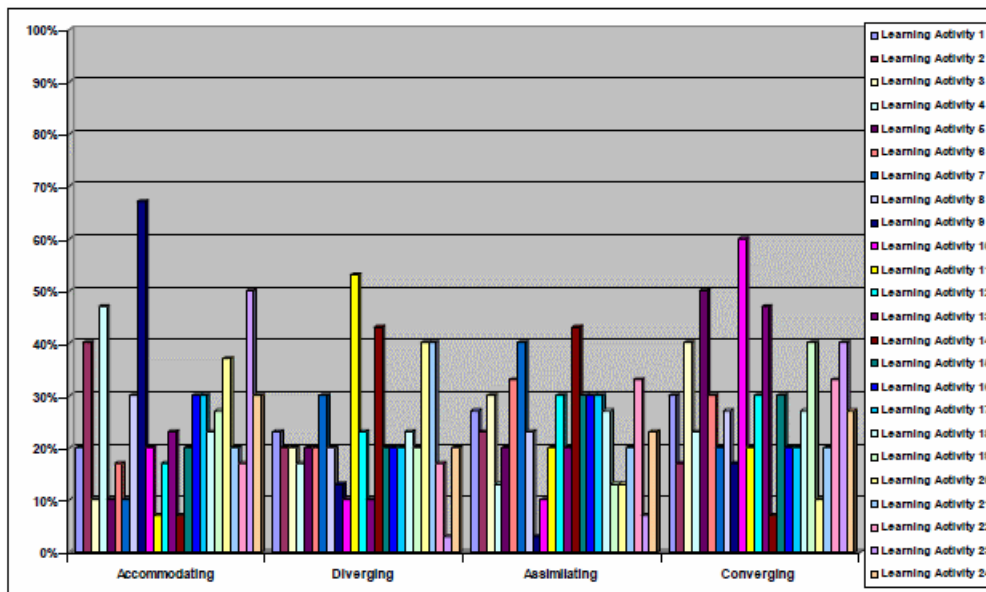
Figure 3: The Learning Styles Preferred by TVE Students

In total, figure 4 compares between the teachers' and the students' average responses to the teaching and learning diagnostic assessment tools.

Looking at the average teachers' responses it can be seen that 48% of the respondents indicated that the converging learning style is the most-used approach to teaching and learning during the delivery of engineering education courses. The respondents clarified that they mainly used the converging learning styles because the existing learning activities of TVE curriculum have been designed mainly to improve students' thinking skills and psychomotor skills so that the students should be able to understand and apply different tasks in practice.

26% of the respondents used the assimilating learning style in the delivery of the learning activities. The average results indicated that the respondents have used abstract conceptualisation as an approach to knowledge transfer, and reflective observation as a process of transferring the knowledge during the theoretical sessions in SBL. The respondents also approved of giving students the opportunity to read, think, analyse situations and put information in a logical sequence during the process of teaching and learning.

In contrast, only 15% of the respondents delivered the learning activities using the accommodating learning style and 11% of the respondents delivered the learning activities using the diverging learning style.

From the students' responses it can be seen that almost an equivalent percentage has been given for each learning style as shown below:

- 27% of the respondents preferred the converging style,
- 26% of the respondents preferred the accommodating learning style,
- 24% of the respondents preferred the assimilating learning styles, and
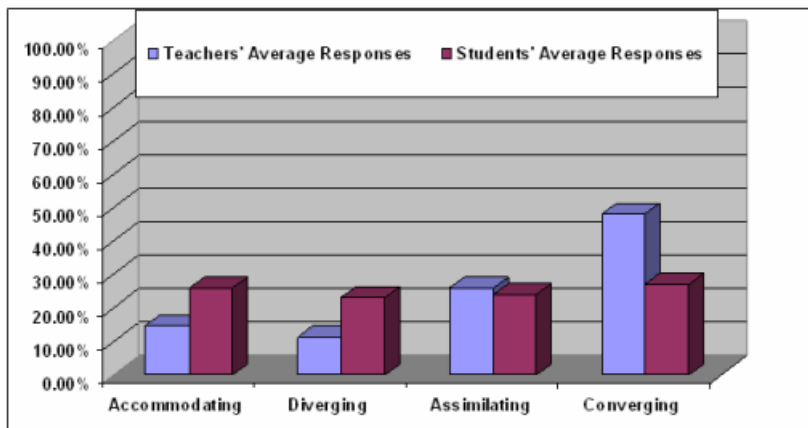- 23% of the respondents preferred the diverging learning style.

