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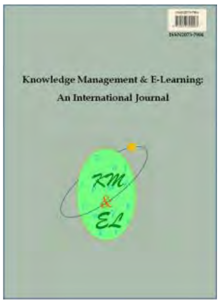

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Future-proofing students in higher education with unmanned aerial vehicles technology: A knowledge management case study

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Abstract: In this paper we report experiences in implementing a new course 'Understanding Drone & Robotics Technology – History, Usage, Ethics & Legal Issues' at the Singapore Management University framed as a strategic knowledge management (KM) initiative in an institution of higher learning aimed at capturing, sharing and creating new knowledge about disruptive technologies such as unmanned aerial vehicles. We posit the new course as a knowledge innovation initiative (similar to a KM-enabled business case in a corporate setting) in support of the university's mission and vision so as to deliver new value to students and to stay ahead of the latest technological developments. In line with a 'normal' KM initiative, we examine how the new learning and teaching initiative was conceived, pushed forward and eventually launched, creating a new multi-disciplinary learning experience for students, instructors and other stakeholders. We explain the knowledge strategy of the course and use I. Nonaka's SECI framework to shed light on selected aspects of the pedagogical approach towards achieving the desired learning outcomes. Overall, the paper intends to make a case for more collaborative knowledge leadership as a strategic enabler of multi-disciplinary knowledge innovation in a rapidly changing higher education landscape.

Keywords: Knowledge management; Pedagogical knowledge transfer; Multi-disciplinary teaching and learning; UAVs; Drones; Robotics

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1. Introduction

The idea for the course 'Understanding Drone & Robotics Technology – History, Usage, Ethics & Legal Issues' (UDRT) course came up as a response to the increasing use of drone technology and robotics in business and society. Drones are unmanned, multi-purpose tools. Their history can be traced back to World War I when the US army experimented with unmanned aerial torpedoes. Nowadays, drone technology belongs to the military arsenal of many nations. Drones serve many purposes (intelligence, surveillance, reconnaissance, traffic and crowed management etc.), and they can be deadly. In business and society, drones are utilised to capture images of people and/or buildings, to monitor agricultural conditions, to take pictures from (or of) hard to reach places, to assess the impact of climate change on rainforests, to film events, to deliver parcels, to survey real estate, to deliver help to heart attack victims in remote areas via a flying defibrillator or to fly life-saving kits to swimmers in emergency situations. In view of their increasing importance in terms of commercial value creation, research & development (R&D) (it is estimated that about $6.4 billion is spent annually for R&D on drones), job creation, innovation (e.g., Internet of Things), new forms of warfare as well as legal/moral-ethical/regulatory concerns, it is imperative that students learn to critically appreciate the multiple and often conflicting implications and consequences of such robotic technologies for business and society.

The course curriculum features eight broad topics: (i) an initial introduction into the evolution of the course, incl. structure, learning objectives, outline specifics and deliverables; (ii) a critical discussion about the social impact of these technologies with reference to industrialization, militarization, urbanization, labor markets etc.; (iii) an overview about the history of automation and drone technology from the industrial revolution and early robots to autopilot features in commercial airliners, factory automation and artificial intelligence in various fields (e.g., medical diagnosis); (iv) a deep dive into the business side of drones and how they are used in smart logistics, agriculture, 3D modeling, security, environmental analysis, news reporting, filming, human rights monitoring etc.; (v) several sessions on the legal & ethical issues of drone technology such as regulatory frameworks and stakeholder-specific policy imperatives, incl. safeguards for dealing with newly emerging/disruptive technology; (vi) a deep dive into the technological modus operandi of driverless vehicles, industrial/home robots and love robots as well as drone related apps and functionalities (e.g., extended camera function); (vii) a hands-on 'Flying Drones' session with a team coordination perspective (hands-on) where student teams need to master a timed indoor obstacle course and a timed team coordination activity; and (viii) a future outlook session with special emphasis on the critical analysis of these futuristic new technologies (Ball, 2015; Birtchnell & Gibson, 2015; Graves, 2016; Mirot & Klein, 2014; Morris, 2015; Zuger, 2016; Wakefield, 2016; Randle et al., 2019).

Small drones are deployed in engineering design classes, e.g., at Canadian institutions of higher learning as discussed by Schuchter (2021) and Wlodyka & Dulat (2015) and also at Singapore's technical universities such as Singapore University of Technology and Design (Tan, Foong, & Hölttä-Otto, 2021). As Morris (2015) has highlighted, journalism programs at the University of Nebraska and the University of Missouri have attempted to adapt drones for civilian use cases such as reporting on natural disasters. Unmanned aerial vehicles (UAVs) have been utilized in educational contexts to facilitate scientific projects such as the mapping of ice algae. They are great learning tools for students enrolled in environmental / biodiversity study programs. Media studies, airborne geosciences (e.g., at the University of Edinburgh) and the use of UAVs for recording historic buildings, monuments, archaeological sites and landscapes are other examples. Our course differs from these use cases because of its multi-disciplinary nature.

The overall objective of our UDRT course is to equip students with core knowledge of drone and robotics technology from a holistic perspective – i.e., technology, business and societal impact as well as ethical issues. Learning objectives include:

- To explain the disruptive potential of drones and robot technologies in business and society, e.g., with reference to logistics, supply chain management, transportation etc;
- To gain practical experiences in piloting mini drones on campus and develop students' problem-solving, collaboration and team-building skills on the basis of hands-on user operations while mastering an obstacle course;
- To articulate some of the legal, regulatory & ethical-moral issues of deploying drones and robots in business and society.

