THE IMPLEMENTING OF CDIO CONCEPT IN THE NKRAFA

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ABSTRACT

The objective of this paper is to illustrate whether implementing the CDIO concept in the Navaminda Kasatriyadhiraj Royal Air Force Academy (NKRAFA) can result in better air cadet performance. Traditionally, the air cadets learn UAVs through several activities including in-class learning, practical training, and also joining such UAV competitions as NKRAFA UAS Contest. However, they could find solutions only for simple missions. The CDIO notion, therefore, was employed in the academy via curricular planning using problem-based learning. The concept has been implemented in the institute since 2015 through the tasks imitated from the actual UAV missions operated by the Royal Thai Air Force. After implementing the CDIO concept, the air cadets can better develop their strategies, as well as form their teams for joining competitions both domestically and internationally. Consequently, utilizing the CDIO concept can result in better air cadet performance regarding UAVs' mission planning. Implementing the CDIO principle can also establish the foundation of the student-learning method that could be more developed in other fields in the future.

KEYWORDS

Air Force, Unmanned Aerial Vehicle, Military Doctrine, Behavioral Change, Standards: 1, 2, 3, 5, 6

INTRODUCTION

Recently, Unmanned Aerial Vehicle (UAV) has been widely used in many domains e.g. freight transport, telecommunication, precision agriculture, military, and so on. It normally refers to a pilotless aircraft that can be deployed on missions that are considered too dangerous for pilots to operate or ones that overcome regulatory concerns. UAVs were originally developed and used for military purposes (Vacca and Onishi, 2017). The first generation of UAVs was "Ariel Target" in 1916. After that, many remote-controlled aircraft followed. With the advancement in technology, there is a growing interest in utilizing UAVs for military missions. It is considered a combat machine that can be used to reduce the risk of the crew. In the first generation, it was more like a surveillance aircraft. However, UAVs today are dangerous weapons that can carry aircraft ordnance such as missiles, or bombs and are used for drone strikes. Moreover, UAVs often carry out tasks that are more difficult and dangerous because of their agility with no life on board to concern with. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers. This makes them easy to use and they are allowing researchers to complete challenging tasks with few simple steps. Therefore, the use of UAVs has gained popularity among educators and researchers around the world in recent years. (Freeman, P. K., & Freeland, 2019)

Navaminda Kasatriyadhiraj Royal Air Force Academy (NKRAFA) is an academy in which air cadets are educated and trained to produce commissioned air officers with knowledge, ability and military leadership for the Royal Thai Air Force (RTAF). The institute's curriculum covers both academic and military studies including theoretical and practical aspects, following the needs of the RTAF especially in the field of aviation (Jantarachotigul, 2020). Thus, an excellent educational framework is required for implementing along with the curriculum so that the air cadets can deal with problem-solving more efficiently and effectively. To this end, the principle of CDIO was brought to test in the NKRAFA's curriculum by firstly introducing in UAV mission training, which is one of key policies of the RTAF. Thus, this paper aims to illustrate whether the implementation of the CDIO concept in NKRAFA can result in better problem-solving performance of the air cadets. The rest of the paper describes the pre- and the post- CDIO concept utilization with the conclusion in the end of the paper.

PRE-IMPLEMENTATION OF CDIO CONCEPT

Before 2014, the UAV concept was delivered to air cadets via class lectures and in-class activities. However, the number of participants in the UAV class was restricted since only 2 out of 7 academic departments offered courses regarding UAVs; Aeronautical Engineering and Mechanical Engineering Department. While the rest rather emphasized other study areas, e.g. Civil Engineering, Industrial Engineering, Computer Science, and Material Science. Meanwhile 2014, UAVs have been received more attention from the RTAF as seen from an introduction of the policy that encourages UAV applications by funding and supporting missions for which UAVs were researched and developed (Royal Thai Air Force - RTAF, 2014). As a result, in that year, the NKRAFA started a scheme that encouraged the air cadets to participate in a UAV competition, calling 'UAS Contest'. This competition has been annually subsidized by the RTAF. In 2014, the participants were mainly from Aeronautical Engineering and Mechanical Engineering Department because they were trained and educated in the UAV domain as mentioned earlier. By joining this UAV contest, the objectives and rules are shown as follows:

Objectives

1. Air Cadets had knowledge and experiences with components and subsystems of the unmanned aerial vehicles (UAVs)
2. Air Cadets were capable of flying UAVs autonomously
3. Air Cadets were capable of planning the flight according to the assigned mission
4. Air Cadets could do the parameters tuning of the flight controller to control the UAVs effectively

Rules

After Air Cadets finished the training to be able to take off and land the UAVs autonomously, the mission of the competition was the following.

