International Journal of Engineering & Technology, 7 (4.21) (2018) 1-6

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Framework of Drone-based Learning (Dronagogy) for Higher Education in the Fourth Industrial Revolution

Helmi Norman [1*], Norazah Nordin [1], Mohamed Amin Embi [1], Hafiz Zaini [1], Mohamed Ally [2]

[1] *Faculty of Education, Universiti Kebangsaan Malaysia Bangi, Selangor, Malaysia*
[2] *Center for Distance Education, Athabasca University, Alberta, Canada*
**Corresponding author E-mail: helmi.norman@ukm.edu.my*

Abstract

The fourth industrial revolution is impacting the world in three megatrends which include physical, digital, and biological trends. Drone technology is gaining more interest from all sectors including the education sector. Drones is one of the technologies in the physical world that has the potential for redesigning education in the fourth industrial revolution. Yet, as the technology is newly made for the public, its' affordances in educational environments are still not fully understood. Hence, the study investigates dronagogy for higher education and develops a framework for dronagogy a learning strategy. The study applies a case study using small autonomous drone integration in using problem-based learning and MOOCs using the pedagogy-space-technology framework. Learning analytics are used for assessment of learning in terms of active learning time while dronagogy was applied as learning tasks. The findings revealed that that dronagogy could be used as a learning strategy in different learning contexts and dronagogy could be used to guide integration of drone-based learning in higher educational settings for the fourth industrial revolution.

Keywords: *Drone-based learning, fourth industrial revolution, pedagogy-space-technology framework, 4IR learning strategy, higher education*

1. Introduction

In the fourth industrial revolution (4IR), the blurring of physical, digital, and biological worlds is affecting the educational landscape. Technological advancements in 4IR such as drones in the physical world, Internet-of-Things (IoT) in the digital world, and synthetic biology in biological world is offering educational affordances that have been never possible [25]. As learners today are digital natives, blending teaching and learning with technology is important to engage them in learning. Yet, merely using technology without well-designed pedagogy may lead to disruption of learning rather than engagement [19]. Design of the "right" blended between pedagogy, space and technology is crucial is ensuring both instructors and learners are empowered during teaching and learning [20].

One of the emerging technologies of 4IR is drones. Drones could be considered relatively new technologies as they have used in the past for military purposes. The emerging aspect of drones are they are available in the current public market, as drones' usage have shifted from military purposes (e.g. for intelligence) to agricultural, passenger and delivery drones [5]. For agriculture, drones have been utilized to monitor tree plantations. In a study by [23], drones were used to gain information on geometric features of agricultural trees for optimization of crop management operations. The drones assisted farmers in terms of three-dimensional (3-D) features such as canopy area, tree height and crown volume that were important information for plantation status. With regards to delivery drones, Dubai created a "buzz" by the launching of the world's first "drone taxi" for passenger transport. [2] reported that the drone can autonomously take passengers and transport two passengers other locations via use of mobile apps [2, 13]. As for delivery drones, several companies such as Amazon are using drones for delivery services. In late 2016, Amazon launched the "Prime Air" service that offers transportation of small goods and products via drones within a maximum air time of 30-minutes (Amazon, 2017). This spurred a discussion of on customer-drone relationship in which service-delivery drones with regards to consumer-brand relationships were studied [17].

Albeit emerging usage of drones in various sectors, the usage of drones in education is still new. Previous studies have shown educational affordances of drones in fields of geology journalism education [10], model-based learning [11], and environmental chemistry [6]. In environmental chemistry, [6] used drones for environmental sampling experiments. The drones were used to find suitable sampling sites in which they could collect samples for their experiments. In addition, drones assisted students in risk assessment – whether the sites where suitable for land exploration and the degree of safety at the potential sampling site. In model-based learning, [11] modeled activities and features of the drones to teach about situational analysis, in which students analyze situations and scenarios (in this case, setting up and flying the drones) and map them to produce mental models. In relation, [10] describe the potential of drones to be applied in geology and journalism education. The former explained that drones could be potentially aerial surveys, field mapping, and monitoring (i.e. dangerous or hard-to-reach locations such as volcanoes and overhanging rocks outcrops). The latter highlighted that drones could be integrated in journalism as newsgathering tools.