Course design, teaching and learning approach as well as normal class proceedings are conceptually informed by the integrated curriculum model based on an instructional method centering upon a multidisciplinary team of instructors from different areas (business, IT, engineering and law/ethics) as well as multidisciplinary learning materials aimed at enabling learners who belong to the digital natives category (Bennett et al., 2008; Voogt et al., 2013; Gan et al., 2015) to connect knowledge from various relevant subject areas. In line with media richness theory (Daft & Lengel, 1986; Hare et al., 2011; Elwood et al., 2012) and the theory of student centered learning (McCombs & Whisler, 1997), we added a drone flying practicum conducted by students under the supervision of the instructors so that the learners would appreciate some of the drone-related course contents, internalizing important course aspects such as ethical concerns (e.g., privacy matters) or safety considerations. Students who crash a mini drone themselves experience first-hand what regulators have to deal with when makers of innovative 'flying cars' or established firms such as Amazon apply for drone flying permits. In this sense, we believe that a personal drone flying experience is highly effective in communicating and appreciating important lesson contents such as regulatory matters.

Eight Parrot ('Mars Airborne Cargo') minidrones were purchased (one drone for altogether 8 groups which were divided into 2 larger groupings with one classroom allocated each) at a cost of about S$ 1,000. These smaller Parrot drones are 'ultra-compact and easy-to-pilot vehicles which can be controlled with a smartphone or tablet via Bluetooth. The Airborne Cargo drone weighs 1.9 ounces and boasts superior flight stability because of its 3-axis gyroscope and accelerometer'. It has a propeller circuit breaker 'which automatically shuts things down in case of a collision'.

Before the 'formal' flying session, students were briefed about legal-regulatory cum safety matters, and they had the opportunity to watch introductory videos about set-up etc. provided by French mini drone maker Parrot on YouTube. Groups were then given ample time to experiment with the drones in class and to beef up their flying skills. After these segments, each group was asked to nominate 'their best pilot' to become the designated pilot for that group for follow-up, competitive flying activities. The next step included the mastery of three exercises to showcase and further improve one's flying competencies. If they managed to complete these (three) exercises within the time given, they were entitled to further practice with the drone.

In line with the theory of student centered learning, the 1st run of the drone course turned out to be heavy on essay writing. Individual assessment made up 60% of the final grade, comprising (i) class participation (15%); a research paper on the historical and sociological impact of technology (10%), e.g., the role of robots in Japanese society and business systems; a term paper (20%), e.g., to explore how drone delivery systems will shape a 'smart city' by 2025 (Mohammed et al., 2014; Shelton et al., 2015); and a MCQ test (15%). Group assessment made up 40% of the final grade, comprising (i) a minor group project plus presentation (15%); e.g., reflecting about the historical development and future impact of love robots vis-à-vis their general risks, incl. ethical-moral issues; and (ii) a major group project plus presentation (25%) such as an in-depth, critical discussion of the business and legal implications of selected UAV-related technologies (see Tables 2-4, 11 + 12).

1.1. Problem and challenge statements

The core 'problem' the course attempts to address can be summarized as follows: How do disruptive technologies such as unmanned aerial vehicles and robot technologies affect business and society – broadly speaking?

The associated teaching and learning challenge addressed in this paper is as follows: Given the disruptive change in the global economy and job markets, how can universities better prepare graduating students and future-proof them?

To tackle this challenge, we combined our discipline-based knowledge (business management, IT/engineering and law/ethics) to enable students to learn factual information and technical facts more readily, to think critically about the respective 'disruptive' potential of new technologies and to appreciate related legal-ethical concerns and unintended consequences such as intrusive effects. Accordingly, we have framed our new course 'Understanding Drone & Robotics Technology – History, Usage, Ethics & Legal Issues' as a strategic knowledge management (KM) initiative. The term knowledge management refers to the process by which an organization collects, organizes and shares both explicit and tacit information assets and knowledge such as documents, data bases, procedures, and un-captured expertise to achieve organisational objectives such as improving operational processes, sharing of specialist expertise, making better decisions and/or creating new value through innovations (Davenport & Prusak, 1998; Davila et al., 2013; Koulikov, 2011). The core 'knowledge management (KM) challenge' this paper attempts to examine is: How best to capture, share, create and use relevant knowledge and information about the complex subject matter unmanned aerial vehicles and robot technologies in order to achieve the learning objectives?

1.2. Method

Methodologically, we are using a case study approach in the tradition of Yin (1994) with the aim of analytical generalization to apply the SECI knowledge management concept and to share our related practical pedagogy applications. The SECI knowledge creation model (Nonaka, 1991; Nonaka & Takeuchi, 1995) puts emphasis on the conversion of tacit and explicit knowledge into organizational knowledge via four modi: (i) from tacit knowledge to tacit knowledge (S = socialization); (ii) from tacit knowledge to explicit knowledge (E = externalization); (iii) from explicit knowledge to explicit knowledge (C = combination); and (iv) from explicit knowledge to tacit knowledge (I = internalization). Table 8 exemplifies how we managed these critical knowledge transfer activities within the course, with particular reference to students' project works which helped them to acquire, transfer and generate new knowledge and insights in line with the course objectives. In selecting ‘the right cases’, Eisenhardt (1989) posits that qualitative samples should be purposive rather than random. Cases should be selected such that they are likely to replicate or extend the theory. We believe that our new course innovation ‘Understanding Drone & Robotics Technology – History, Usage, Ethics & Legal Issues’ is such a case.

2. Instructors as innovative knowledge champions: Turning a multi-disciplinary learning and teaching vision into reality

2.1. Leadership as an enabler of knowledge innovation

We look at the development and implementation process of our course as a creative knowledge innovation (Davila et al., 2013; Backhouse, 2013), i.e., we utilized existing research and our combined teaching and learning experiences as well as interests to generate new knowledge (i.e., learning contents) that students need in order to meet the overall course objectives.

