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Social Network Analysis to Examine the Effectiveness of e-PBL with Design Thinking to Foster Collaboration: Comparisons between High and Low Self-regulated Learners

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Abstract: In TVET teaching and learning, learners' collaboration is important to ensure learning effectiveness. However, employing either design thinking or online problem-based learning would not lead to fruitarian. Hence, to devise teaching and learning that employs design thinking (DT) and online problem-based learning (ePBL) pedagogies used in tandem with social media learning environment in Facebook are hypothesized to improve TVET learner's collaboration. By adopting the Social Constructivism learning theory that social interaction fosters collaborative learning and build learners' knowledge and understanding, this study is commenced. Social interaction that fosters learners' collaboration is moderated by type of learners' self-regulation (SR) towards learning. Previous research hypothesized that ePBL alone only worked effectively for high self-regulated learners. The learning outcome inequity present due to the pedagogy limitation. This research devises ePBL with DT as a combination of pedagogies that benefits the low SR learners as well. To monitor collaborative learning occurrences, network ties via social media footprints of individual TVET learners is tracked from the learners' Facebook group. The effectiveness of treatments is monitored using social network analysis i.e. graph theory and centrality concept employing NodeXL software. Samples of 142 TVET pre-service teachers that currently enroll in Design and Technology course at Teachers' Training Institutes in Malaysia participated in this study. The samples are intact group and classified into high-SR learners and low-SR learners. Social network analysis using Vertices index, Geodesic distance and graph visualization findings show that ePBL with DT works in fostering learning collaboration for both high-SR and low-SR learners. This implies that national e-learning policy and ePBL embeddedness into technical subject is promising, regardless of the type of learners provided that DT is incorporated into the pedagogy.

Keywords: TVET, self-regulated, e-PBL, design thinking, social network analysis, collaboration

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1. Introduction

In Malaysia, the preparation for TVET pre-service teachers are held by the Teachers' Training Institute or *Institut Perguruan* (IPG), a government-owned entity that educate pre-service teachers to fill-in public school teaching positions. IPGs are responsible to prepare future TVET teachers with the ability to teach and facilitate learning using online technologies (Albion, 2008; Greenhow, 2007) and integrate them with the new policy (i.e. DePAN) that called for nurturing technology-driven teaching and learning (T&L) among pre-service teachers (Ministry of Higher Education Malaysia [MOHE], 2011; Moursund, 2003; Jonassen, 2000). Hence, the primary purpose of this study is to examine the effectiveness of online problem-based learning (ePBL) with design thinking techniques and strategies incorporated into TVET pre service teachers' online learning using the Facebook site, and comparisons made between high versus low self-regulated learners; the pre-service teachers at IPG.In terms of the policy, the Malaysian government encourages social media capability building among school teachers and technology skills development through the Malaysian education system. In the year 2011, the National e-Learning Policy or *Dasar e-Pembelajaran Negara* (DePAN) was launch by the Ministry of Higher Education Malaysia (MOHE). However, the process of implementing T&L online requires skilled and social media savvy teachers. Technology savvy teachers should be familiar with the use of new information, communication and technology (ICT) and well-verse with new forms of collaboration media for learning i.e. social media. With the availability of new forms of social media technology, TVET pre-service teachers are expected to be the medium of change. Thus, the TVET pre-service teachers need to be exposed to an environment of learning online by creating online learning activities, promoting virtual discussion sessions that enable the process of structuring knowledge and building a student-centered online learning environment as preparation before they start their teaching in schools (Knowles, Holton, & Swanson, 2014). Therefore, there is an urgent need to ensure the training of TVET pre-service teachers embedded with competency in integrating technology in T&L (MOHE, 2011).

Besides the technology aided T&L approach, learning is made more effective through collaborative learning, particularly in this era whereby crowdsourcing is accessible. Hence, complementing learning with design thinking would enable collaborative learning (Luka, 2014). On the other hand, design thinking is considered as an alternative method used in the TVET learning process to build technology-savvy pre-service teachers because it involves the process of collaboration to solve real-world problems by seeking information from other peoples' feedback and experiences (Ray, 2012). In addition, design thinking is capable of integrating humans with technical factor such as designing solutions (Leifer & Steinert, 2011). The benefits of design thinking with T&L is that it fosters collaboration among students to solve problems (Rauth, Köppen, Jobst and Meinel, 2010). Moreover, T&L is expected to be more innovative with the use of design thinking methods and ICT helps make the process of TVET T&L more efficient (Angeli and Valanides, 2009; Chai, Koh, Tsai and Tan, 2011).

