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Introduction of Hands-On Session Using Kolb Experiential Learning Theory Approach in Teaching Chemical Instrumentation Subject

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ABSTRACT

Chromatography is a high-technology instrument that is widely used in the various in the various industry for decades. Hence, Science Bachelor Graduates' that possesses ability to handle instrumentation are useful for their job nature. Learning approach that depends highly on lecture mode only enhance students' knowledge on chromatographic techniques, but they might not possess skills on instruments handling. Therefore, the learning approach of Chemical Instrumentation Method (KKKR5833) subject using a Kolb Experiental Learning Theory are running by hybrid mode of lecture and hands-on teaching approach on chromatography. A total of 16 registered students were the respondent of this study. These students had been given lecture on the theoretical part of chromatography and later on, in agreement with the experiential learning theories, student will experience hands-on learning activity in HPLC laboratory session. Finally, a full report after completing the hands-on session for their overall experience in laboratory. Majority of the students that took this elective subject agreed that hands-on experience of using chromatography increases their knowledge on it and mastering the preparation of sample skill is very useful while 50% of the students put more effort in this subject and manage to score excellently. Moreover, majority graduate student express agreement that basic knowledge and skills on chromatographic is important before working and indicated that students with knowledge and skills on chromatographic instrumentation have higher chance of employment. This statement also agreed by respondent from industries. This prove that hands-on teaching and learning approach in laboratory using chromatography instrument able to enhance knowledge and student skills.

Keywords: High performance liquid chromatography; hands-on; chromatographic instrumentation; learning activity; elective subject; Kolb Experimental Learning Theory; hybrid mode

INTRODUCTION

As a practicing profession, the engineering curriculum must include laboratory experience to prepare students for engineering practice when they graduated. Laboratory experiments are practical activities used to integrate theory with practice, and therefore need to be carefully designed and implemented to enable students to make the connections between theory and practice. In this regard, much research reported that laboratory works has been found to be superior to lectures and tutorials in teaching manual skills, providing an understanding of equipment and developing skills of scientific inquiry (Salim et al. 2009; Penerbit UKM 2016.

Laboratory experience is important in preparing students with hands-on skills, leadership skills, team working skills and communication skills, which are needed in the real world. Laboratories are the platform from which teamworking, oral and written communication skill development and engineering ethics are applied and emphasized. The laboratory experience which most students have prior to entering tertiary institutions does not guarantee a good performance in the Engineering laboratory courses. Therefore, it is the responsibility of the University, the faculty and the department to provide sufficient practical activities in order to prepare students with the skills expected at the workplace. Every student must register and pass the specified laboratory course to graduate (Salim et al. 2009; Penerbit UKM 2016).

This research is to report the results of the importance and benefits of using hands on approach in teaching and learning activity in the laboratory using analytical instruments which is HPLC. This research context referred to the elective course entitle Chemical Instrumentation Method (KKKR5833). The main purpose of this elective course is to provide exposure and knowledge to students regarding the concept of chemical instrumentation in conducting chemical analysis. It will emphasize on the basic theories and key principles of chemical instrumentation as

well as provide the opportunity for students to use most of the equipment found in the departmental analysis laboratory through lab work given throughout the course. The general concepts of electronic design such as multiplication of signals, electronic digits and signal-to-noise ratio equipment will also be discussed.

Furthermore, students will also be exposed to the latest instrumentation analysis in the determination of the chemical structure, measurement of the concentration and purity and undergoing the process of quality assurance in instrumentation measurement. Teaching plan for this course include 14 weeks of learning and assessment of courses covering assignments (25-40%), mid-semester exams (30-40%) and final examination (40-50%) (Salim et al. 2009; Penerbit UKM 2016).

Normally, knowledge is presented monotonously during lecture. Thus, it is very difficult to include all aspect of skills such as communication, teamwork, critical thinking, innovation, and creativity in lecture hall only (Bennett et al. 2000; Norzaini and Doria; 2021; Yusriza et al. 2021). To balance the aspects mentioned above, the assignments are prepared to provide students the opportunity to cultivate all generic skills as well as self-learning and experience-based learning skills (Chang et al. 2016; Tony et al. 2018; Chee 2019; Irina et al. 2019; Ridzuan et al. 2019; Aisyah and Mimi 2021; Noraien 2008). According to William et al. this is a new teaching approach are good to implemented to students in the era of technology (William et al. 2016; Waleed et al. 2018).