Table 1
KM enablers

Enablers	Characteristics / Action Items
Leadership Practices and Strategy	• Leadership support and strategic alignment • Capability to leverage on knowledge assets to reinforce org. core competencies
Culture Practices	• A robust culture of knowledge sharing and innovation that endorses communication, learning, collaboration, knowledge reuse and knowledge creation in ways that enhance value
Human Capital Management Practices	• Supportive human capital management functions (e.g., performance appraisal system and reward & recognition policies) on sustainable buy-in and effectiveness of (new) KM tools and systems
Technology Practices	• Relevant KM tools and systems (IT) to collect, store, disseminate and share information • Seamless communication within the organization, users and ext. stakeholders
KM Processes	• Policies, rules and procedures (action steps) to identify required knowledge assets and how they are collected, adapted and transferred across the organization (e.g., content submission process)
Measurement Practices	• Capturing, measuring, tracking and quantifying the value of knowledge assets • Performance usage metrics such as number of ideas generated in one part of the org. and adopted somewhere else

We regard our new UDRT course as an important teaching and learning resource that is critical for future-proofing our students. We created new practice activities (e.g., the drone flying practicum) for the students in support of the envisaged learning outcomes. From a knowledge leadership perspective (Von Krogh, Nonaka, & Rechsteimer, 2012; Rao & Weintraub, 2013), we perceive 'us instructors' as knowledge leaders and innovation champions (see Table 1).

Having taught KM electives at university level for more than 15 years, two of the inventors and instructors of UDRT were aware of the importance of knowledge sharing (Lee & AI-Hawamdeh, 2002; Menkhoff et al., 2010; Abu-Shanab & Subaih, 2019) and collaborative leadership (De Meyer, 2011; Menkhoff, 2020) as enablers of managing knowledge and championing the idea for a new multi-disciplinary teaching and learning opportunity. The champion concept can be traced back to MIT professor Donald A. Schoen (2005) who observed in a 1963 study on radical military-related innovations that they were often driven by extraordinarily engaged persons who played a key role throughout the entire process from ideation to implementation. Champions are the individuals who emerge to take creative ideas (which they may or may not have generated) and bring them alive (Johansson, 2006; Shane, 1994). Their role is critical as innovation implies change, insecurity, resistance and risks.

2.2. Leveraging a community of instructors across different disciplines to cope with new disruptive technologies

One novel element of the UDRT course innovation is the fact that it is taught by a multi-disciplinary team of trusted colleagues from different disciplines (business, IT, law, engineering). The development process was straightforward and relatively issue-free once approval had been obtained from the mighty curriculum committee of the university and the funding approach had been sorted out. The UDRT teaching team can be regarded as a community of interest (Wenger et., 2002) whose members are passionate about disruptive technologies such as UAVs and who wish to expand their knowledge base by interacting with each other regularly, including students and external subject matter experts. Depending upon the intensity of the exchange, COIs can help to advance knowledge and create new opportunities for value creation, e.g., at the intersections of different disciplines – something which has been termed 'intersectional innovation'. Today, there are many innovation challenges which cannot be solved by one scientific discipline alone. Many questions relating to health, energy, climate change and so forth require thinking across different fields.

3. Knowledge strategy of UDRT: Future-proofing undergraduates for the era of the fourth industrial revolution

Besides Big Data Analytics and the Internet of Things, drones, robots and Artificial Intelligence (AI) are the new technologies that are taking businesses by storm. With the dawn of the Fourth Industrial Revolution, much job disruption has taken place around the world. UPS has prototyped a drone-enabled truck that can deliver parcels that used to require two delivery trucks, and it is now driven by one delivery person (Kastrenakes, 2017). Some technology-industry luminaries have openly called for countries and governments to start addressing the negative impact of disruptive technologies on society to properly balance the positive impact of drones and robots on business bottom-lines; Bill Gates has called for a "robot tax" to be paid by robot-owning companies, and Elon

Musk has suggested to provide an universal basic income as a form of society safety net for people who lost their jobs as a result of these new technologies. Recently, the European Union has built upon Asimov's Three Laws of Robotics and pushed forward a new legislation initiative that mandates a "kill switch" for robots (PHYS.ORG, 2017).

Given such tectonic shifts in the global economy and job markets, how can universities better prepare graduating students to learn using a multi-disciplinary approach rather than further relying on the tradition of subject-based learning with a single focus on Literature, History, Law, Architecture, Science, Medicine, Economics, Engineering, etc.? How to successfully convert students so used to subject-based learning into competent graduates who are relevant and ready for the Fourth-Industrial-Revolution workplace? Our course UDRT addresses this issue and provides a knowledge-based solution (see Fig. 1).

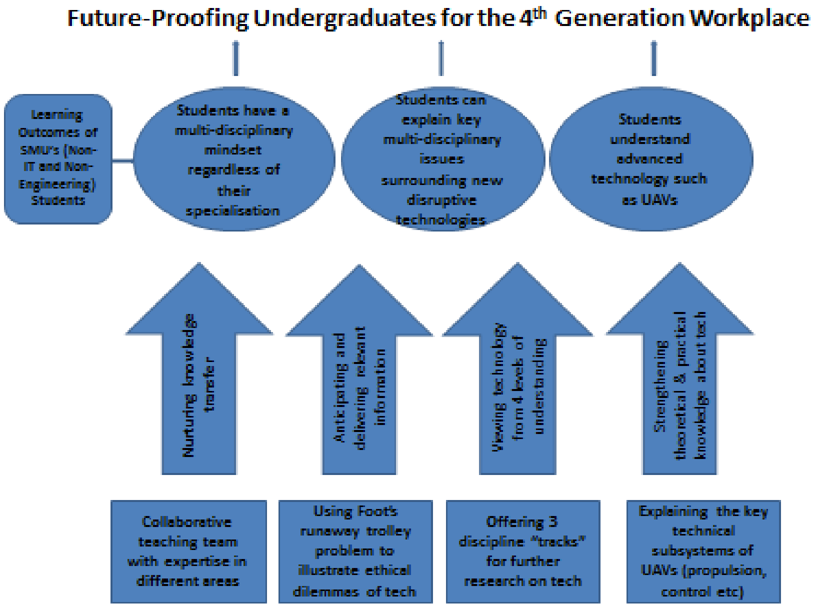

Fig. 1. Knowledge strategy of UDRT

To achieve the learning outcomes of UDRT such as the development of a multi-disciplinary mind-set amongst students regardless of their specialisation as illustrated in Fig. 1, the course is built upon a particular knowledge strategy with four thrusts: (i) nurturing knowledge transfer amongst students (and instructors) through project works, (ii) anticipating and delivering relevant information to all users, e.g., through lectures, (iii) helping learners to view technology from different levels of understanding, and (iv) strengthening learners' theoretical and practical knowledge about robotic technologies.