Figure 4: The Average Responses to the Learning Styles

The above findings showed that the TVE students had widely varying learning preferences. The TVE students preferred learning styles are not always compatible with the delivery styles of the TVE teachers. It is therefore imperative to modify the teaching and learning process to incorporate different learning styles in the delivery mechanism. The next section describes a typical example of development of learning content to achieve this aim.

Theoretical Guideline for Development of Learning Content to Assist Teachers in Meeting Students' Learning Styles Requirements

To satisfy the needs of the students and assist the teachers in the delivery of the learning activities, two well known and widely used learning theories have been identified; Bloom's learning theory (for curriculum content development) and Kolb's learning theory (for teaching and learning delivery).

Bloom's learning theory has been used to develop curriculum content for a typical module (Abdulrasool and Alseddiqi, 2010). The three learning domains of Bloom are; cognitive (to structure activities and exercises which measure students' knowledge); affective (to structure the learning activities and exercises that measure students' attitude during the delivery of the module); and psychomotor (to structure the content of the technical and practical competencies learning activities) (Anderson and Krathwohl, 2001).

On the other hand, Kolb's model and its learning styles are used for delivering the knowledge, the attitude skills, and the practical learning activities. Kolb's model helps in allocating the time of delivery for each learning activity as well as the proper sequencing of the delivery (Kolb, 1984).

In the following, the two learning theories have been integrated for developing an effective teaching and learning guideline. The guideline ensures developing the curriculum content with skills including; cognitive, affective, and psychomotor, as well as developing their learning methods through; observing, thinking, partitioning, and acting modes.

After identifying the purpose of each learning theory, figure 5 presents the next step in developing an effective teaching and learning guideline. The learning domains of Bloom have been integrated within the four phases of Kolb's model. Figure 5 shows that:

- The learning activities corresponding to the cognitive domain will be delivered using three approaches of learning styles: assimilating (thinking – observing), accommodating (acting – partitioning), and converging (thinking – partitioning).
- The learning activities corresponding to the affective domain will be delivered using three approaches of learning styles: diverging (acting – observing), converging (thinking – partitioning), and accommodating (acting – partitioning).
- The learning activities corresponding to the psychomotor domain will be delivered using three approaches of learning styles: accommodating (acting- partitioning), diverging (acting – observing), and converging (thinking – partitioning).
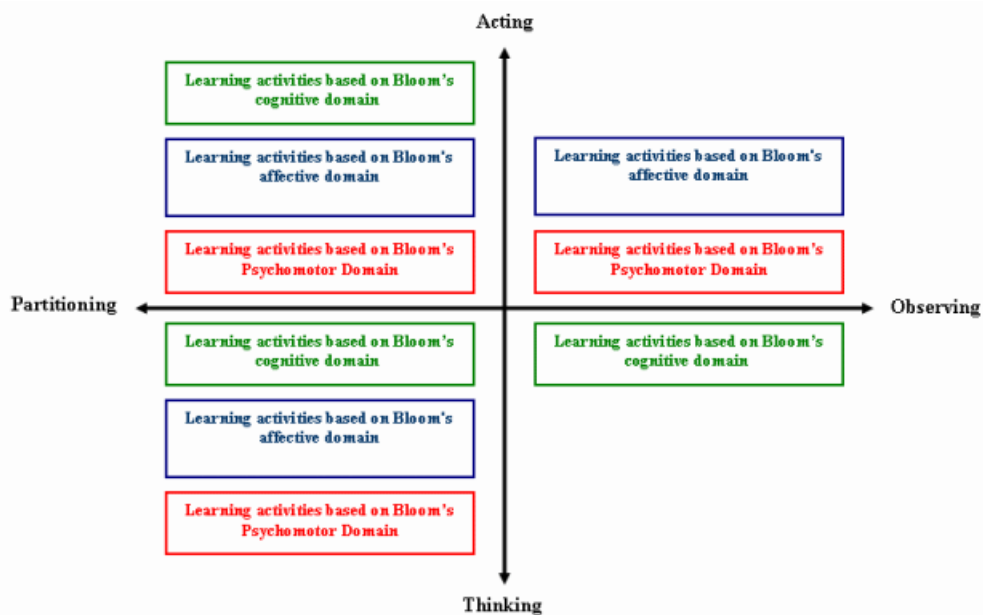