The main objective that is greatly emphasized in this course is students can apply the theory learned in lectures to laboratory activities using high-tech instruments for their job in the future. The analytical industry is handling various types of analytical instrumentation that serve the needs of the society (Ika et al. 2011; Marfunizah et al. 2018; Waleed et al. 2018). These industries are constantly looking for potential workers that have the knowledge and skills in handling the chromatography instrumentation because not all graduated students have this knowledge and skills. They do not have to train their workers if they already have such skills and knowledge. In addition, the student has been hands-on skills which is not only focus on theory. Thus, the students that have these kind of skills and knowledge are having a higher chance of employment compared to those that do not have (Mohamed 2014, Rosilah et al. 2017; Mohammad 2016). The aim of this paper is to investigate the students and industry perception towards this subject implemented in Department of Chemical and Process Engineering (JKKP), Faculty of Engineering and Built Environment (FKAB) UKM. Thus, we want to determine the performance of the students when the developed teaching method have been implemented in the current semester.

EXPERIENTIAL LEARNING THEORY

There is various theoretical model that tried to explain how human being learn. One of the theories which is well known and also referred by many researchers and educator is experimental learning theory. This theory emphasized on the aspect of developing students' skill on whole and holistic through experiencing learning in the real world. This theory is introduced by Kolb (1984).

According to Kolb, experiential learning theory is particularly interesting because it emphasize on cognitive influences, emotions and physical and social experience towards educational growth of a person (Kolb 1984). Besides, this theory also focuses on learner's learning perspective. Thus, the planning of teaching and learning activity is planned as such that it fulfills the needs of students where the students are required to involve actively in the learning process. Therefore, it can be concluded that experiential learning theory rejects conventional and didactic teaching and learning approach (Kolb 1984).

According to Kolb's experiential learning cycle, learning process can be categorized to 4 phase where the early phase will provide feed forward for the following phase (Kolb 1984). In addition, an active learning process will only happen when an individual gone through all four phases as stated:

1. Concrete experience
2. Reflective observation
3. Abstract conceptualization
4. Active experimentation

It is all known that universities have the responsibility to prepare leaders and members for the community that is able to apply the knowledge they gain to real-world context (Mehrnaz and Khairuddin 2016). Therefore, with reference to Kolb's experiential learning theory, a hybrid learning, and teaching approach is used.

MATERIALS AND METHODS

TEACHING METHOD

The teaching method used to teach this course in university is a hybrid learning and teaching approach which emphasize on both lecture and laboratory session that encourage student's active involvement. During lecture, knowledge is presented to students in theory according to syllabus while during laboratory session, students will be given opportunity to hands on the high technology instruments that they had learnt theoretically in lecture. After lecture, the students might not able to get a clear picture on how the HPLC works and how to handle it and thus, laboratory session is introduced to give students experience in handling those high technology instruments and not only understand it in theory. This course is a 2-hour credit course which include 1 hour of lecture and 2 hours of laboratory after the lecture in a week.

This approach of teaching and learning is extracted from the Kolb experiential learning theory. In Kolb's theory, students were to touch all 4 stage to complete the learning process. In this hybrid theory, it reflects the 4 stages

of learning as students have to pass all 4 stages which is planning or trying out what they have learnt, doing or having an experience, reviewing or reflecting on the experience and learning from the experience. The laboratory session of this course manages to provide them the platform for all 4 stages:

1. read up the manual and how to handle the activity before entering laboratory
2. laboratory session on HPLC
3. hands-on on the HPLC and preparation of samples
4. laboratory report on the session

In addition, laboratory procedure on the activity will be given to students earlier so that they could be prepared with knowledge such as preparation of standards and samples for the chromatography analysis (Skoog 2017).

Hands-on in instrument HPLC is included from standard preparation, sample preparation, HPLC set up, injecting sample or standard into HPLC and analysis or chromatography.