Key propellants included (i) a collaborative, multi-disciplinary teaching team (COI) from different schools with expertise in business, law/ethics and technology, (ii) the use of relevant pedagogical approaches such as Foot's runaway trolley problem to illustrate the ethical dilemmas of advanced technologies such as autonomous UAVs or cars, (iii) the availability of 3 different discipline "tracks" for further technology research, and (iv) technical explanations pertaining the key technical subsystems of UAVs such as propulsion or control.

3.1. Examples of pedagogical knowledge transfer strategies used

3.1.1. Project work

Group projects represent a core element of the knowledge transfer process in UDRT. Group assessment makes up 40% of the final grade, comprising (i) a minor group project plus presentation (15%) and a major group project plus presentation (25%). Each project group comprises between 5-6 students. The topics are to be taken from the "vertical" domain areas as illustrated in Table 2.

Table 2
Vertical domain areas for group project topics

Home/Companion Robots	Driverless Cars	Robots (space exploration)
Robots (automobile factories)	Robots (car & bike parking)	Robots (intelligent speech)
Robots (other industries)	Military Drones	Robots (recreation)
Love Robots	Commercial Drones	Robots (journalism, events)

For their minor group projects, students are requested to do research on the assigned topic (one of the "vertical" domain areas) and elaborate on the following areas: (a) historical development, (b) overview of the technology used (in layman's terms), (c) examine what can go wrong with the technology and possible impact, and (d) explore the legal and ethical-moral issues. A simple example is shown in Table 3.

Table 3
Examples of minor group project topics

Vertical Domain Area	Historical Development	Use of Technology	Tech Failures & Impact	Legal, Ethical, Moral Issues
Driverless cars	Cruise control proximity warning (for parking)	Digital image processing Electronic throttle control	Self-driving car fatalities due to safety blind spots	Trolley problem of whether to sacrifice one person to save a larger number

Each group is given 15 minutes to present their findings in class. No report submission obligation but students are required to add brief speaker notes of about 50 words to each slide of their PowerPoint deck with relevant content.

While Project #1 (minor) covers the "vertical" domains, the focus of Project #2 (major) is related to the "horizontal" considerations. Students have to select three "vertical" domains. They also need to choose one of the following "horizontal" areas to focus on technology, business applications, and social/legal/ethical-moral issues. A simple example is shown in Table 4. During their final presentations, students are expected to explain each item in detail, e.g., by answering questions such as: *How does* *touch-friendly e-skin work? What does understanding human speech involve? How to achieve real-time uninterrupted video transmission?*

Table 4
Examples of major group project topics

Horizontal Domain Area	Home/Companion Robots	Military Drones	Love Robots
Technology	Accurate speech to text conversion	Very accurate positioning	Touch-friendly e-skin
	Understanding human speech	Real-time video transmission	

Each team is required to do a 15-minute presentation in class in Week 13 and to include brief speaker notes of about 50 words for each slide with content in their power point files.

3.1.2. Ethical thought experiments

A key pedagogical approach utilized in UDRT to shed light on the multi-disciplinary issues surrounding new technologies in an era of the Fourth Industrial Revolution such as advanced driverless vehicle technologies (when mature and fully deployed, they will take over the role of the human driver) and associated ethical issues centres around the Trolley Problem (see Table 2). A typical related scenario discussed in class includes a driverless vehicle with a hardware failure that has totally lost control of the brakes; a young child who throws a tantrum, breaks away from her parent and dashes across the road five metres away from the driverless car; on the kerb next to the car is a group of five elderly persons having al fresco afternoon tea at a sidewalk café table. In such a situation, should the car go straight and knock into the young girl, or should it swerve and crash into the group of five elderly persons? One might argue that the car should go straight because the young girl is at fault; another person might propose to give the little girl a chance at life and program the computer to swerve the car since the five elderly persons have lived quite long lives. Before the computer controlling the driverless car can be programmed to "make such a decision", human society must first agree about a solution. The ethics debate is still on-going, and a solution is not going to be found any time soon because the ethical dilemmas are complex (Chipman, 2015; MIT Media Lab, n.d.).

Is the scenario presented above a social science problem only? Certainly not! Is it a computer science problem only? No. Or think about the case of a severe injury involving a driverless car, and the victim who wishes to take legal action. Should the victim sue the owner of the driverless car, the car manufacturer, or the company that produced the software that drives the car? That we cannot sufficiently answer these questions at this point in time is not surprising. Regulatory and legal-ethical solutions almost always lag behind risky technological developments.

Ethical dilemmas pertaining new technologies as outlined above are traditionally studied by social science and law students only. They are usually not well covered in computer science or IT schools. Engineering and IT schools typically cover driverless-car related topics like LIDAR, signal processing, and pattern recognition (which are usually not covered in law and social science classrooms). Business students are used to calculating the ROI that results from the deployment of drones, robots, and driverless-truck technologies, but they may not be deeply familiar with how the safety software works or how onboard computers can be protected against hackers. How relevant is drone usage for Accountancy and Economics undergraduates who were also enrolled in UDRT (see Table 5)? Designing 12 weeks of meaningful learning activities about drones, robots and AI aimed at engaging a group of very diverse students and better prepare them to face the uncertainties of their future workplace was a key challenge the instructors faced when UDRT was first taught.