In order to contextualise the research, integration of all these three elements simultaneously; (i) new ICT adoption, (ii) collaboration in T&L and (iii) design thinking (DT) method, this research selects a primary school subject that contains these three elements. Therefore, Design and Technology or known as *Rekabentuk & Teknologi* (RBT) subject is chosen as the focus. As a technical subject, RBT is suitable to be integrated with design thinking approach moreover in accordance to the Ministry of Education Malaysias' recommendation on embedding Project Based Learning (PBL) into learning (Ali, Khan and Abdul Ghani, 2018; Embi, 2016). However, PBL requires students' immersion in the project and that demands a time commitment. Thus, in addition, the use of ICT in PBLs can overcome some of the constraints encountered during the implementation of conventional PBLs i.e. time and meeting after school hours (Bruckman, 2006). Therefore, the commencement of PBL through online is the solution, and this idea is consistent with Solomon (2003) who described the use of online PBL (ePBL) to facilitate access to communication and collaboration within the team, furthermore it enables access of information from the outside world. In addition, it can be done outside of school hours through online applications such as email, forums, blogs and social media sites (Solomon, 2003). The ePBL also makes it easy to access referral sources for information through virtual libraries that are physically far from home (Solomon, 2003). Besides ePBL, types of self-regulated learners are critical factors in the success of online learning. The ePBL with DT are superior compared to ePBL without DT for high self-regulated learners. Thus there is a need for research to uncover the strategies for promoting ePBL with DT that would benefit both types of self-regulated learners.

1.1 Social Media Data Analysis

On the other hand, social media utilisation for ePBL brings challenge in terms of monitoring the events or occurrence of T&L that took place in online. Reason being, social media data is characterised as high volume, high velocity, and highly diverse. Hence interpreting it presents several challenges and requires skill (Sivarajah et al., 2017). Thus, analysing unstructured data involves the application of new tools and capabilities, particularly for real-time analytics. Conditional to the social media analytics layer of interest, researchers require different monitoring tools. Since there are various social media analytics tools available, to align with the research objectives of social media strategy, NodeXL is chosen for the analysis tool. NodeXL helps to construct and analyse Facebook networks (based on co-likes and co-comments).

In translating the monitoring of the effectiveness of ePBL with DT approach in Facebook, the concept of network space distance is used. It is defined as the number of edges between two points (nodes or vertices) and geodesics are

called the "shortest paths". In addition, the concept of centrality measures is used to indicate the importance of the nodes. Therefore, prominent nodes are often connected extensively to the other nodes in the network. Wasserman & Faust (1994) has proposed several centrality measures for network analysis, including 1) degree centrality (i.e., a measure of the degree of nodes), 2) closeness centrality (i.e., a measure of how close an actor is to all the other actors), and 3) betweenness centrality (i.e., a measure of the number of geodesics between nodes going through a node). Hence, degree and neighbourhood are local measures: they can be computed for every single actor. Another fundamental concept used to measure a network is the geodesic distance between two actors, which in single unweighted networks corresponds to the minimum number of connections to be traversed to reach one actor starting from the other. This concept is essential as it is often used to define other centrality measures, most notably closeness and betweenness. By applying these concepts, social network analysis (SNA) has enabled the study of online collaborative learning.

Despite the importance of online learning, it is worth mentioning that blended learning environment that involves a combination of face-to-face and online learning is still a common practice in Malaysia. However, the process and technique to observe students' face-to-face learning are widespread, the online learning that takes place in social media is new. Hence, it needs to be done with the help of NodeXL software. NodeXL software have the ability to visualise and analyse the interactions that occur in online learning environment in Facebook. The process of monitoring the patterns of participation and effectiveness of ePBL with design thinking is feasible with NodeXL (Doran, Doran, & Mazur, 2011). Thus, this article aims to provide evidence of the effectiveness of e-PBL with DT to foster collaboration and also to empirically uncovers that it works for both high and low self-regulated TVET learners.

This article is structured as follows. The next section discusses the method used in this study. This section discusses the research methodology used that comprises the sample of the study, context and research design. Then, it is followed by the findings and discussion section. The final section provides the concluding remarks of this article.

2. Method

This study used analytical approach of social media data from Facebook. Data were collected using social network analysis employing NodeXL software. The unstructured data of communications that occurred in the Facebook Group of pre-service teachers' involved in the research are analysed using graph theory and data visualisation. More detailed information about the study sample; context and design, related to the research are discussed in the following sections.