GROUPING DIVISION

As the laboratory have limited apparatus and instruments for students to use, students will be divided into small groups. A small group is preferred so that the student have the chance to hands on and not just sit in during the laboratory session. Each group contains three to four members who need to know each person's role. The students will divide jobs among themselves equally and know each other job.

TYPES OF SURVEY CONDUCTED

The types of survey used to find out the results of effectiveness of introducing hands-on activity into teaching this elective subject are:

1. survey form for students and people working in industries
2. interview with students

The survey form for students and people working in industries are created respectively through google form and distributed to target respondents to give respond. Different questions regarding the effectiveness of this hybrid form of teaching is evaluated by students whereas different questions regarding the needs and expectation of industries towards graduates that will work with them.

The interview carried out with students which require students to share their experiences of going through this hybrid teaching method and how this teaching method affects them.

Practical 1 – Determination of Standard Curve using High Performance Liquid Chromatography

Objective

- To study about high performance liquid chromatography system
- To use HPLC for determination of standard curve of analyte
- To learn how to use micropipette in the preparation of standard solution

Methodology

1. Calculate the total mass (g) need to be used to prepare standard solution of concentration 1000 ppm.
2. Prepare stock solution of 1000 ppm and perform serial dilution for concentration of 100 ppm, 10 ppm, 8 ppm, 6 ppm, 4 ppm and 2 ppm.
3. Transfer the prepared standard solution to HPLC bottle for analysis.
4. Analyse the chromatogram obtained from HPLC.
5. Prepare a standard curve and determine the equation obtained.

FIGURE 1. Example of procedure/methodology of chromatography laboratory

FIGURE 2. Student is preparing a standard solution using a micropipette

FIGURE 3. The standard solution prepared according to the required concentration

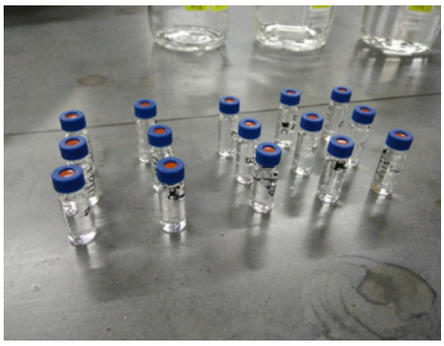

FIGURE 4. The standard solution was transferred into the HPLC container, ready for analysis

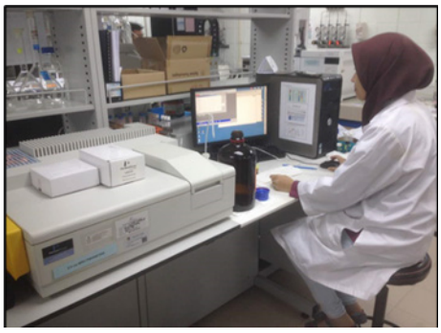

FIGURE 5. The student is analyzing samples using UV-Vis Spectrophotometer

RESULTS AND DISCUSSION

Referring to the survey conducted on all students who have taken this subject, all the students agreed that the experiments carried out had increased their knowledge and interest towards this subject. Those students also became clearer about the operating system of chromatographic instruments in the laboratory.

Referring to Figure 6, 100% of the students supported the fact that with the addition of experiment that involve instrumentation in laboratory is very good and appropriate. Students mentioned that they are interested in this subject because it does not only focus on classroom learning but also alternate with laboratory session. They also mentioned that the laboratory session helped her a lot in understanding the theory when she has the chance to experience hands-on and have a clear picture on how HPLC works. In addition to that, laboratory session could also develop students' laboratory skills and HPLC handling technique. This is an advantage towards students after they graduate as they have an extra skill that the industry is looking for.

Figure 7 explains the level of effort that the student has given towards this elective subject. A total of 12 students that have taken this elective subject put an excellent to satisfactory effort towards this subject. Students said that they have work hard and also willing to spend their time to prepare the experiments provided and to analyze the data obtained. This may be due to the increase of interest towards this subject as they can experience hands-on activity in the same time gaining knowledge on chromatography and instruments instead of just focusing in lecture class. The more they understand the subject, the more they develop interest in it. Thus, the student would be willing to put effort in studying this subject (Kumneger & Belay 2018; Kok et al. 2018).