Figure 5: The Division of Bloom's domains in Kolb's Learning Styles

Figure 6 presents the proposed teaching and learning guideline for engineering education courses. The main focus of the guideline is to meet the students' learning styles requirements. The guideline consists of three elements: element 1 consists of the learning domains of Bloom's learning theory which should be used for curriculum development; element 2 is Kolb's learning styles and its integration with Bloom's learning levels; and part 3 gives the teachers the opportunity to choose suitable teaching and learning methods for the management of learning activities. For instance, in a cognitive learning activity, there are ways of learning such as thinking-observing and thinking-partitioning. On the other hand, the guideline identifies different examples of teaching and learning methods that are appropriate for teachers to choose from. Also, the teaching and learning examples include various experiential learning opportunities for students such as simulation of real work applications (using diagrams, hyperlinked text, video, pictures, interactive examples, virtual reality simulations, and animations).

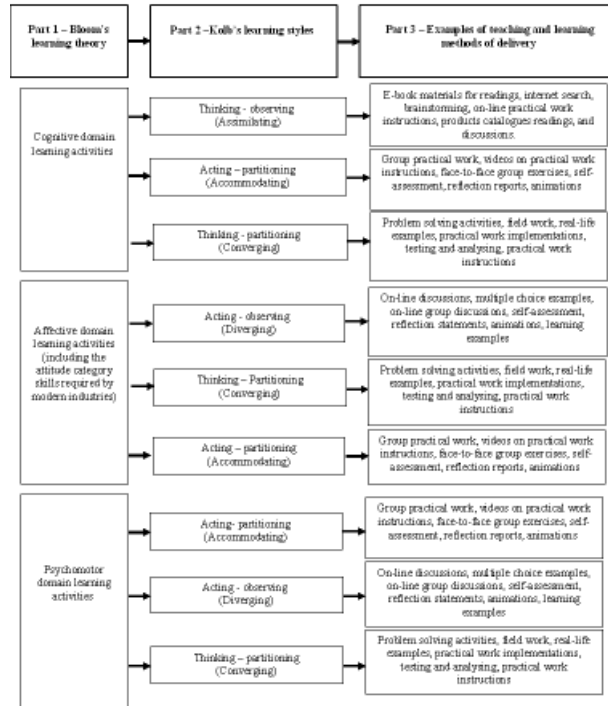| Part 1 – Bloom's learning theory	Part 2 – Kolb's learning styles	Part 3 – Examples of teaching and learning methods of delivery
Cognitive domain learning activities	Thinking - observing (Assimilating)	E-book materials for readings, internet search, brainstorming, on-line practical work instructions, products catalogues readings, and discussions.
	Acting – partitioning (Accommodating)	Group practical work, videos on practical work instructions, face-to-face group exercises, self-assessment, reflection reports, animations
	Thinking - partitioning (Converging)	Problem solving activities, field work, real-life examples, practical work implementations, testing and analysing, practical work instructions
Affective domain learning activities (including the attitude category skills required by modern industries)	Acting - observing (Diverging)	On-line discussions, multiple choice examples, on-line group discussions, self-assessment, reflection statements, animations, learning examples
	Thinking – Partitioning (Converging)	Problem solving activities, field work, real-life examples, practical work implementations, testing and analysing, practical work instructions
	Acting – partitioning (Accommodating)	Group practical work, videos on practical work instructions, face-to-face group exercises, self-assessment, reflection reports, animations
Psychomotor domain learning activities	Acting- partitioning (Accommodating)	Group practical work, videos on practical work instructions, face-to-face group exercises, self-assessment, reflection reports, animations
	Acting - observing (Diverging)	On-line discussions, multiple choice examples, on-line group discussions, self-assessment, reflection statements, animations, learning examples
	Thinking – partitioning (Converging)	Problem solving activities, field work, real-life examples, practical work implementations, testing and analysing, practical work instructions