Despite all these potential and educational affordances, there are still limited frameworks and models to guide integration of drone-based learning in higher educational settings [6]. Previous research related to framework or models of drones include studies by [9], [26] and [11]. In the study of [9], a framework for collaborative learning was produced by using drones as the subject matter. Here, students were required to design and manufacture drones, and this assisted them in production of drone conceptions. As for [26] study, a project-based learning toolkit was developed for automation and robotics engineering, where a series of activities were designed in development of an aerial robotic system (i.e. drone). With regards to [1] study, they studied on frameworks for internal and external auditing in which they proposed a framework for prototype inventory counts. Although these studies proposed drone-based frameworks, the studies used drones as educational outputs rather than offering frameworks that assist educationists in designing learning environments by integration of drones. Moreover, there are also limited frameworks that link drones to the aspects of pedagogy, space, and technology. As such, in resolving the issues and filling in the gaps, this study investigates the educational affordance of drones (i.e. consumer quadcopters) and develops a framework of drone-based learning for 4IR higher education. The study also links the framework with the design of pedagogy, space and technology for 4IR.

2. The Dronagogy Framework

The proposed framework for dronagogy is adapted from the works of [16] and [5]. [16] proposed a pedagogy-space-technology framework for design and evaluation of learning places. In the framework, all three aspects (pedagogy, space and technology) influenced each other in a reciprocal manner, in which an intended pedagogy could influence arrangement of space, while a space could equally influence what people do in it and influence teaching and learning patterns. Similarly, a learning space could influence opportunities and constraints on a type of technology, while a particular technology could influence how a learning space is utilized by educators and learners. Thus, the study adapts the pedagogy-space-framework and links the framework for framing drone-based learning. The proposed framework for drone-based learning in 4IR Education is illustrated in Figure 1.