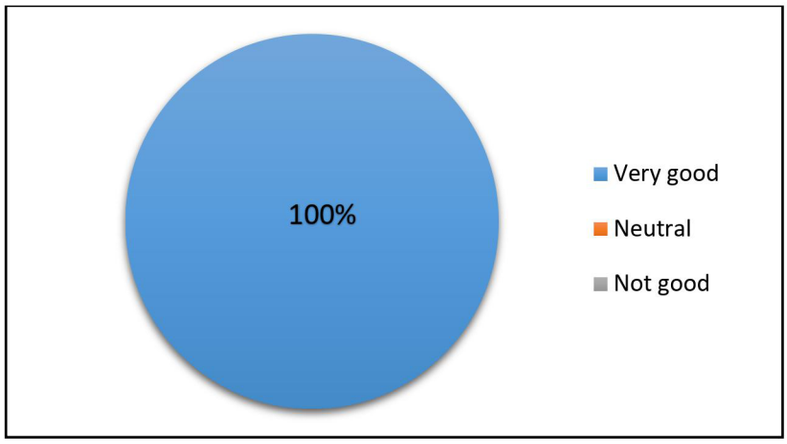

FIGURE 6. Survey on using chromatographic instruments in laboratory

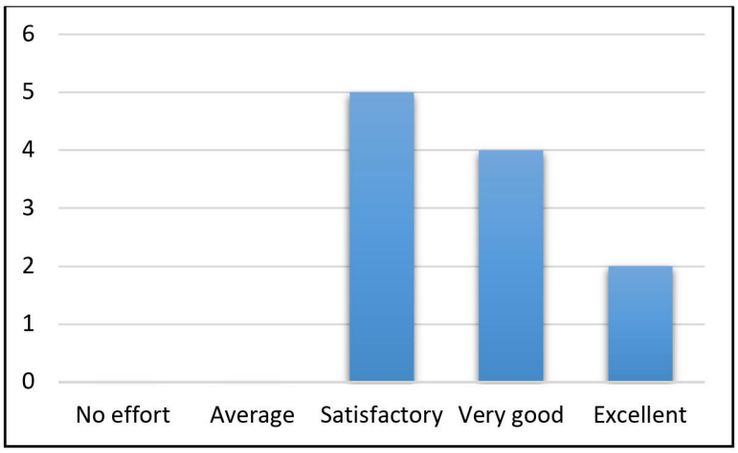

FIGURE 7. Aspect effort the students given to this subject

From the survey conducted, the students have rated that the contribution of knowledge of the subject towards students was very good. This subject contribute not only knowledge but also skills towards students in terms of instrumentations and chromatography. This is shown from the student's knowledge before following this subject as in Figure 8. Students' knowledge is found to be inadequate or in moderation in this subject. When the students follow this subject class, the students have started to develop interest in this subject as it increases the knowledge about chromatography and instrumentations in students improved to very good and excellent level.