Figure 6: The Proposed Guideline for Teaching and Learning in Engineering Education

This guideline offers the full map for developing activities to link between the curriculum content and the appropriate teaching and learning delivery. Through this guideline, the teachers will be able to effectively manage teaching and learning process to satisfy the identified students' requirements.

The guideline provides an embedded pedagogical framework for improving the effectiveness of engineering education courses. Specifically, the guideline has been used for structuring the content as well as improving the teaching and learning methodology for a school to work transition module. The guideline will be followed in the implementation phase of an innovative SBL- WBL transition module.

Conclusion

This study indicated that TVE system needs an effective teaching and learning process for the delivery of engineering education courses. Teaching and learning diagnostic assessment tools have been produced to elicit the responses from both TVE teachers and students. The results from the teaching and learning diagnostic assessment tools showed that the TVE teachers preferred learning styles for delivering of the learning activities were different than the learning styles preferred by TVE students. In order to satisfy the needs of TVE students

and assist TVE teachers in the delivery of the learning activities, a guideline has been proposed. The guideline has integrated Bloom's learning theory (for curriculum development) with Kolb's learning model (for teaching and learning delivery). Furthermore, the guideline has been developed to improve the effectiveness of teaching and learning approach for engineering education courses. The guideline included a framework which has been developed through investigation of various elements of teaching and learning processes involved through the benchmark studies available in literature. The guideline will be used as an effective tool for developing and delivering various engineering education courses. In addition, the guideline has been followed in structuring the content of an effective SBL- WBL transition module and will be followed in the delivery process of the module. The guideline will be then evaluated by TVE experts and improved for better results.

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Appendix 1- The Teacher's Diagnostic Tool