2.1 Sample of Study

For this study, the ePBL group with DT and the ePBL without DT was represented by two Facebook groups of TVET pre-service teachers of different self-regulation levels: a group of high self-regulation pre-service teachers and a group of low self-regulation pre-service teachers. The level of self-regulation of pre-service teachers was measured using an online self-regulation questionnaire developed by Barnard et al. (2009). A total of 142 pre-service teachers were involved in this study. The number of pre-service teachers, according to the treatment group and the level of self-regulation based on the results of the self-administered questionnaire administered before the treatment was conducted as shown in Table 1.

Table 1 - Number of samples, according to group and level of self-regulation.

	ePBL with DT	ePBL without DT
Learner with high self-regulation	31 samples	34 samples
Learner with low self-regulation	36 samples	41 samples

2.2 Context and Research Design

To examine the effectiveness of design thinking (DT) on ePBL, this study compares the pre-service teachers' interaction in performing activities in both applying design thinking (ePBL with DT) and without applying design thinking (ePBL without DT). Past researches show the level of self-regulation determines the effectiveness of online learning (Barnard, Paton & Lan, 2008; Cho & Shen, 2013; Hodges & Kim, 2010; Matuga, 2009; Puzziferro, 2008). To address the differences highlighted by past research, this study investigates the effects of ePBL with a design thinking approach versus ePBL without design thinking on a different type of self-regulated learners.

In the context of this study, ePBL is based on the phases of Project-Based Learning conducted online as proposed by Bender (2012). In this study, ePBL refers to an online project assignment that pre services undertake in RBT course. The phases are:

(a) Group identification and planning,
(b) Information seeking,
(c) Project design,
(d) Project construction, and

(e) Project presentation.

In this study, the design thinking applied is based on the design thinking process by Ling (2015) model. Ling, (2015) divides the design thinking process into five steps namely:

(a) Empathy to understand and challenges and problems encountered,
(b) Define the challenges and problems encountered,
(c) Develop ideas for exploring solutions,
(d) Develop prototypes for solving problems and problems encountered, and
(e) Testing the prototype and review for decision making.

In this study, the social network analysis applied graph theory and clustering methods to group the low self-regulated and high self-regulated learners. In addition, this study uses closeness centrality measure to identify how close the learners in each complete network e.g. low and high self-regulated groups. Closeness centrality captures the average distance a learner is from all other learners in the network and the function of a learners' geodesic distance to others, which equals the length of the shortest path connecting a pair of learners. The geodesic distance index can be interpreted with absolute values closer to 1 indicating more cohesive relations in the complete network of study. For example, small geodesic distance indicates closeness between learners. Moreover, the vertices index is used to measure the number of contacts made by the learners. Vertices index is used when comparing between group as evidence that there is connectivity among learners found in the entire matrix of social media networks.

Table 2 - Description of selected social media networks' matrix terminology.

No.	Terminology	Description
1.	Vertices Index	The number that appears on the bottom row is the total number of vertices found in the entire matrix of social media networks
2.	Geodesic Maximum Distance (Diameter)	Geodesic distance is the shortest distance connecting two people (Hansen et al., 2011). For example, suppose the intersection is a road and the corner is a house, then Geodesic distance is the number of paths one must take to move from house to house by choosing the shortest distance. Therefore, the maximum geodesic distance is the longest distance between two vertices.
3.	Geodesic Average Distance	Geodesic average distance values indicate how closely members of a community are connected. If the geodesic average distance value is high, then most people in the community do not know each other (Hansen et al., 2011). However, if the geodesic average distance value is low, then most people in the community get to know each other.

3. Findings

The results of social media analysis are reported according to the five phases of ePBL as proposed by Bender (2012). After each phase was completed, social media data are downloaded from the Facebook application and analysed using NodeXL software. Table 3 summaries the results for each phase.

In phase one, the highest vertices is group of learner classified as high-SR with ePBL+DT, followed by low-SR with ePBL+DT, high-SR with ePBL and low-SR with EPBL with vertices index of 60, 35, 31 and 22 respectively (refer Figure 1).