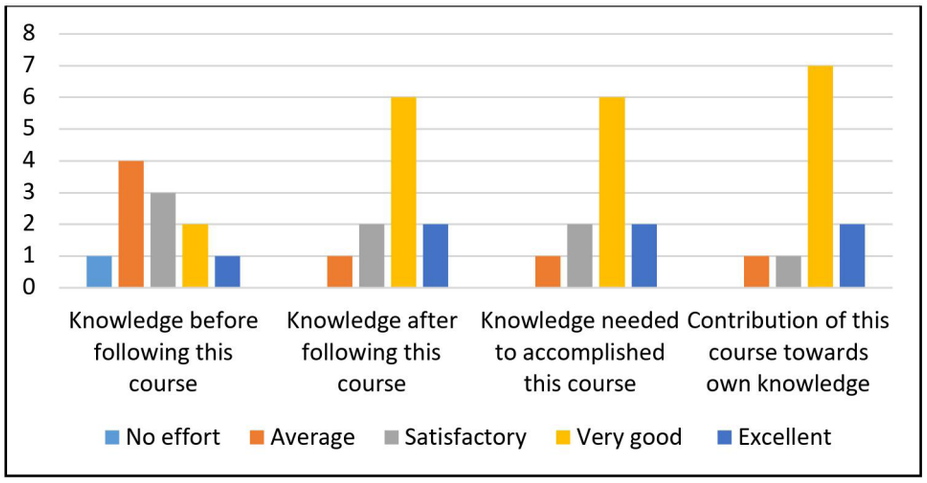

FIGURE 8. Contribution to knowledge of this subject

Skills and responses to lecturers' efforts to teach this subject have been evaluated as shown in Figure 9. Figure 7 explains the level of effort that the student has given towards this elective subject. A total of 12 students that have taken this elective subject put an excellent to satisfactory effort towards this subject. Students said that they have work hard and also willing to spend their time to prepare the experiments provided and to analyze the data obtained. This may be due to the increase of interest towards this subject as they can experience hands-on activity in the same time gaining knowledge on chromatography and instruments instead of just focusing in lecture class. The more they understand the subject, the more they develop interest in it. Thus, the student would be willing to put effort in studying this subject (Kumneger & Belay 2018; Kok et al. 2018).

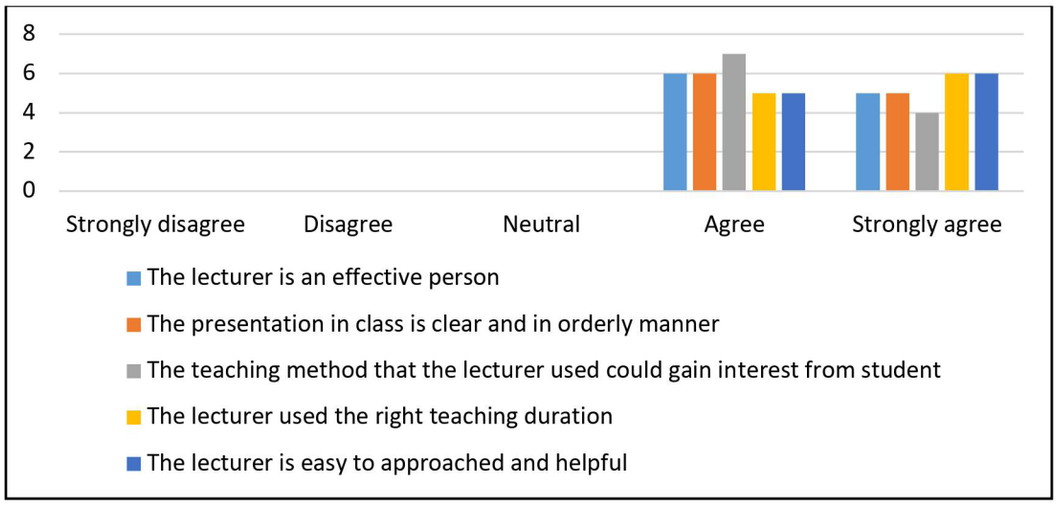

FIGURE 9. Skills and responses towards lecturers' efforts in teaching these subjects

The industry reported from a survey that basic knowledge of chemical instruments such as high-performance liquid chromatography (HPLC), gas chromatography (GC), ultra-violet visible spectroscopy (UV-Vis) and so on are important criteria for an employee before starting work in the field of factory analysis or company with analytical laboratory. According to literature, the company would like to hire a worker with the skills and knowledge in chromatographic instrumentations to work in their analysis laboratory instead of workers that do not have such skills and knowledge (Mehrnaz and Khairuddin 2016; Kok et al. 2018; Nur Ain et al. 2020). 92.9% of the industry site agreed that the subject of chemical instrumentation provides early exposure to students on the importance of basic knowledge of handling instruments in the analysis laboratory (Figure 10). They also suggest that important aspects such as instrument overhaul methods are introduced to students. It is important for students to have basic knowledge on instrument repairs.