3.2. Facilitating technology learning in a diverse classroom

Table 5 shows the diverse student profiles according to their major specializations for the first and second runs of this new module.

Table 5
Student profiles

Discipline Area	Run 1	Run 2
Accountancy	5	4
Business	15	10
Economics	6	4
Law	5	9
Information Systems	12	11
Social Sciences	1	3
Exchange	1	3
Total Class Size	45	44

Students who chose to study non-IT and non-engineering disciplines do so for a variety of reasons – they are stronger in English, they do not have a strong Mathematics foundation, or they simply have a better aptitude for other subjects. Given this backdrop, instructors must facilitate learning about advanced technologies without using jargon so as to succeed in tickling the imagination of a group of undergraduates most of whom do not major in IT and engineering. How can the learning gaps for each category of students be bridged so that they get maximum value at the end of the study? How to make technology jargon understandable to the layperson and to transfer important knowledge without frustrating them?

One approach we used at the beginning of the course (week 1) in order to tackle such issues was to explain to the students in class that technology can be viewed from four levels of understanding as indicated in Tables 6 and 7 below.

Table 6
4 levels of technology understanding

Level	What the Level Means
Clueless	I do not know what it is / what it is used for.
Black Box	I know how to use it, but I do not know how it works.
How It Works	I know how it works, but I do not know how to build it.
How To Build It	I know how to design and build it.

Table 7
Examples of term paper topics (Technology Track)

Student's Specialisation	Term Paper Topic
Law	Explosive Ordnance Disposal (EOD) Robots
Social Science	Smart Speaker systems (e.g., Google Home)
Business	Unmanned Aircraft Systems (UAS) Traffic Management
Accountancy	Security patrol robots

Using the analogy of a motorcar, students with driving licenses were asked which level of understanding they had; and most arrived at the conclusion that they understood the motorcar at the Black Box level – how to pump fuel, turn on windscreen wiper, change a flat tyre. We next went on to explain the four levels as applied to common technologies.

The Instructor used the Mobile Phone as an example to explain to the class in detail "How it works" – how limited frequencies resulted in the design of the cellular system, cell towers and base stations, why dropped phone calls happen (e.g., when cell capacities are exceeded), how mobile phones work when the user is in an underground road tunnel, or in the basement of a shopping mall, how Telco A's subscriber is able to connect and talk to his friend who subscribes to Telco B and so forth. He also highlighted that at an introductory level, internet research and watching relevant YouTube videos are useful approaches to broaden one's basic understanding of technology. Regardless of their academic backgrounds, this approach helped to put most students at ease and to make them comfortable with handling technology knowledge for the next 12 weeks.

For the individual Term Paper assignment, students were given a choice of three tracks (Business, Legal/Ethical and Technology) in order to select their preferred Term Paper research topic. Three quarters of the class of 44 students choose the Technology track even though only 25% of the students were from the School of Information Systems (SIS). This is a proxy for the comfort level of the non-technology students when faced with a technology research topic. Table 7 shows samples of the topics chosen by the technology-track students who did not come from SIS.

Table 8 presents some of the strategic pedagogical knowledge transfer activities of UDRT with particular reference to students' project works and the 4-level tech framework discussed earlier in form of I. Nonaka's SECI framework (1991). It sheds light on how knowledge was acquired, transferred and newly generated amongst the course participants.

3.3. Provision of UAV engineering knowledge

Understanding the opportunities and practical limits of UAV technology requires engineering inputs. To ensure that students appreciate this important aspect of the subject matter, an attempt was made to reach out to a colleague from Singapore University of Technology and Design (SUTD) who kindly accepted the invitation to become an informal member of the UDRT teaching team. The formalisation of this arrangement is deemed necessary to further enhance students' course experience and delivery quality.

UAVs are intricate machines comprising of mechanical and electronic components bounded together using computer programming. So even though they are fairly complex machines, they can be broken down into smaller and more comprehendible subsystems. This is crucial as appreciating the potential, capabilities and limitations of UAVs requires a fundamental understanding of the components and technologies that produce the subsystems, such as propulsion, navigation, sensing and control. With this knowledge, students can understand theoretical and practical limits of current UAV technology.

Table 8
Use of SECI framework in UDRT

SOCIALISATION Tacit → Tacit	EXTERNALISATION Tacit → Explicit	COMBINATION Explicit → Explicit	INTERNALISATION Explicit → Tacit
By working in diverse project teams of 6 persons, each student contributed varying amounts of prior knowledge (legal, ethics, business, IT, economics, social science). Within the social setting of the team project, students shared their prior knowledge with other team members to 'put everyone on the same page'.	After dividing the presentation scope into logical sub- topics, each student was assigned one or more sub-topics to work on. For their respective sub-topics, each student had to do basic research and draft the presentation materials.	While working on creating the in-class presentation materials for the team project, students created their own respective versions of the (sub-topical) content. To ensure coherency, each project team had to appoint one or more information integrators to ensure a seamless final product. These integrators had to read everyone's explicit contents and to combine them into the final set of (explicit) materials for presentation.	Using the 4-level framework for understanding technology, each student did research (utilizing explicit knowledge) on their respective term paper topic. Students translated new knowledge obtained from course-related resources and the Internet into credible term papers.