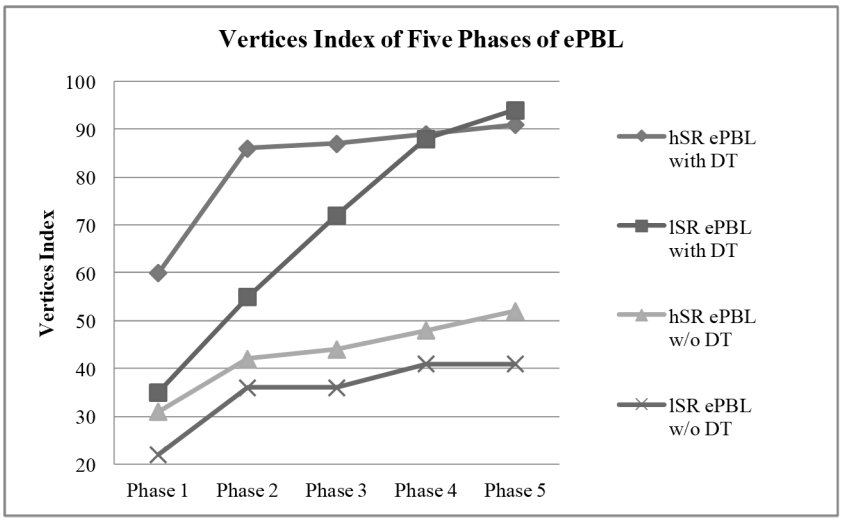

Fig. 1 - Vertices index for five phases in ePBL.

In phase two, the highest vertices is group of learner classified as high-SR with ePBL+DT, followed by low-SR with ePBL+DT, high-SR with ePBL and low-SR with EPBL with vertices index of 86, 55, 42 and 36 respectively (refer Figure 1). In phase three, the highest vertices is group of learner classified as high-SR with ePBL+DT, followed by low-SR with ePBL+DT, high-SR with ePBL and low-SR with EPBL with vertices index of 87, 72, 44 and 36 respectively (refer Figure 1). In phase four, the highest vertices is group of learner classified as high-SR with ePBL+DT, followed by low-SR with ePBL+DT, high-SR with ePBL and low-SR with EPBL with vertices index of 89, 88, 48 and 41 respectively (refer Figure 1).

3.2 Closeness Centrality Using Geodesic Distance

The lowest geodesic average is favourable. Based on Figure 2, in phase one, the average geodesic score following decreasing pattern are group of h-SR ePBL+DT, l-SR ePBL+DT, h-SR ePBL and l-SR ePBL with 2.46, 2.49, 2.49 and 2.61 respectively. In phase two, average geodesic score following decreasing pattern are as follows group of l-SR ePBL+DT, h-SR ePBL+DT, h-SR EPBL and l-SR ePBL 2.77, 2.83, 2.87 and 4.02. In phase three, average geodesic score following decreasing pattern are as follows group of h-SR EPBL+DT, l-SR EPBL+DT, l-SR ePBL and h-SR ePBL 2.78, 2.81, 4.02 and 4.50. In phase four, average geodesic score following decreasing pattern are as follows group of l-SR ePBL+DT, h-SR ePBL+DT, l-SR ePBL and h-SR ePBL 2.80, 2.91, 3.47 and 4.52. In phase five, average geodesic score following decreasing pattern are as follows group of l-SR ePBL+DT, h-SR ePBL+DT, l-SR ePBL and h-SR ePBL 2.80, 2.91, 3.47 and 4.03. This indicates that each member of the low-SR and high-SR that follow ePBL with DT knows each other better than the group of low-SR and high-SR who follows ePBL without DT.