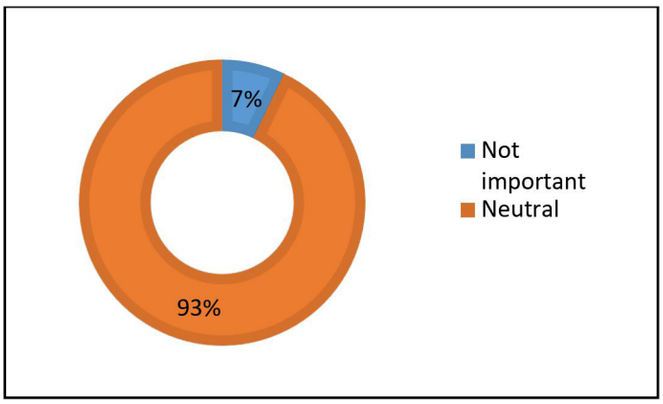

FIGURE 10. Importance of chemical instrumentation method towards industries

Normally, chemical instruments present in Analytical Laboratory in the industries are HPLC and GC according to the survey that have been conducted with the people from different industries (Figure 11). This is particularly relevant for the purpose of this subject which emphasizes the usage of HPLC instrument in laboratory activities. Students are exposed to skills on using HPLC instrument tools such as procedures to prepare standard solutions for calibration purposes, sample preparation for analysis, how to inject sample into HPLC, sample analysis and analyzing data from chromatogram obtained. This is a very useful knowledge that has been acquired by students who take this elective subject.

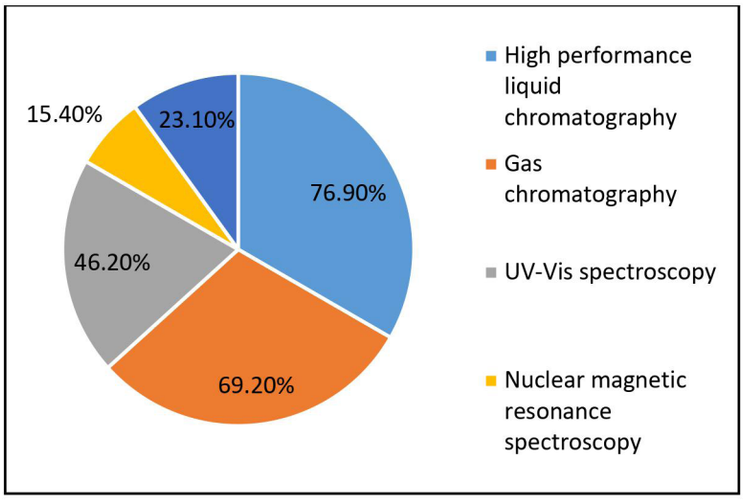

FIGURE 11. Most important instruments in analytical laboratory

Figure 12 shows the estimated fee required by industries to send their employees for training on using chromatographic instruments. The results showed that the industry required more than RM5000 to send an unskillful employee to attend the training or workshop on usage and handling of the instruments in the analytical laboratory. If the industries have many instruments to use in their industrial processes, then the higher the amounts will be allocating to send employees to workshops or appropriate training to produce skilled workers. This high amount of budget needs to be spent by the industrial manager to ensure that its employees become proficient in analyzing samples using chromatographic instruments. Among the important workshops to be attended were the introductory workshop on chromatography, the technique of analyzing samples using chromatographic instruments and methods for analysis. If the student already well equipped with chromatography skill and knowledge, they will have a higher chance of employment since the employee in the industries do not have to use their budget to send workers for training or workshop (Kok et al. 2018; Nur Ain et al. 2020).