1. Split the air cadets into 8 groups and each group consists of 10 cadets (2 cadets from each class)
2. Each group would have to search and identify the targets that were randomly placed on the football field.
3. Each group would receive the coordinate of 24 targets for flight planning. However, each group would need to search and identify only 3 targets that had the number of their group on that target.
4. Each group needed to specify the shape and color of the targets that had their group number on (see Figure 1).

5. Scores of the mission would be based on the correctness of the searched and identified targets and the amount of time spent on the whole mission.

Figure 1. Example of the competition mission layout

Figure 2. Provided UAVs for the competition

Figure 3. Air Cadets' flight test during the competition

After hosting the competition for two consecutive years, post-match results were not relatively satisfactory. Although the air cadets from every department joined the race, the key players were still mainly from Aeronautical Engineering and Mechanical Engineering Department. The participants from other departments were mostly responsible for administrative tasks rather than operating the field missions. As a result, those who were not in the field test did not have any inspiration after the competition witnessed from the post-competition questionnaire. Other activities such as club establishment were also not found after the race. Furthermore, the UAV team members (air cadets and professors) that joined other competitions held by other universities were only from the two mentioned departments. The overall satisfaction in 2014 and 2015 are shown in Table 1. The overall rating is moderate. And there are some negative comments about time-consuming and not having a background understanding.

Table 1. Overall Satisfaction in the year of 2014 and 2015

Year	Number of Response	Overall Satisfaction	SD	Comments
2014	75	3.9	0.51	1. Time consuming 2. Not having background understanding 3. A bit boring
2015	69	3.7	0.49	1. Time consuming 2. Not having background understanding 3. Unrelated to the field of study

COMPETITION WITH CDIO CONCEPT

Due to unsatisfactory feedback from the previous competitions, the CDIO concept was introduced to the staff group. The idea was about providing air cadets the real-world situation of which the cadets have to find the solutions. The academy then decided to change the rules by focusing on the importance of using UAVs in military contents and Air Force missions. Before the race, the air cadets were lectured about UAVs and the instructions of aerial use. Then they acquired the concept of air operations and military doctrine in the next stage.

Procedures and Rules

The process began with the step of giving the air cadets lecture about aircraft design for 10 hours by using the Plane Maker aircraft design aid, which is part of the X-Plane 9 flight simulator. This made the air cadets able to design wing shape, body, tail ring set, ground control and also to simulate this aircraft by using the X-Plane 9 flight simulator. Then the instructor introduced the theoretical concept of flight control for 10 hours including relevant gauges in a flight control system such as speedometer, altimeter, GPS positioning system, and tilt gauge. Subsequently, the air cadets conducted practical studies using the AutoPilot flight control system to configure various connecting the flight control system to the aircraft's motor, wireless communication system, and Ground Control Station (GCS). Once completed, the unmanned flight system could be simulated using the AutoPilot Flight Control System in conjunction with the X-Plane 9 flight simulator to simulate the system and practice proficiency in flight control. Then, the cadets had an opportunity to install automatic flight control systems with the aircraft to test a flight for achieving the positions that were originally planned for the mission.

After instructing how to design and use UAVs, the basic air doctrines were introduced to air cadets. These included: 1. Strategic Attack: Destroy the strengths of the opponent, 2. Counter Air: Offensive Counter Air and Defensive Counter Air, 3. Counter Land: Dominate the enemy's ground environment, 4. Information Operation: Induction or protection of information, 5. Airlift: Transport of personnel and air ammunition, 6. Intelligence: Analyze, evaluate, and interpret news and data, 7. Surveillance and Reconnaissance: Systematic observation of the airspace, 8. Navigation and Positioning: Air Navigation and Coordinate Map, and 9. Military operations other than war: resolving conflict, promoting peace, and supporting civil authorities in response to domestic crises.

By using an air combat simulation model, air cadets were divided into two teams; the red team and the blue team. Each team would have four sub-groups: 1. Intelligence Surveillance and Reconnaissance (ISR Team) – responsible for linking all battlefield functions and information collected from air surveillance to assist a combat force in employing its troops, 2. Command and Control (C2) – responsible for directing all resources to achieve the goals, 3. Squadron (SQRN) – responsible for air attacking and bombing based on the C2 command, and 4. Special Forces (SF) – responsible for searching and rescuing the troops and civilians.