While UAVs refer to a generic class of aerial vehicles, they have often been directly associated with multi-rotors, specifically quadcopters due to the widespread availability and simplistic design. A quadcopter only consists of four moving parts, the four motors and propellers. However, there are in fact many types of multi-rotors: mono-rotors, duo-copters, tri-copters, quad-copters, hexa-copters, octo-copters, etc. In addition to multi-rotors, helicopters and fixed wing crafts are also viable platforms for UAVs although they are more relatable to manned and commercial aviation. While in flight, a multi-rotor UAV has 4 degrees of freedom: Altitude, Roll, Pitch, Yaw. By applying the mathematical principle of systems of equations, at least 4 independent propulsion/actuation systems are required. This is the fundamental reason why most multi-rotors have 4 rotors. Additional rotors can be added for increased payload capabilities and redundancy/safety so that in the event of propulsion failure, the multirotor can still be controlled in the air. Depending on the desired use cases for UAVs, understanding these design options is important for the successful implementation and adaption for all kinds of commercial applications.

The next important aspect is how UAVs achieve controlled flight with four motors (for quadcopters). This can be easily relatable to the fundamental laws of physics: specifically, Newton's Laws of Motion. Perceiving altitude control is the most straightforward as increasing or decreasing all the thrust for all 4 motors would gain or losing altitude. Pitching and rolling (going forward/backward and sideways) is slightly more complex but can be easily understood if connected to a playground see-saw where differential thrust from 2 sides of the UAVs provide a differential moment to tilt the multi-rotor to a specified direction. Arguably the hardest to comprehend is the yawing (or rotation) motion, which requires an understanding of conservation of momentum. But a simple experiment with a swivel chair will allow students to experimentally understand how changing rotation speeds of different rotors can produce a yawing motion. These simple exercises would allow students to understand quickly how UAVs (in this case quadcopters but can be extended to any UAV) achieve controlled flight. In modern UAVs, stabilizing of UAVs is performed automatically using electronic flight controllers.

A UAV also comprises a multitude of electronic and mechanical parts. For each motor that drives a propeller, a dedicated electronic speed controller (ESC) is required. This component converts electrical signals from the flight controller and applies appropriate signals to the coils in the motors so that it operates at the desired rotation rate (and hence effective thrust) for each motor. At the heart of the UAV is the flight controller (FC) which provides for self-stabilization of the UAV by using its onboard sensors (gyroscope, accelerometer and magnetometer) to determine the current pose of the UAV and maintaining a stable pose in presence of disturbances such as noise. For remote control operation, the flight controller would have to be connected to a radio receiver that will allow a human operator to remotely pilot the UAV using a radio transmitter. In autonomous operation, a GPS receiver as well as telemetry radio will be mounted and connected to the FC. It is also important to know that the entire aerial craft is powered by a battery which provides power to all the electronics and the propulsion system. These batteries are typically lithium-polymer batteries which have very high energy density and can discharge large amount of energy quickly. Great care must be taken when operating these batteries. Newer platforms utilize cameras onboard of these UAVs for gesture control and feature additional proximity sensors to detect obstacles and prevent collisions.

How these UAVs are designed and fabricated has a big impact on commercial viability. For generating and testing prototypes, a variety of rapid prototyping processes can be used: 3D printing, laser cutting and water jetting. 3D printing is an additive manufacturing approach where materials (usually plastics) are added to create the final part. Laser cutting and water jetting are subtractive manufacturing approaches where material (metal, plywood, carbon fibre) is slowly removed from a material stock to obtain the desired size and shape.

Different approaches have both advantages and disadvantages: 3D printing can produce highly intricate shapes, but the outputs are not as strong as traditional parts made by using subtractive manufacturing. A more common approach is to employ a hybrid approach where different components are obtained using a variety of fabrication approaches. For example, the main fuselage can be created from water jetting carbon fibre to obtain an extremely strong and rigid lightweight frame, and 3D printed parts can be used to provide interconnecting parts that hold the various parts of the UAV together.

In summary, like most systems, UAVs are bounded by a set of physical laws which students should be aware of so that they can propose use case-related solutions that are physically realizable. To generate new applications for UAVs, it is best that students are made aware of the critical components that make it fly as well as to get a first-hand experience of flying an actual UAV remotely. In addition, the manufacturing processes should also be taken into account as some processes are not scalable and usually employed only during the prototyping stage.

3.4. What students think about UDRT

Student comments do support the plausibility of the arguments made above. They range from ‘should be made compulsory to all students’ to ‘love the course though slightly heavy on the assignments and projects required’. Participants felt that the course is very interesting and effective in enabling them to understand more about drones and robots. They also appreciated the opportunity to fly a mini drone physically. A site visit to a robotics centre was perceived as informative and useful in helping them ‘to understand AI better’. Another student felt that the course was fun and exciting, exposing learners to very different learning concepts and ideas, and that more such modules should be offered in future. Students acknowledged that the course topics are ‘still not really understood by many’ and felt that ‘the in-class discussions and the instructors’ insights contributed to a better understanding and grasp of the topic’.

In terms of suggestions for further improvements, some students lamented about the usefulness of the final quiz (suggesting replacing it with a ‘not too overwhelming’ commentary report) and argued that the instructors should provide more practice questions for the quiz so that they know what to expect. Others expressed concern about the importance of having a ‘unified’ presentation assessment approach across all instructors so that ‘students coming from other schools who may not be experienced in certain fields (e.g., coming up with a business proposal or understanding laws or the technological hardware) are not disadvantaged’ when being assessed.

To address such grading related anxieties, we make it a point to clarify all the requirements and what we expect from each component at the beginning of the course. We also explain the scoring guide (rubrics) we use to evaluate students in addition to regular consultation sessions (see Tables 10-12).

3.5. Learning outcomes

In terms of learning outcomes, course evaluation metrics and data suggest that the course design proved to be effective in enabling students to critically evaluate the multiple and often conflicting implications and consequences of drone and robot technologies in business and society. Students managed to develop several use cases of these emerging technologies and demonstrated (i) how they can produce new value creation opportunities in business and society, and (ii) the ability to critically apply moral-ethical perspectives to tech-induced problems. They succeeded in spelling out the competing, and often contradictory concerns that can arise from the development and use of a disruptive technologies related to UAVs and robots (e.g., runaway A.I.) as part of their project assignments as indicated by the classic clash between utilitarianism and deontological ethics (Laakasuo & Sundvall, 2016).