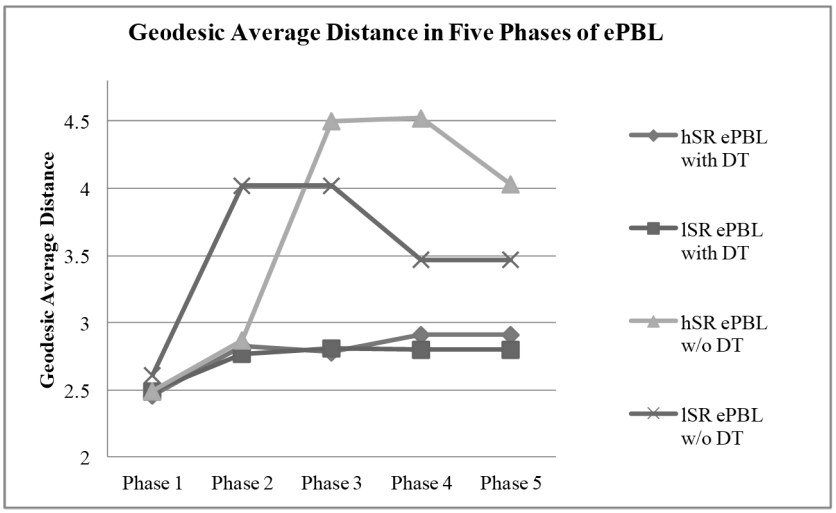

Fig. 2 - Geodesic average distance of five phases in ePBL

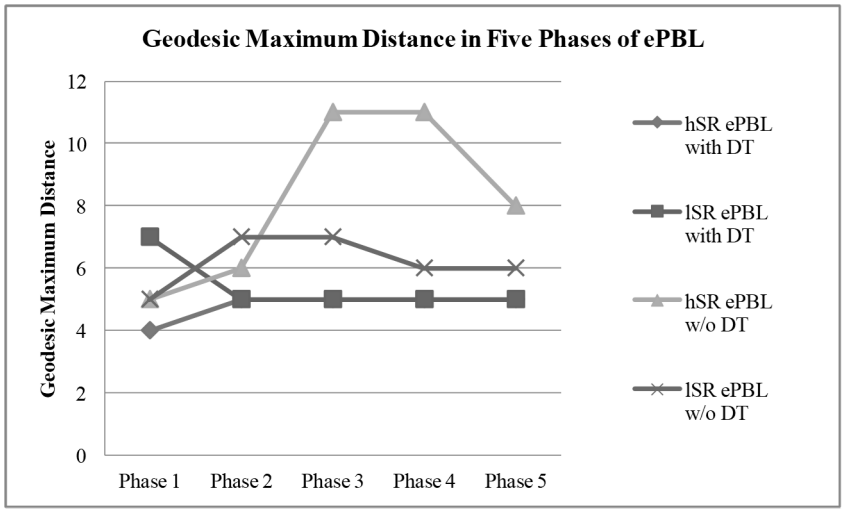

Fig. 3 - Geodesic maximum distance for five phases of ePBL.

Geodesic maximum distance indicates the longest distance between two vertices. Based on Figure 3, group of high and low SR that follow ePBL with DT has the least distance between two vertices. On the other hand, high SR that follow ePBL without DT has the longest Geodesic maximum distance. This result is reflective of the Geodesic average distance i.e. group that follow ePBL with DT shows higher degree of centrality and closeness centrality.

Table 3 - Summaries of social network analysis.

	hSR, ePBL with DT					hSR, ePBL w/o DT					lSR, ePBL with DT					lSR, ePBL w/o DT				
Index	**P1**	**P2**	**P3**	**P4**	**P5**	**P1**	**P2**	**P3**	**P4**	**P5**	**P1**	**P2**	**P3**	**P4**	**P5**	**P1**	**P2**	**P3**	**P4**	**P5**
Vertices	60	86	87	89	91	31	42	44	48	52	35	55	72	88	94	22	36	36	41	41
Unique Edges	112	162	180	185	188	34	48	51	58	63	49	147	171	181	184	24	39	39	48	48
Total Connectors	112	162	180	185	188	34	48	51	58	63	49	147	171	181	184	24	38	39	48	48
Connected Components	1	1	1	1	1	4	2	1	1	1	3	1	1	1	1	3	2	2	2	2
Max. vertices in connected component	60	86	87	89	91	16	22	44	48	52	21	55	72	89	94	15	33	33	38	38
Max. connectors in connected component	112	162	180	185	188	20	24	51	58	63	37	147	171	181	184	19	36	36	46	46
Geodesic Max. Distance (Diameter)	4	5	5	5	5	5	6	11	11	8	7	5	5	5	5	5	7	7	6	6
Geodesic Avg. Distance	2.46	2.83	2.78	2.91	2.91	2.49	2.87	4.50	4.52	4.03	2.49	2.77	2.81	2.80	2.80	2.61	4.02	4.02	3.47	3.47

3.3 Graph of Complete Network to Observe Cohesion and Density of Learners Collaboration

The hypothetical sociogram consists of 31, 36, 34 and 41 learners and relationships among them are represented as lines. Each line represents a symmetric tie, in this case the frequency with which two learners discuss issues related to their project. Figure 3 shows five phases of online PBL. Density is the extent of the connection between learners'. Assuming that the relations are non-directed binary (present/absent) ties, the density measurement is the ratio of reported dyadic ties among one another.