Figure 4. Team with four sub-groups

The scenario arose with the boundary conflict between the two countries. The leaders of the countries stated the negotiation. However, they could not make any commitment that led to the deployment of arm forces. The prime minister of each country approved the deployment of defensive forces and primarily focused on air and missile attack. The C2 team had 10 minutes to plan and establish an air operation and 10 minutes to plot all necessary places (airport, headquarter, school, etc.) on the grid provided. Then the ISR team began reconnaissance operation for the first round (2 minutes) with the flight ceiling that was high enough to avoid the sensor on the ground. The collected data was reported to the C2 team to adjust the flight planning. The ISR team then had another chance for reconnaissance operation. Afterward, the air attack operations were activated. When the team dropped the bombs (flour bags) into the strategic targets such as headquarter and airports, the 20 million Token (created currency) was transferred to that team. However, if the bombs dropped into civilian targets such as temples and schools, 20 million Token was withdrawn. And if the sensor could detect any flight, 10 million Token was withdrawn as well. At the end of the scenario, life bags were dropped to help alleviate the war effects. This stage was called military operations other than war.

Figure 5. Competition Environment

Consequences of the Competition

All air cadets were able to take part in all competition processes. Although some cadets did not have any background on using UAVs, they had choices of participating in Command and Control as well as other field-operated functions. This led them to understand the missions of the RTAF as well as the military doctrine. When they received the given problem, they were keen to run brainstorming as a team. The necessary information (i.e. avoidance ceiling for the ground sensor, resolution of the UAV camera, the weight of flour bag, and so on) were not given to them at first; therefore, they had to figure out themselves by going through series of trial and error. They took every minute as a treasure and eager to find the solution when they faced the problem. This cannot be seen in the usual class environment especially when the students are in the military. The overall satisfaction raised from below 4 to 4.47 (SD 0.63). Surprisingly, comments from the questionnaires were that the competition should have been longer. Furthermore, they requested more participants to join the competition as shown in Table 2.

Table 2. Overall Satisfaction in the year of 2015

Year	Number of Response	Overall Satisfaction	SD	Comments
2015	65	4.47	0.63	1. The competition should have been longer 2. More cadets should have participated 3. The rules should have been well organized to avoid confusion

After receiving good feedback in 2015, the competitions were conducted in 2016 and 2017 continually with the same rules. And overall satisfaction scores were both higher than 4.5. The number of air cadets joining the competition rose to 120 cadets in 2017. The rivalry lasted two days. The first day was for testing and rehearsal and the second day was the competition day. There was an increase in the number of cadets interested in UAVs and wanted to join other competitions held by other universities. This led to the establishment of the NKRAFA UAV Club in 2017.

The Impact of the competition

As mentioned before, the cadets interested in UAV who joined the competition outside the academy were all from Aeronautical and Mechanical Engineering Departments. After the club setting, the number of cadets from other departments has increased gradually. In 2017, the two teams from NKRAFA won the first and second prizes of Autonomous Aerial Vehicle Challenge 2017 (AAVC 2017). Additionally, the team members were from different departments and classes (freshmen, sophomore, and junior). The professors from other departments also joined as team members. This causes the attentiveness of UAVs in the academy. More cadets have joined the club and the number of professors taking part in such activities increased as well as the number of research regarding UAVs as shown in Table 3.

Table 3. Number of cadets, professors and researches relating to UAV

Year	Number of cadets in the club	Number of professors	Number of researches
2017	20	7	12
2018	24	10	12
2019	39	15	17

In 2018, cadets in the UAV club found that there was an international UAV competition called UAV Challenge 2018 held in Australia and they asked professors for permission to join this competition. It was a big surprise since it was a rare occasion that cadets asked to join the competition themselves. However, there was no budget at that time because it needed at least one year in advance to do paperwork. All professors in the academy were firstly asked for a donation, and later on, they received a special budget from the Commander in Chief of the Royal Thai Air Force to join this competition. They contacted the organizer of the event themselves. They also sent an email to the commercial firm to acquire information about the UAV parts shown in Figure 6 (note that the company name was censored). The team contained members from various departments (Aeronautical Eng., Mechanical Eng., Electrical Eng., Civil Eng., and Material Science Departments). They also had all classes (freshmen, sophomores, juniors, and seniors) on the team. Although they won the fourth rank out of 55 qualified teams, they were the only team that received the Airmanship award. This award was judged by the decision-making of the team members.