In terms of measuring evidence of learning, several direct and indirect measures were used as indicated in Table 9. Direct measures such as quizzes, grades for class projects and opinion editorials were aligned with the intended key learning objectives for the course in order to provide concrete evidence that learning has occurred, while indirect measures such as the amount of class time spent on group projects (outside the classroom) or course evaluations point to possible learning outcomes.

Table 9
Evidence of learning

Direct Measures (provide concrete evidence that learning has occurred)	Indirect Measures (point to possible learning outcomes)
• Class participation • Quizzes • Grades for class project presentations, documentations, and opinion-editorials	• Amount of class time spent in group projects (outside the classroom) • Course evaluations • Course grade distribution

Several assessment rubrics were shared with the students prior to class as part of the course outline (range: A = ‘Exceeds expectations’ to C = ‘Below expectations’) to put them at ease with regards to class participation, the writing of opinion editorials (see Table 10) and overall group project quality expectations.

Table 10
Rubrics for opinion editorials

A Grade	B Grade	C Grade
• Extensive research work done. • Very good articulation of the scope. • Excellent and thorough analysis. • Excellent writing style that makes reading very enjoyable. • The open editorial has a very good (catchy) headline and makes a point clearly and persuasively.	• Sufficient research work done. • Clear articulation of the scope. • Good analysis. • Good writing style that gets the message across clearly. • The open editorial gets to the point and has a good headline.	• Partial research work done. • Content barely covered the intended scope of the opinion editorial. • Average analysis. • Writing style makes the open editorial difficult to read. • The open editorial is not getting to the point and not worth the reader’s (valuable) time.

Table 11
Rubric for group project

A Grade	B Grade	C Grade
• The research work is very detailed and complete. Coverage of the TEBSLE issues is excellent. • Excellent analysis at a highly professional level which touched on all the relevant issues of the topic. All major and minor key points were well covered. • Very engaging presentation that greatly captivated the interest of the audience.	• The research work is mostly complete. Coverage of the TEBSLE issues is good. • The analysis was done at a detailed level that touched on the important issues of the topic. Major key points were covered; some minor points were missing. • The presentation was done in an interesting manner that engaged the audience most of the time.	• The research work is incomplete. Coverage of the TEBSLE issues has several missing items. • The analysis was done at a superficial level that rarely touched on the deeper issues of the topic. Some important points were missing. • The presentation was uninteresting and could not effectively engage the audience.

Note. TEBSLE = Technology, Ecosystem, Business applications, Social, Legal and Ethical-moral issues

A customised group project assessment rubric (ranging from ‘Exceeds expectations’ to ‘Below expectations’) aligned with the intended key learning outcomes helped to measure goal attainment and served as a grading decision tool. This rubric was not shared with the students in written form as there were concerns that it might become a sort of creativity blocker in view of widespread ‘grade anxiety’ amongst students. Table 12 presents extracts of this scoring rubric.

Table 12
Assessment rubrics for group projects

Evaluation Criteria	Level 1 (below expectations: 1-3)	Level 2 (meets expectations: 4-6)	Level 3 (exceeds expectations: 7-10)	Score
A. Analytical thinking capacity and identification of challenges related to technological transformations				
Ability to identify and assess the disruptive potential of drones, robot technologies and digital transformation in business, e.g., with reference to smart(er) and more economical delivery modes (UPS case).	Not able to identify, explain and assess transformation opportunities and challenges faced by the business organisation(s) studied (e.g., safety-related, regulatory challenges).	Transformation opportunities and challenges faced by the business organisation(s) studied have been satisfactorily identified, explained, and assessed.	Transformation opportunities and challenges faced by the business organisation(s) studied have been identified, explained, and competently assessed.	
B. Ability to conduct a deep study into one product/domain (e.g., home robots or driverless vehicles), covering relevant critical issues such as regulatory concerns				
Ability to describe how the technology works in terms of business and operational applications as well as to critically assess the organisation’s status and operational strengths within its ecosystem. Ability to critically reflect about related privacy and regulatory concerns.	Unable to dive deep into the various (often conflicting) implications of emerging technologies such as UAVs or robots.	Student project is sufficiently in-depth and detailed, covering all the important topical course content issues of the chosen emerging technology.	Student project dives deep into the various (often conflicting) implications of the chosen emerging technology, covering all the important topical course content issues in a manner that is not only interesting to read but also novel and inspiring.	
C. Recognition of / sensitivity to ethical issues raised by the technology concerned, including the ability to propose viable safeguards and measures to address them (e.g., fatal collisions of autonomous vehicles)				
Ability to identify and critically reflect about related social issues and to suggest possible remedies (e.g., retrenchments, retraining, universal basic income) as well as legal and ethical-moral issues.	Lack of recognition and sensitivity to ethical issues. Safeguards and measures are not well thought through and explained.	Adequate recognition and appropriate sensitivity to ethical issues. Safeguards and measures are appropriate and potentially workable.	Strong and nuanced recognition and appropriate sensitivity to ethical issues bearing in mind the uniqueness of the technology in question. Demonstrates keen understanding of safeguards and measures while being aware of their limitations and pitfalls.	
Subscores				
			Total Score :	

3.6. Instructors' reflections

Over time, the course design evolved to become more streamlined. During the first run, there were some overlaps in content between the instructors as can be expected in a multi-disciplinary course. For example, one cannot discuss drone applications in the real-world without highlighting issues and concerns involved in some of the use-cases (e.g., privacy concerns when UAVs are used for crowd monitoring purposes). But over time, we learned to keep overlaps to a minimum and describe only what is absolutely relevant for particular use cases. As for content delivery, the team of Instructors had varying styles and that provided a welcome variety for the students; for example, the ethics part of the course should rightly be taught with much seriousness as ethics could involve life-and-death implications; whereas the technology part of the course can be taught in a slightly more light-hearted manner.