The data of this study are binary and non-directed i.e. either mutual relation is present between learners or is absent. Dense structure exhibit high social closure, indicates learners' tight ties. However, the less dense shows little social closure. From Figure 3, neither the size nor the density of these graphs is exceptional, but unlike the majority of graphs used for this visualisation, they exhibit a mesh-like structure. However, ePBL with design thinking foster tight social closure and the density of the complete network improves for both high and low self-regulated learners. But for pedagogy employing only ePBL (without DT), it shows that regardless of high or low self-regulated type, there is little social closure in the complete network graphs throughout the five phases of ePBL without DT.

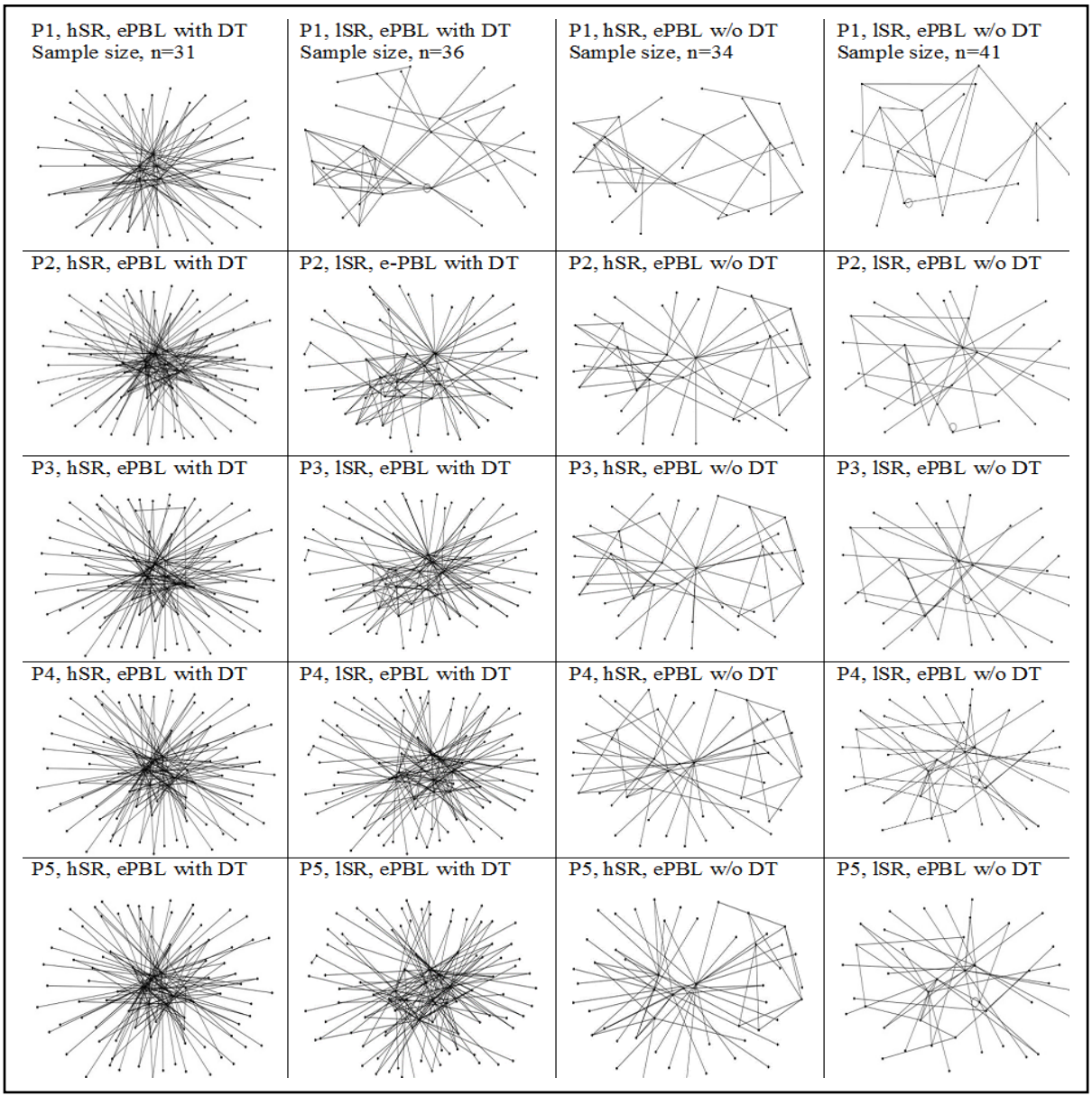

Fig. 3 - Graphs of learners' complete network for five phases of ePBL.