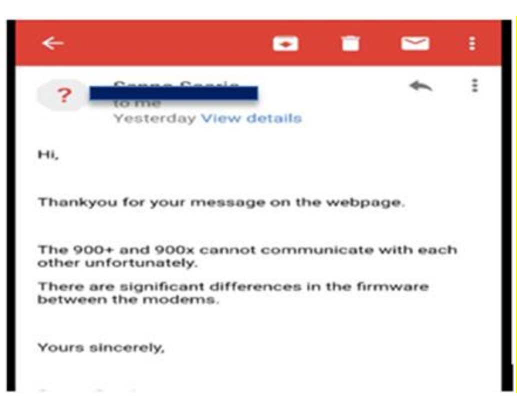

Figure 6. Email sent by cadets

CDIO STANDARDS

To teach cadets, the hardest thing is that they do not have any inspiration to learn because they already know their career path. Therefore, they do everything just enough to pass the criteria. Moreover, a military person will follow the order from his commander by nature that he is taught to be a follower. And cadets have a bit of this nature from military training and the environment (Jantarachotigul, 2020). However, the academy has the mission to produce commissioned air officers that will be leaders of the Air Force. One of the most vital skills for leaders is critical thinking. This contrast makes it challenging to teach cadets at the academy.

When we looked back to what happened, this practice seemed like the first step of CDIO Implementation. Traditionally, problems were given to air cadets with a platform for solving. They did it unintentionally in the same manner as the air cadets did in1960s. Soldiers passed their traditions from generation to generation with very little difference. This implementation can be the first step of behavioral change. The authors have taught air cadets in this academy for more than 10 and 16 years, and we have never seen this scenario before. This transition brings alertness to the academy. The air cadets have willing to study and find the solution themselves, which is the key to educating people.

The academy is now interested in the idea of implementing the CDIO concept by encouraging all departments to carry out the CDIO concept into a new curriculum submitted to the Ministry of Higher Education, Science, Research and Innovation by 2024. The academy has set up a series of problem-based learning workshops since 2018. Based on Self-Assessment of CDIO Compliance projected by CDIO Initiative (2014), this complies with Standard 1 - CDIO as Context. The chief commanders of the academy now understand the need of implementing the CDIO concept in the academy. They also have willing to create an internal environment in which everyone can take part in the program. Not only ones in the academy, but also alumni and stakeholders participate in the program. There are several meetings between the academy and the representatives from every directorate in the air force to evaluate the learning outcomes. The necessary results they need are problem-solving skills, interpersonal skills, and technological skills. They appreciated that cadets could produce microsatellite. This was after the competition and the establishment of the UAV club. Apart from designing and experimenting with UAVs, they expand their knowledge by gathering information about satellites, designing, and producing it by themselves. The academy now recognizes that multidisciplinary education is a need. Therefore, instead of studying military sciences, the new curriculum (2020) allows cadets to choose a group of elective courses to learn (for 15 credits) in three domains: Air Power, Space, and Cyber. These comply with Standard 2 - CDIO Syllabus Outcomes and Standard 3 - Integrated Curriculum.

Beyond the first three standards, the competition is the first step that inspires cadets to think systematically and logically and act intentionally. It relates to the fifth standard of CDIO - Design-Implement Experiences. When cadets conceived the problem, they developed their strategies based on previous knowledge and brainstorming. They have to integrate all technical information and military procedures. After designing, they have to test whether it works in a given situation. We have increased the complexity of the rules every year. Although the rules for 2015-2017 were the same, the detail of objects was different such as the side of the target got smaller. In 2018, the rule for the competition was revised based on the rules that the team encountered when they joined the international competition. These included UAV use in medical function and evacuation.

To accomplish the competition goal, space for cadets to work and test their UAVs is a must. After the first year of the competition, the academy set up the laboratory called CDIO Room for Aviation and Space Technology (as shown in Figure 7) that opens 24 hours, and all cadets can use this room to discuss and exchange their knowledge with others. The activities that occurred in this room are not limited to the projects relating to UAVs. It is student-centered, user-friendly, accessible, and interactive. This creation of new workspaces conforms to the sixth standard - CDIO Workspaces.

Figure 7. CDIO Room

CONCLUSION

UAVs have been received more attention for both private operations and military missions. The NKRAFA encouraged air cadets to learn the UAV concept not only in-class lectures but in field competitions. Thus, the air cadets would receive more understandings of UAV operations via assigned missions. The competition, however, did not convince the air cadets to show their problem-solving ability resulting in unsatisfied performance. The NKRAFA, therefore, has employed the CDIO concept for applying the UAV learning technique, with the hope that the air cadets would able to improve problem-solving performance. By implementing the CDIO concept in UAV competitions, the air cadets have satisfactory results as expected. Therefore, this excellent educational framework is certainly suitable for implementing along with the curriculum in order that the air cadets are able to deal with problem-solving circumstances more efficiently and effectively. The principle of CDIO would be more vital for educating implementation in the future particularly in UAV mission training, which is one of the key policies of the RTAF.

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