No.	Statements (Teaching and Learning Styles)	Accommodating	Diverging	Assimilating	Converging	Total Corresponding Teaching Styles
1	During the delivery of a new lesson, I concentrate on	Involving students in participate positively in the class	Giving students the time to listen and observe	Giving instructions for critical thinking	Practical tasks and applications	Assimilating
2	When operating a new machine for the first time in the workshop, I prefer the students to	Work with other students from the given instructions/guidelines	Listen to the teacher, look at all sides of required work issues, and concentrate on the new experience	Read the manual and understand the work instructions	Try things out individually	Diverging
3	I believe that the students learn better when they	Study with other colleagues	Write their own notes	Use their imagination and examples	Do simulation work	Converging
4	The theory lessons normally tend to be	Group discussion learning style	Questions and answers	Self-study	On-line learning style with real work examples	Diverging
5	The available learning materials include	Films/Videos	Pictures	Animations	Experiments	Converging
6	During the delivery of a learning lesson	I divide students into groups	I invite a guest speakers	I provide critical thinking activities with examples	I provide an intelligence questions and answers style	Converging
7	The available learning materials contain	Problem solving activities	Group activities	Pictures and videos	Practical sessions	Converging
8	During the teaching and learning process, I am the kind of person who	Relies on my experience	Relies on my observations	Relies on my ideas	Tries things out for myself	Converging
9	When I am explaining something to a student, I prefer to	Give some examples from my experience	Answer questions	Be logical	Work practically and get it done	Converging
10	During a practical session in the workshop, I am the kind of teacher who	Explains the practical instructions to students	Shows the students how to work things out	Lets the students think about how to work things out	Lets the students try things out	Accommodating
11	I use learning materials which contain	Videos	Pictures and diagrams	Charts	Practical sessions	Converging
12	I tend to say that the learning materials help the students to	Use their experience	Watch things	Think about new ideas	Implement tasks	Converging
13	I believe students learn faster by	Following instructions and written notes	Listening and asking questions	Being given ideas and examples	Doing assignments and practical applications	Converging
14	I usually	Divide the class into working groups	Answer questions	Explain things	Ask students to do the work	Converging
15	I usually deliver lessons to students in	Large classroom	Groups	Small classroom	Workshop	Converging

16	Students always gain the highest score when they are working on	Problem solving exercises	True or false questions	Descriptive questions	Practical exercises	*Diverging*
17	When I deliver a new learning activities/project	I let the students to test different approaches to completing the activities/project	I divide the students into groups to complete the project/activities	I let the students read and think	I let students have a go and try things out	*Accommodating*
18	During the delivery of a learning lesson, I prefer	Group discussion learning	Face-to-face learning	Self-study learning	Online learning	*Diverging*
19	When I open a new topic to discuss with students, I tend to	Ask questions	Listen and think	Participate in answering the questions	Evaluate the situation	*Accommodating*
20	I prefer students who are able to	Participate in group work	Observe and watch situations	Produce ideas and theories	See and touch objects	*Converging*

Appendix 2- The Student's Diagnostic Tool

Teaching and Learning Styles		Accommodating	Diverging	Assimilating	Converging	Preferred Learning Style
No.	Statement					
1	During the delivery of a new lesson, I like to	Be positively involved	Take my time to listen and observe	Follow practical instructions	Be practical	Converging
2	When operating a new machine for the first time in the workshop, I prefer to	Concentrate on the new experience	Look at all sides of required work issues	Analyse concepts and situations	Try things out	Diverging
3	I learn better when I	Study with my colleague	Write my own notes	Use my imagination and examples	Do simulation work	Converging
4	I do not like the theory lessons to be	Group discussion learning style	Questions and answers	Self-study	Online learning style	Diverging
5	I like the learning materials to include	Videos	Pictures	Animations	Experiments	Assimilating
6	During the learning process, I do not tend to	Learn independently and immediately	Reflect on my observations	Observe results and think of new ideas	Reflect on my experience in the practical work	Assimilating
7	I prefer the teacher who uses	Groups discussions style	Guest speakers	Examples	Questions and answers style	Converging
8	I do not prefer learning materials which contain	Problem solving activities	Group activities	Pictures and videos	Practical sessions	Converging
9	I am the kind of person who	Relies on my experience	Relies on my observations	Relies on my ideas	Tries things out by myself	Converging
10	When I am explaining something to someone, I prefer to	Give some examples from my experience	Answer questions	Be logical	Work practically and get it done	Converging
11	I usually learn faster from	Following instructions and written notes	Listening and asking questions	Giving ideas and examples	Doing assignments and practical applications	Assimilating
12	I do not like to be	Active in group work	Observe and watch situations	Produce ideas and theories	Able to see and touch objects	Converging
13	When the teacher is introducing a new situation to me	I accept the new situation as it is	I am aware of what is going on around this situation	I do a study around the situation	I evaluate the situation	Accommodating
14	During a practical session in the workshop, I do not prefer a teacher to	Explain the practical instructions	Show me how to do it	Let me think about how to do it	Let me try it out	Accommodating
15	During a class discussion, I tend to	Participate and explain things	Be quiet and reserved	Be active and excited	Take responsibility for things	Assimilating
16	I tend to say that	I like using my experience	I like watching things	I think about new ideas	I like doing tasks	Accommodating