4. Discussions

This study found that, for a group of pre-service teachers who applied design thinking to ePBL, high and low self-regulation learners showed an increase in the network of contacts. On the contrary, this study found that without the application of design thinking to ePBL, a group of high and low self-regulating learners showed little improvement and a constant number of close contacts between the next phases of ePBL. However, compared to learners following ePBL without DT, it was found that learners with low self-regulation showed slight increase in the network of contacts between the phases of ePBL implementation. Thus, an increasing network of contacts indicates that interactions occur in each phase of ePBL. When interactions occur they talk, exchange ideas and better understand the learning that is going on. Therefore, the more interactions, there is a better the online learning process. This is associated to the achievement of the learners. According to the theory of Social Constructivism (Vygotsky, 1978), knowledge and understanding are formed by interactions between individuals and others. Thus, better or increased interaction is likely to create more effective knowledge accumulation and learning performance (Powell and Kalina, 2009).

In summary the following are conclusion made based in terms of social cohesion and collaboration:

i) Learners who follow ePBL with DT are better than learners who follow ePBL without DT.
ii) High self-regulated learners who follow ePBL with DT are better than high self-regulated learners who follow ePBL without DT.
iii) Low self-regulated learners who follow ePBL with DT are better than low self-regulated learners who follow ePBL without DT.
iv) High self-regulated learners following ePBL with DT did not differ from low self-regulated learners following ePBL with DT.
v) High self-regulated learners who follow ePBL without DT are better than low self-regulated learners who follow ePBL without DT.

The level of self-regulation is an important element that influences the achievement of learners in the ePBL environment (Moursund, 2003). In addition, self-regulation is used by learners to become independent in the search for and use of e-learning (Tantrarungroj & Suwannatthachote, 2012). The findings of this study show that whether or not the design of ePBL design thinking exists, high self-regulation learners benefit more than low self-regulated learners when undergoing ePBL. Thus, the findings of this study are in line with DT from previous studies on the effects of treatment interactions on the self-regulation of learners (Cakir, Korkmaz, Bacanak, & Arslan, 2018; Lin et al., 2016; Prayekti, 2015; Tie & Irfan Naufal Umar, 2011; Young, 1996). High self-regulated individuals tend to effectively control and evaluate their learning such as completing assignments within a set timeframe and managing time well. This is consistent with Prayekti, (2015) findings that online learning environments such as ePBL require high self-regulation in problem-solving strategies, and selecting the right resources.

Given that ePBL treatment is implemented through e-learning, the level of self-regulation is one of the factors that determine the achievement of learners. Highly self-regulated learners often spend extra time learning to use online learning materials because they find it challenging (Barnard, Paton and Lan, 2008). Barnard et al. (2008) also explained that highly self-regulated learners always try to allocate sufficient time even when they themselves decide on using online learning time. Barnard et al., (2008) noted that high self-regulation learners constantly evaluate themselves. In this study ePBL has enabled the formulation of online learning to check pre service teachers' understanding. Moreover, high self-regulated learners also interact with their peers to determine their level of understanding and to check whether there is a difference in their learning content.

Meanwhile, the study also showed that regardless of ePBL group with DT or ePBL without DT, low self-regulated learners achieved lower test and post-test scores on the topic of Workshop Safety Management compared to high self-regulated learners. This may be because this group of highly self-regulated Learners has their own ability to act in their learning goals as stated by Pintrich, (2000). Pintrich (2000) argues that individuals with high self-regulation constantly improve their ability to acquire knowledge and skills without relying too much on their teachers. Furthermore, it was also found that a group of low self-regulated learners and who followed ePBL without DT were less effective in maintaining the RBT subject compared to low self-regulated learners and followed ePBL with DT. This is because the mean post-test scores of the RBT subject for low self-regulated learners following ePBL without DT have decreased. This means that ePBL without DT is capable of improving the achievement of low self-regulated learners in the RBT subject post-test but cannot maintain the achievement in the post-RBT subject post-test. This may be due to the absence of ePBL without DT after the RBT post-test.