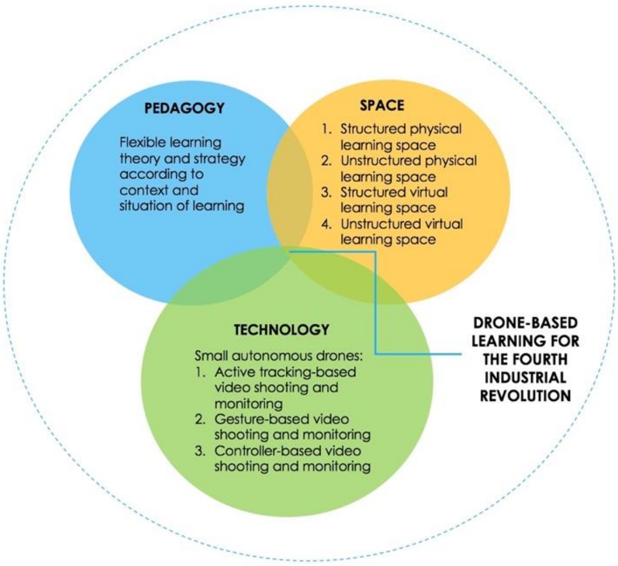

Fig. 1: Framework of drone-based learning for 4IR higher education

Technological aspect

By definition, drones are unmanned aerial devices (UAVs) and are aircrafts that are controlled by human pilots which are not onboard. Drones range from quadcopters, helicopter drones, RTF drones, delivery drones, photography drones and racing drones [5, 9]. This study focuses on small autonomous drones, specifically, quadcopters (or rotorcrafts) that are available in the market for the public. In development of the framework, drone-based learning is linked to the perspectives of pedagogy, space, and technology by [16]. In a review on small autonomous drones, [5] explains that drones have three-levels of autonomy, which are sensory-motor autonomy, reactive autonomy, and cognitive autonomy. Autonomy of drones can be related to robot autonomy, where autonomy is based on their abilities to carry out tasks without human interventions based on aspects such as current state and sensing. At first level autonomy (sensory-motor autonomy), drones can perform high-level human commands (e.g. move to a global positioning system or fly at a given altitude). At the next level autonomy (reactive autonomy), drones are capable of avoiding obstacles, take off, land, coordinate with other moving objects, and maintain a predefined distance from the ground. In the highest autonomy level (cognitive autonomy), drones can carry out simultaneous localization and mapping, recognize objects and humans, plan and learn [5]. Based on the three levels of drone control autonomy, the educational affordances of small autonomous drones can be categorized as follows: (i) active tracking-based video shooting and monitoring; (iii) gesture-based video shooting and monitoring; and (iii) controller-based video shooting and monitoring.

Active tracking-based video shooting is related to video shooting that is performed by the drone on an intended fixated object or area. This is performed by using geolocations and video imagery tracking [8]. Using the active tracking feature, drones video shoot on a fixated target and follow the movement of the target without the interventions of humans using controllers. For instance, drones can be used to video shoot a student conducting fieldwork without the student having to control the drone. Gesture-based video shooting involves human operators using hand gestures to command and control drones as well as give directions of movements. This is done via machine vision techniques using locally on-board video cameras on drones. When a hand gesture indicating an intended direction of drones are given, the drone estimates the angle and distance by the estimated hand direction and face score system [12]. Controller-based video shooting is typically type of video shooting that can be performed by drones. The controller is usually connected via radio or Wi-Fi signals and in some cases connected to mobile phone or tablet PCs for visualization of during video shooting.

Space aspect

The space aspect is defined by [16] as physical learning spaces or places. In relation, [24] elaborated on the physical learning space concept, explaining that learning spaces are on the continuum of two ends of unstructured and structured physical learning spaces. Structured physical learning spaces are spaces that are designed for teaching and learning, such as collaborative teaching and learning spaces. Unstructured physical learning spaces are informal social learning spaces such as "eddy spaces" which are small spaces for learning [24, 21]. This can be further extended to virtual learning spaces, where they can also be categorized as structured and unstructured virtual learning spaces. Here, the structured virtual learning spaces refer to formal virtual learning environments such as massive open online courses (MOOCs) or learning management systems while unstructured ones refer to informal virtual learning environments such as social media and [3].

With regards to drones and learning spaces, drones offer educational affordances in both physical and virtual learning spaces. From physical learning spaces, drones can be designed to be used for structured and unstructured learning environments. In structured learning spaces, drones could be used for outdoor lab experiments and fieldwork. As for unstructured ones, drone features such as active tracking-based video shooting could be used in recording group discussions in indoor or outdoor learning [8]. With regards to structured and unstructured virtual spaces, video shots by drones could be shared in formal and informal spaces such MOOCs and social media.

Pedagogical aspect

In terms of the pedagogical aspect, drones could be used with application of various learning theories and learning strategies. As drones offer interesting educational affordances that could be utilized in different learning contexts, appropriate teaching and learning strategies and theories have to be selected in order to maximize the potential of drones. [5] explains that drones have three-levels of autonomy, which are sensory-motor autonomy, reactive autonomy, and cognitive autonomy. Here, depending on the learning aims, an educator would have to first understand the educational affordance of a drone type (e.g. small autonomous drone) according to the levels of autonomy. This would enable educators to design their pedagogy to suit the educational affordance of drones or utilize drones to suit their pedagogy.

3. Method

Participants

The case study was conducted in an educational technology course at Universiti Kebangsaan Malaysia in a period of five months, from February to June 2018. The course is a postgraduate course that provided exposure on instructional design as well as learning material and task development for blended learning. The course was conducted in blended learning format. The platform used for the virtual learning space was a MOOC on the openlearning.com platform. The MOOC was a self-paced MOOC opened to the public, in other words, anyone, not necessarily a student could enroll in the course. The total number of students currently enrolled for the course is over 650 students.