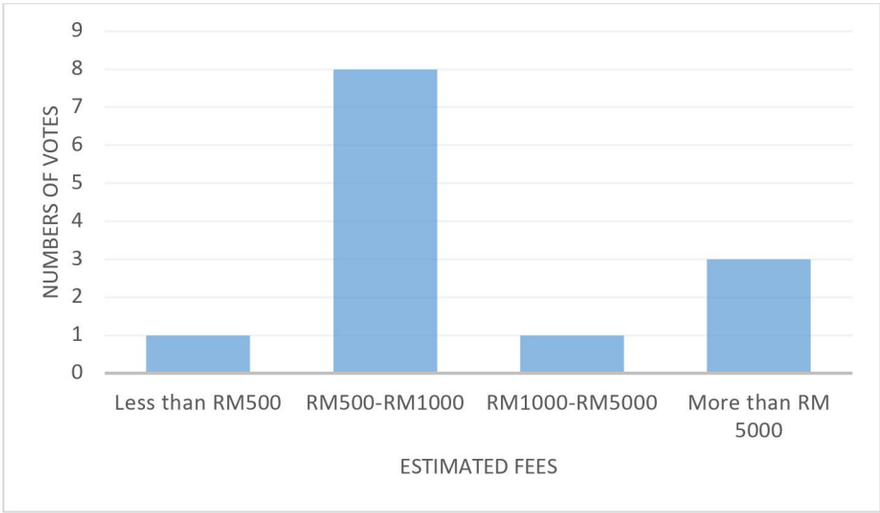

FIGURE 12. Estimated fee required by industry to send employees for training on using chromatographic instruments

The examination results for year 2014, 2015 and 2017 obtained indicate that students are in excellent level after attending lectures in hybrid mode where the lecture is alternate with instrument laboratories session. In 2017 was the first attempt to alternate experiment with laboratories with theory lectures. This shows that the results of the successful decision are that 56.25% of students successfully obtain Grade B and above. Compared to 2015 and 2014. This good performance should be maintained for the year ahead.

TABLE 1. Examination results of students that have taken the elective subject chemical instrumentation method

Grade	Pointer	Lower limit	Upper limit	Number of students	Percentage
		2017			
A	4	80	100	1	0.06
A-	3.67	75	79.9	2	0.13
B+	3.33	70	74.9	5	0.31
B	3	65	69.9	1	0.06
		2015			
A	4	80	100	0	0.00
A-	3.67	75	79.9	6	0.43
B+	3.33	70	74.9	7	0.50
B	3	65	69.9	1	0.07
		2014			
A	4	80	100	3	0.33
A-	3.67	75	79.9	0	0.00
B+	3.33	70	74.9	2	0.22
B	3	65	69.9	1	0.11

CONCLUSION

Overall, this teaching methodology has helped the students as well as the industries in increasing the teaching method versatility. Students able to possess knowledge as well as skills in chromatographic analysis which the industries required by using this hybrid teaching approach in Chemical Instrumentation Method (KKKR5833). In addition, with the hybrid teaching approach, students will have the chance to apply what they have learn in the lecture into the alternating hands-on laboratory session during the course weekly. Effective teaching techniques and hybrid teaching approach are capable of upgrading the education system at Universiti Kebangsaan Malaysia shown by increased number of students that taken this course getting excellent results in examinations. In addition, this teaching approach can also equip students with additional knowledge and skills for their future career.

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Al-Rahmi, W. M., Alias, N., Othman, M. S., Alzahrani, A. I., Alfarraj, O., Saged, A. A., & Rahman, N. S. A. 2018. Use of e-learning by university students in Malaysian higher educational institutions: A case in Universiti Teknologi Malaysia. *Ieee Access* 6: 14268-14276.

Azman, N., Dunne, E., & Carré, C. 2021. A critical analysis of Malaysian higher educational instituitions' response towards Covid-19: Sustaining academic program delivery. *Journal of Sustainability Science and Management* 16(1): 70-96.

Baha, N. A. D., Mansur, M., & Ismail, M. A. 2020. Potensi Kebolehpasaran Bakal Graduan Fakulti Ekonomi dan Pengurusan (Employability Potential of the Faculty of Economics and Management Future Graduates). *Jurnal Pendidikan Malaysia (Malaysian Journal of Education)* 45(2): 13-23.

Bennett, N., Dunne, E., & Carré, C. 2000. *Skills Development in Higher Education and Employment*. Taylor & Francis, Inc., 7625 Empire Dr., Florence, KY 41042.

Bush, T., Hamid, S. A., Ng, A., & Kaparou, M. 2018. School leadership theories and the Malaysia Education Blueprint. *International Journal of Educational Management.*

Chong, C. J. 2019. Preliminary review on preparations in Malaysia to improve STEM education. *Journal of Sustainability Science and Management* 14(5): 135-147.