23

17	I do not like the learning environment in the class to be	With my colleague	In large groups	Individual learning style	In small groups	*Accommodating*
18	I like the teacher who	Divides the class into working groups	Explains things	Answers questions	Asks students to do the work	*Assimilating*
19	When I am learning a new skill, I prefer to	Refer to my experience in practising it	Watch what the teacher is doing	Think about how to do it	Try to do it	*Accommodating*
20	I usually prefer the learning environment to be	Large classroom	Groups	Small classroom	Workshop	*Accommodating*
21	I always gain the highest score when I do	Problem solving exercises	True or false questions	Descriptive questions	Practical exercises	*Assimilating*
22	When a teacher delivers a new lesson, I prefer the lesson's explanations to	Test different approaches to completing activities/projects	Observe situations	Be in writing	Let us have a go and try things out	*Converging*
23	During the delivery of a lesson, I prefer	Group discussion learning	Face-to-face learning	Self-study learning	Online learning	*Assimilating*
24	When a teacher opens a new topic to discuss, I do not tend to	Ask questions	Listen and think	Participate in answering the questions	Evaluate the situation	*Accommodating*

About the Authors

Mohamed Alseddiqi
Mohamed Alseddiqi graduated with a degree in Electronic Engineering with distinction from Glasgow Caledonian University in 2001, followed by an MSc in Engineering Management from The University of Sunderland in 2005. He has worked as a Quality Consultant at The Quality and Productivity Centre from 2006-2008. During this period, he has completed number of projects in developing quality management systems for various organisations in Bahrain and gained a Professional Development Award in Quality from The Scottish Qualification Authority, Scotland. Furthermore, he has worked as a specialist in Technical and Vocational Education Directorate in Bahrain for about six years which included being the project adviser for the Technical and Vocational Education Development Project. Currently Mohamed Alseddiqi is a full time PhD student in the field of performance improvement in Engineering Education at The University of Huddersfield.

Dr. Rakesh Mishra
Dr. Rakesh Mishra is Reader in Fluid Dynamics at the School of Computing and Engineering of the University of Huddersfield. Dr. Mishra's main teaching and research area is thermo-fluids which includes aerodynamics, thermodynamics, engine systems and computational fluid dynamics. Dr. Mishra is also an active researcher on pedagogical issues and has a number of publications in the above research areas. Dr. Mishra has supervised a number of

PGR students in the above research area and currently a number of PGR students are enrolled with him for research degree. Dr. Mishra has presented papers to a number of conferences and have been invited to give several seminars. Dr. Mishra has also chaired a number of conference sessions dealing with green issues.

Salah Mahdi Abdulrasool
The research interest of Mr. Salah abdulrasool is around 'Engineering Education', 'Staff Development','Information Computer Technology (ICT)','Computer Aided Design (CAD)','Computer Aided Manufacturing','Computer Numerical Control'. Mr. Abdulrasool is a Ph.D. student in School of Computing and Engineering, University of Huddersfield, U.K. He has an academic career spanning 25 years. Mr. Abdulrasool worked as lecturer, senior teacher, advisor, quality manager, moderator, technical education specialist in various departments within the directorate of Technical and Vocational education in the Kingdom of Bahrain and operation manager for the Technical and Vocational Education Development Project as well as conducting several workshops and seminars in Engineering and education area. Currently he is chief of Center of Excellence for Technical and Vocational Education - Kingdom of Bahrain. He holds an Honours degree in engineering with technology Management as well an M.Phil degree in Engineering.

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