Pedagogical Design

The pedagogical design applied in the case study was problem-based learning as discussed by [18]. They posit that problem-based learning is defined by three main aspects, which are: the problem, the work process, and the solution. The problem is related to any issues or problems that were intended to be solved while the work process involves processes that were carried out to solve the problem. The solution is the solution designed and developed based on the work process that was conducted. As discussed by [18], defining the three aspects are important in problem-based learning – as to who defines the problem, who organizes and controls the work process, and who owns the solution – between both the educator and learner. In the case study, an overall task was given to learners, where the students were assigned to produce videos related to a given theme. The problem and the work process were own by learners in which learners were responsible to define their research problems, project management and teamwork processes. Meanwhile, the solution was co-owned between learners and educators. With regards to the problem, the educator provided a general rubric for video components, and a general task was given, which was to create a video on the theme of “awareness on the future learning”. The learners were empowered in finding their own topic and research problem that was related to the theme. As for the work process, learners were given total autonomy over management of their learning. Drones were introduced to learners as a potential learning tool and features that included active tracking-based video shooting and monitoring, gesture-based video shooting and monitoring, as well as controller-based video shooting and monitoring. For the solution, learners were required to produce a video that solved the problem identified with the use of drones. The space aspect in this study was the course MOOC as the virtual learning space and physical learning space that included computer labs and fieldwork sites involving drones. The technology aspect integrated were drones, specifically, small autonomous drones, where the drones allowed for active tracking-based video shooting, gesture-based video shooting, and controlled-based video shooting. The brand used of drone used was the DJI Spark that is a mini drone with a mechanical gimbal and camera allowing for intelligent flight control options.

The pedagogical design was applied in three phases, which are the problem phase, work phase, and the solution phase. IIn the problem phase, learners defined their own research problem of their tasks based on the research theme “awareness on the future of learning” (pedagogical aspect). Materials were gathered by using document analysis, in which documents relating to problems related to the community were collected from sources such as newspapers, journal articles, community-based websites and social media sites. Here, the aim was to elicit a real-world problem based on what is happening in the community. This was done via the online collaborative mind-mapping where learners conducted brainstorming over the internet in real-time by using online maps [15]. The mind-maps produced were shared in the virtual learning space, which was the course MOOC (space aspect). An example of an online collaborative mind-map produced by a group of learners in depicted in Figure 2. In this phase, learners also familiarized themselves with drones, in terms of management, safety issues, flight control features, and video shooting techniques (technological aspect). This was important as most of the learners were not familiar with handling and management of drones.

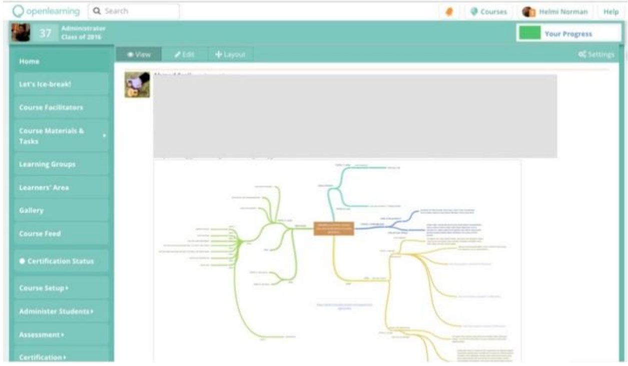

Fig. 2: An example of an online collaborative mind-map created by a group of learners in the course MOOC

With regards to the work phase, learners used drones to create their learning products (technological aspect). Based on the research problems elicited in the previous phase, the learners develop solutions by producing learning products (pedagogical aspect). Based on the problems, learners used the educational affordances of drones which were active tracking-based video shooting, gesture-based video shooting, and controlled-based video shooting. The video shots were conducted in communities based on their research problems (space aspect). With active tracking-based video shooting, learners utilized the features in scenarios that required video shooting on moving objects or focus areas. This feature allowing continuous video shooting on an intended focus areas/object by tracking its' movements, as in Figure 4 and Figure 5. As the study used the DJI Spark drone, four types of video shots were available in the active tracking-based video shooting mode, which were: (i) ascend drones with camera pointing downwards; (ii) fly backwards and upwards with drones locked on an intended focus area; (iii) circle around an intended focus area; and (iv) flying upward with drones circling around an intended focus area [4]. Meanwhile, gesture-based shooting was used for video-shooting without remote controls and controller-based video shooting was used for aerial shots that required high elevation levels.