Embi M. A. 2014. Blended & Flipped Learning: Case studies in Malaysian HEIs. centre for teaching & learning technologies. Universiti Kebangsaan Malaysia.

Fahimirad, M., Idris, K., & Kotamjani, S. S. 2017. Instructional leadership and instructor development: A case study of Malaysia's research universities. *Geografia-Malaysian Journal of Society and Space* 12(10).

Hassan, R., Zaki, W. M. D. W., Kamaruddin, H., Othman, N., Sum, S. M., & Mohamad, Z. 2017. Entrepreneurship education in UKM: Essential skills for first-year students. In *Leadership, Innovation and Entrepreneurship as Driving Forces of the Global Economy* (pp. 675-685). Springer, Cham.

Hin, K. K., Yasin, R. M., & Amin, L. 2018. Pelaksanaan pendekatan interdisiplin dengan bioteknologi dalam sains tambahan (Interdisciplinary approach with biotechnology in additional science). *Jurnal Pendidikan Malaysia (Malaysian Journal of Education)* 43(02): 49-59.

Juharia, A. N., & Bakar, M. H. A. 2020. Popular game elements used in designing game-based learning STEM application for school students– A review. *Jurnal Kejuruteraan* 32(4): 559-568.

Khalid, I. L., Harun, R., Muda, A., & Ismail, I. A. 2011. Level of knowledge on environmental issues and environmental education of primary schools headmasters in Kuala Lumpur, Malaysia. *World Applied Sciences Journal* 14: 97-100.

Kolb, D. A. 1984. The experiential learning theory of development. *Experiential Learning: Experience as the Source of Learning and Development*: 132e160.

Ma'Dan, M., Ismail, M. T., & Daud, S. 2019. Importance of human capital development and competitiveness in enhancing competency level among Malaysia University graduates: Literature review. *e-Bangi* 16(8).

Mansor, N. 2008. Sustaining Esl students' interactions in a collaborative learning via email discussion: A case study at UMT. *Journal of Sustainability Science and Management* 3(1): 30-40.

UKM. 2009. *Panduan Prasiswazah: Fakulti Kejuruteraan dan Alam Bina: Sesi Akademik 2009-2010*. Fakulti Kejuruteraan dan Alam Bina, Universiti Kebangsaan Malaysia.

McGaghie, W. C., Issenberg, S. B., Barsuk, J. H., & Wayne, D. B. 2014. A critical review of simulation-based mastery learning with translational outcomes. *Medical Education* 48(4): 375-385.

Reza, M. I. H. 2016. Sustainability in higher education: Perspectives of Malaysian higher education system. *Sage Open* 6(3): 2158244016665890.

Salim, K. R., Puteh, M., & Daud, S. M. 2009. A review of the current laboratory practice in Malaysian university: A preliminary study. In *International Conference on Engineering and Education in The 21st Century. March* (pp. 23-25).

Skoog, D. A., Holler, F. J., & Crouch, S. R. 2017. *Principles of Instrumental Analysis*. Cengage Learning.

Tadele, K., & Sitotaw, B. 2018. Perception and trends in assessment of students' learning in Physics courses. *Latin-American Journal of Physics Education* 12(1): 7.

Wan, C. D., Chapman, D., Hutcheson, S., Lee, M., Austin, A., & Md. Zain, A. N. 2017. Changing higher education practice in Malaysia: the conundrum of incentives. *Studies in Higher Education* 42(11): 2134-2152.

Yacob, R., Saruwono, M., Ismail, Z., & Pheng, L. S. 2018. Influence of human factors on the uncertainties of refurbishment projects: A proposed conceptual approach. *Journal of Engineering (UKM)* 2019-SI-2 (1).

Yusof Y. M., Ayob A., & Saad M. H. M. 2021. Penggunaan teknologi kejuruteraan dalam pendidikan STEM bersepadu. *Jurnal Kejuruteraan* 33(1): 1-11.

Zen, I. S., D'souza, C. L. A. R. E., Ismail, S., & Arsat, M. 2019. University living learning labs: An integrative and transformative approach. *Journal of Sustainability Science and Management* 14(4): 139-155.