Although low self-regulated learners and adhering to ePBL with DT were not effective in maintaining the RBT subject but when examined through social media analysis of low self-regulating learners and following ePBL with DT showed a sharp increase in phase indices second to fifth phases of ePBL with DT compared to self-regulated learners and followed by ePBL with DT. The increase in this index indicates that lower self-regulating learners and participating in ePBL with DT are very active in completing the task with the support of design thinking provided (Catanese, De Meo, Ferrara and Fiumara, 2010). Therefore, the failure of the self-regulating learners and following the ePBL with DT may be due to the lack of support provided during the retention period.

Lan, Bremer, Stevens and Mullen (2004) explain that low self-regulation individuals find it difficult to determine online learning strategies. They are less involved in group discussions and do little extra work to master the content (Lan et al., 2004). This may be due to low self-regulation individuals lacking in their ability to act in achieving their learning goals (Barnand et al., 2009). This finding is consistent with Youngs' (1996) study that found that low self-regulated individuals were less likely to ask and less likely to seek help in learning than high self-regulated individuals. In fact, a review of social media analysis also found that low self-regulated learners following ePBL without DT showed lower social media networks compared to low self-regulated learners following ePBL with DT.

The findings also have implications for the role of lecturers in RBT learning activities. It is hoped that through the findings of this study, the role of the lecturer is diminished and the learners play a dominant role in active learning. Lecturers act as facilitators and learners are actively involved in learning. Through ePBL with this DT as well, the lecturers are studying with their learners whether they realize it or not. In addition, by applying the theory of social constructivism (Vygotsky, 1978), collaborations between learners and peers, lecturers and experts in the social environment encourage learners to learn in an active learning environment and to share and exchange new ideas (Jarvis, 2005). The study also suggested the use of ePBL with DT as an alternative method of learning that is capable of overcoming the constraints faced by lecturers where all learning materials can be loaded through online applications that allow learners to download the material anytime, anywhere and wherever they are. In other words, online learning enables lecturers and learners to practice learning while at home and informal information can be referred to repeatedly.

The ever-evolving technological advances in education pose a challenge for future teachers to strive to make changes to appropriate T&L practices before they are placed in schools. Knowledge and skills in using online technology applications are essential for learners as online technology is a key enabler for information acquisition (Zhang, 2014). Through ePBL with DT and ePBL without DT, the knowledge and skills of using online technology are inherent.

Besides, the study also found that the learning activities produced can enrich the knowledge and learning experience of the learners through authentic activities while solving the challenges they are facing as they are in real context. Learners can apply the knowledge and skills to solve the challenges they face by following the steps of the design thinking process with their team members. As such, learners have the autonomy of implementing new ideas into the projects that allow trainers to undertake exploration, construction and presentation of projects (Bouillion & Gomez, 2001). The implications of the findings suggest that the selected technology design project should be able to attract the learners as well as enhance the skills and knowledge competencies that ultimately provide satisfaction and confidence in the achievement of the pre services' goals. The frequency with which learners collaborate online influences the knowledge, understanding and achievement of learners (Chapman, Ramondt & Smiley, 2005). In this study, it is proposed that learners use online technology applications as a tool to collaborate and encourage them to learn with others in a collaborative environment. The integration of design thinking processes not only facilitates the work of the project by the learners but also enhances the learners' interest in accessing Design and Technology related materials available online worldwide. Therefore, the implications of the findings suggest that ePBL with DT in general has the potential to produce knowledgeable learners and to apply the skills in their life.

In this paper, the issue of effectiveness of ePBL with design thinking for high and low self-regulated learners was raised. The findings shows support for ePBL with DT is more effective compared to ePBL without DT in supporting TVET pre-service teachers' teaching and learning.

5. Conclusions

This study examined the effectiveness of online Project Based Learning with Design Thinking (ePBL-DT) versus ePBL without DT (ePBL) on collaboration between learners with high (hSR) and low self-regulated (lSR) on an assignment for Design and Technology subject at IPG, Malaysia. The collaboration is measured through indices of centrality closeness, vertices index and visualisation of group clusters among the four treatment groups. Learners who follow ePBL with DT indicate better scores than learner who follow ePBL without DT. However, the consistency of the collaboration of learners following ePBL without DT was found to decrease when analysed using geodesic distance average and geodesic maximum distance. In conclusion, the results of this study indicate that ePBL with DT is more effective than ePBL without DT in supporting the T&L of the project assignment in Design and Technology topics. The finding of this study implies that ePBL with DT are a combination of pedagogy that helps foster collaboration and learning for both type of self-regulated learner. Hence, the use of these two pedagogies for online learning mode is advisable for TVET pre service teachers.

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