Fig. 4: A mobile phone connected to the drone remote for viewing and monitoring of the video shots captured by the drone

Fig. 5: An example of active tracking-based video shooting conducted by a group of learners using drones and the different types of video shots afforded by the drone

In the final phase (solution), learners performed video-editing and shared their learning products (i.e. videos) on the course MOOC (space aspect), as shown in Figure 6. The videos were developed in solving research problems that were identified in the problem phase (pedagogical aspect). Learners then peer-reviewed their work and suggested feedback on refinements. These feedbacks were then implemented to enhance the learning products.

Fig. 6: Learning products (videos) produced by learners using drones shared on the course MOOC

4. Results and Discussion

The results are discussed in terms of the learning analytics with regards to: (i) learner geographical locations; (ii) total active students over time; and (iii) three-dimensional data of total active time, total comments and total progress. The analytics were generated by the MOOC and the Tableau Public software.

Learner Geographical Locations

The learner analytics showed the learner geographical locations are shown in cartogram in Figure 7. The learners currently come from 30 countries which covers continents including North America, South America, Europe, Africa, Asia and Australia.

Fig. 7: A cartogram of learner geographical locations

Total Active Students over Time

The total active students over time were also assessed via learning analytics, which is displayed in Figure 8. Analytics from February to June 2018 showed that there were two highest peak of active learning time, which were 87 active students (April) and 65 active students (June). These peaks were caused by the discussion of dronagogy learning activities that was conducted. In the first high peak, the learners discussed on drone video shooting activities, where in the second peak, learners discussed about editing and production of the drone video shots.

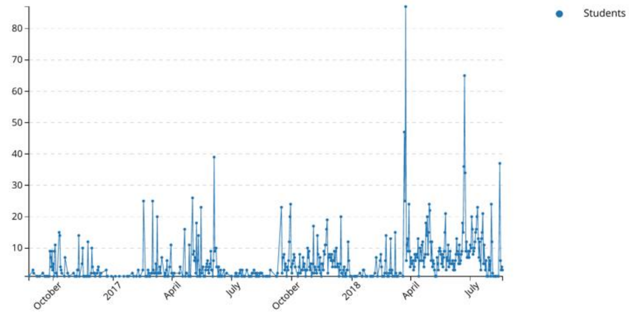

Fig. 8: A mobile phone connected to the drone remote for viewing and monitoring of the video shots captured by the drone

Number of Comments and Likes over Time

Learning analytics were also assessed with regards to number of comments and likes over time (as in Figure 9 where the red line represents number of likes while the blue one represents like over time). Similar to the total active time diagram in Figure 8, there were also two peaks for number of comment and also likes from February to June 2018. The analytics indicated that the two highest peak of likes (red line) were 720 likes and 893 likes, while the highest peak of comments were 203 comments and 237 comments. Interestingly, this was inverse with the total active time, where the highest active time (first peak) had a lower number of likes and comments while the second highest active time (second peak) had a higher number of likes and comments. This signifies that learners were more active in communicating on the subject of drone video editing and production rather than drone video shooting activities.