This is a course that has been both invigorating and inspiring from course design to delivery. The field evolves relentlessly but the "answers" to the ethical big questions remain resistantly immune to clear answers. As such, the aim is to provide students with the thinking and analytical scaffolding to work out the answers for themselves. Ultimately, it is about making the "right" decision based on their unique considerations and circumstances from an individual, organisational, and societal perspective. The student must also know that there is often no perfect or right answer and that they must be aware of stakeholders' concerns, especially their rights, interest and power.

Student engagement in an era of rapid digital transformation is critical for learning effectiveness (Handelsman et al., 2005). Given the multidimensional nature of the engagement concept in terms of skills engagement, participation/interaction, emotional engagement etc., getting students successfully involved in a course that is taught by several instructors from different discipline areas is not that easy. While we are trying to foster a safe learning environment for collaborative learning in every new course run, several students continue to express Angst about 'fair' grading during the post-course evaluations – something which can derail attempts to impart cross-disciplinary knowledge into them.

An open question is whether university instructors are sufficiently prepared (and rewarded) to appreciate lines of connection between multiple disciplines, including mastering the difference between multidisciplinary (instructors from different disciplines are collaborating, each making use of their disciplinary competencies) and interdisciplinary teaching. The latter implies the need to integrate and synthesize concepts, knowledge, and analytical approaches from different disciplines as well as the humble insight that instructor professional development is critical to acquire adequate technological knowledge and skills to integrate new technology trends (e.g., virtual reality) into teaching practice (Hu et al., 2021). It is fun to make the transition from intradisciplinary (working within a single discipline) to multidisciplinary (and eventually interdisciplinary) teaching and learning work with trusted, collaborative and knowledgeable colleagues. Without continued enthusiasm, such innovative endeavours are doomed to fail unless the organisation really walks the interdisciplinary talk.

4. Conclusion

In this paper, we shared experiences in developing and implementing a new knowledge-intensive course with emphasis on emerging technologies such as UAVs and robotics. Framed as a case of collaborative KM in an institution of higher learning, we argued that novel multi-disciplinary course initiatives which focus on new technologies can be instrumental in helping students to appreciate how the Fourth Industrial Revolution embeds itself in business and society at large and to internalise the importance of a multi-disciplinary outlook in a volatile world characterised by volatility, uncertainty, complexity and ambiguity. The innovative course initiative UDRT which we introduced and examined in this paper helped both students and involved Faculty to capture, share and generate important new knowledge about disruptive technologies related to UAVs and robots. This in turn helped both sides to better appreciate how these technologies do actually function and their potential impact on business, society and us people. The trial runs of the new course initiative helped to streamline learning goals, objectives and outcomes as stipulated in Table 13.

Table 13
Learning goals, objectives, and outcomes of the course

Learning Goals	Learning Objectives	Learning Outcomes
To develop competencies related to the historical evolution of UAVs (drones) and robot (digital) technologies, including the critical analysis of contemporary use cases of such novel technologies in logistics, supply chain management, transportation etc.	Students are literate about new technologies related to drones and robot (digital) technologies. By doing research on the workings of the respective technology, they internalise the basic technology functions, and can explain how they (basically) work.	Students will demonstrate the ability to critically explain the functioning of selected use cases of drone and robot (digital) technologies in areas such as logistics, supply chain management, transportation etc.
To introduce students to the disruptive potential of drones, robot technologies and digital transformations in business and society, e.g., with reference to logistics, supply chain management, transportation etc.	Students can describe and analyze key commercial (incl. military) applications of drones and (digital) robot technologies in various sectors and describe how UAVs fly. They can interpret how new disruptive technologies produce new value creation opportunities in business and society. Students can articulate the start-up potential and future impact of drones & robot technologies.	Students will demonstrate the ability to critically evaluate the multiple and often conflicting implications and consequences of drone and robot (digital) technologies in the business sector.
To sensitise students to the imperatives of ethical concerns and legitimate policy objectives in the development and use of digital technologies, and to consider how decision-making can better engage the broader concerns of society and other stakeholders.	Students can assess 'the good', 'the bad', and 'the future' of novel technologies such as robotics and UAVs and articulate some of the legal, regulatory & ethical-moral issues of deploying drones and robots in business and society. Students can evaluate the call by robotics experts to ban autonomous weapons and their concerns about the potentially disastrous effects of the artificial intelligence revolution for humanity.	Students will demonstrate the ability to identify key stakeholders in business and society and understand their interests, critically apply ethical perspectives to problems, and manage the competing, or even conflicting, concerns that often arise from the development and use of a disruptive technologies related to UAVs and robots.

Increasingly and especially with the Fourth Industrial Revolution gathering speed, universities are well advised to ensure that students acknowledge the importance of having a multi-disciplinary mindset regardless of the school / discipline they belong to. This requires that students force themselves out of their comfort zone into areas they may not be familiar with or may initially not be interested in. We believe that more emphasis on multi-disciplinarity can buffer them from future job disruptions after they have graduated, helping them to embrace a lifelong learning mindset and to cope with the new realities of an ever-changing world.

The UDRT experience has shown that any new pan-university knowledge innovation initiative (similar to a KM-enabled business case in a corporate setting) in support of the university's mission and vision requires the right KM enablers, especially if the initiative relies on the inputs by different disciplines. Besides supportive leadership and a robust innovation culture, it is critical that the multi-disciplinary teaching and learning vision is effectively aligned with appraisal and reward mechanisms based on measurable, relevant key performance indicators.

Some of the limitations encountered while embarking on the case study research presented above include the small response rate that may limit the generalization of the findings, researcher bias and the limited number of transformative technologies used in the course.

Author Statement

The authors declare that there is no conflict of interest.

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