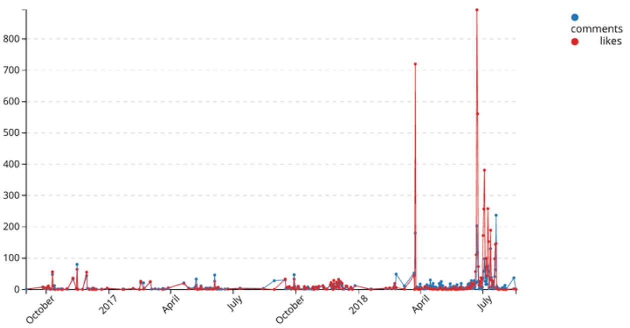

Fig. 9: Number of comments and likes over time

Three-Dimensional Data of Total Active Time, Total Comments, and Total Progress

Three-dimensional data among total active time, total comments, and total progress were also accessed, as shown in Figure 10. The darker colors in the cartogram represents the higher progress over time with highest number of comments, where the highest (in three-dimensional data) was 1 day 16 hours with 100 percent progress and 80 total comments.

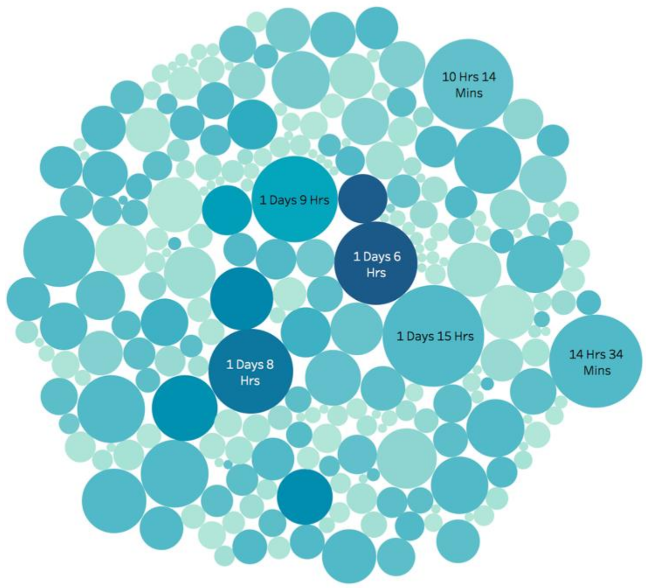

Fig. 10: Three-dimensional data of total active time, total comments and total progress

5. Conclusion and Future Directions

The study has proposed a framework for drone-based learning for higher education in the fourth industrial revolution, which consisted of three main aspects of pedagogy, space and technology. A case study was also discussed in applying the framework in a learning situation, where small autonomous drones' educational affordances were integrated with regards to the technological aspect, while problem-based learning, MOOCs and outdoor physical learning spaces where used in terms of the pedagogical and space aspects. The study also learning analytics with regards to: learner geographical locations, total active students over time, and three-dimensional data of total active time, total comments and total progress. The findings indicated that learners were more active in communication on the subject of drone video editing and production rather than drone video shooting activities.

The limitations and future directions of the study are as follows. First, with regards to drones, the study used small autonomous drones for learning. Utilization of other types of drones, such as helicopter drones, RTF drones, delivery drones, photography drones and racing drones, could offer different educational affordances. Second, the study was conducted with participants who were postgraduates taking an educational technology course. Using undergraduates and applying it to a different field other than social science, for example engineering, could yield in different findings. Third, with regards to the pedagogical aspect, problem-based learning was integrated as the teaching and learning strategy. Application of other learning strategies such as heutagogy or challenge-based learning could be more suitable depending on the learning contexts and could yield in other interesting educational affordances of drones [27, 28, 29]. Finally, MOOCs were used as virtual learning spaces for project discussion and management of learning products. It would be interesting to investigate how other learning environments such as mobile learning and ubiquitous learning environments combined with other 4IR technologies such as mobile augmented reality and interaction analysis tools such as social network analysis could be used in drone-based learning [14, 22]. In sum, it is hoped that the study could be used for educators and researchers interested in the field of drone-based learning.

Acknowledgement

The authors acknowledge the Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme (FRGS) grant number FRGS/1/2016/SSI09/UKM/02/2 and Universiti Kebangsaan Malaysia under Dana Penyelidikan Strategik grant number KRA-2017-008.

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