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Rapid Learning Cycles for project-based learning

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ABSTRACT

CONTEXT

The Massey University Bachelor of Engineering (Honours) programme is based on a series of Project-based learning (PBL) courses. It is observed historically that students have difficulty initiating project work, planning projects and deciding what decisions and information should be their focus. "Rapid Learning Cycles", developed by K. Radeka, combines New Product Development models "Lean Product Development" and "Agile Scrum" into a framework that uses regular cycles for project execution. The process identifies Key Decisions to be made in a project and determines the Knowledge Gaps to be closed within cycles. This allows team members to make these high impact/ high unknown decisions with a better understanding of the alternatives, maximising the value of the time spent learning. The approach has the potential to be used where student projects are short (one or two semesters), allowing students to make better-rationalized decisions and complete projects with a disciplined framework.

PURPOSE OR GOAL

It is hypothesised that the Rapid Learning Cycles (RLC) framework, or an adaption of it, is a suitable learning framework for Project-based learning courses, where project teams have to complete a project in a reasonably short time frame, resulting in improved learning outcomes, and project quality and delivery. In particular, those projects within a Product Development context may benefit, improving the relevance of students' skills to industry.

APPROACH OR METHODOLOGY/METHODS

Final year engineering students majoring in Engineering and Innovation Management (EIM) complete a double semester Industry-based Capstone project in small teams. An EIM team at one Massey University campus was introduced to RLC informally and encouraged to use the approach to manage their project. Other EIM teams at a second Massey University campus were not introduced to RLC and used other product development processes to manage their projects. A post-project survey was used to review the project management methods considering such aspects as ease of project planning, ease of decision making, project delivery, knowledge management, ease of project start-up, and attainment of learning outcomes. This was to understand the factors that the students found difficult in managing and completing projects.

ACTUAL OR ANTICIPATED OUTCOMES

As expected, the students using the RLC framework, being self-taught in it, adapted the RLC framework to their circumstances and also reduced their use of the framework as the project reached a conclusion at the end of Semester 2 when other course work made maintaining a regular cycle of learning difficult. The project was completed successfully. The results from all students of the elements of project management indicated that different methods were used with success.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The adoption of the Rapid Learning Cycles framework produced a project that was planned well, had a high degree of completion, had few issues getting started, and use of the framework decreased as the project neared completion. With a low survey participation rate there was no evidence of RLC being better than other methods used of managing projects but flexible methods seemed to help students in managing their projects. The use of RLC and other flexible methods of project management will be considered further for PBL based courses

KEYWORDS

Project-based learning, Rapid learning cycles, project management

Introduction

The Massey University Bachelor of Engineering (Honours) programme is based on a series of Project-based learning (PBL) courses that form 25% of the programme in each year, and is termed the 'project spine'. It is observed historically that students have difficulty initiating project work, planning projects and deciding what decisions and information should be their focus. In 2012 Massey University offered a redesigned Bachelor of Engineering (Hons.) [BE (Hons.)] degree, using a curriculum based on the CDIO standards (www.cdio.org). The redesigned degree was aligned to meet the revised accreditation criteria of Engineering New Zealand (ENZ). ENZ had identified the graduate attributes required from engineering education to increase the relevance of graduates' skills to what employers required (Engineering New Zealand, 2010), aiming to reduce the gaps between graduate attributes and professional competencies of the International Engineering Alliance (IEA, 2013) and the then current ENZ accreditation criteria and graduate profile (Goodyer & Anderson, 2011).

The redesigned programme was to address not only the need for graduates who are "rounded" with stronger "soft" or professional skills around teamwork, ethical considerations, sustainability, management and leadership, life-long learning and have a greater practical appreciation of the theoretical knowledge that they were being taught but also meet the graduate attributes of the Washington Accord WA6 – WA12 (IEA, 2013) that are part of the graduate profile. PBL is believed to develop these skills more than a traditional learning approach (Mills & Treagust, 2003), (Hadim & Esche, 2002)) and by having PBL in each year of an engineering programme it follows the fourth principle towards guiding the transformation of Engineering Education for the greater engagement of students (Beanland et al., 2013).

The Washington Accord Graduate Attribute Profile for 'Project Management and Finance' states (IEA, 2013):

> *WA11: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work as a member and leader in a team, to manage projects and in multi-disciplinary environments*

Project Management activities (Planning, Costing, Ethics, Team Development, Project Monitoring, etc. and combinations of these) were seen as the most important activities in Engineering Management by more than 50% of responses in a survey of the Engineering Profession in New Zealand (Pons, 2016). In the redesigned BE (Hons) degree at Massey University project management and teamwork are introduced in Year 1 of the degree with teams of students, guided by academic staff acting as supervisors, planning a project and carrying out its implementation during the semester or double semester of the project.

At Massey University the courses are mapped to the graduate attributes using a 3-level system. The level of competency expected increases each year. For WA11, for example, in Year 2 for the students are expected to have obtained at the end of the course a programme-defined Level 1-2 where the basics of project management are reinforced and consideration of basic financial principles, particularly related to return on investment from a new product (the context of the project), are an important aspect of the project.

In Year 4 (the final year) Capstone Project there is an expectation that at the end of the course students will have obtained Level 2-3 where students are expected to take full responsibility for the definition and completion of this project – they are required to apply all aspects of engineering management and economic decision-making which have been introduced in other courses and projects throughout the degree. Students work in a team environment, being expected to take individual responsibility for specific tasks (taking leadership in specific areas) and to contribute to overall team management and successful project completion. Level 3 is expected to meet the indicated levels of attainment defined by

ENZ in “Requirements for Accreditation of Engineering Education Programmes” for a student meeting the graduate attribute requirements (Engineering New Zealand, 2020).

It has been observed that students have difficulty in planning and monitoring team projects, particularly double-semester projects, as the team may not realise that they have fallen behind (Konings & Legg, 2020). To some degree this is avoided through regular meetings with supervisory staff but where increasing autonomy is expected, there is less contact with staff, and the workloads of other courses are high, especially in the final year, it is easy for student teams to end up significantly behind planned objectives (Konings & Legg, 2020). Lawanto, Cromwell, and Febrian (2016) presented the components of project management used by students for self-regulation of the Capstone projects broken down into team management, time management and resources management. They found that students adopted a teamwork strategy from a task interpretation standpoint and ‘such strategic actions and monitoring of personal, team and project status were employed to a lesser degree’ (Lawanto et al., 2016). Students tended to be focussed individually on completing assignments, skill development and defining their role, rather than on the team capability and utilisation. A significant concern from the study was the lack of, and infrequent efforts to define, update and adhere to a project schedule with a conclusion that project teams could be more successful if time and scheduling management was adhered to (Lawanto et al., 2016) and this would be necessary to meet the expectations of WA11 (IEA, 2013).

There is a wide body of knowledge on project management, in particular the Project Management Institute’s (PMI) ‘Body of Knowledge (PMBOK)’® (Project Management Institute, 2017) that describes the activities a project manager would consider. However, the context and scope of the engineering student projects, the limited time frames for student projects where the project is competing for the attention of the student against the demands of other courses, the difficulties the students face in completing projects, the strategic approach students take of focussing on their individual tasks, and the level of understanding required by students to complete the project suggests a need for a project management framework that will develop the understanding and learning of the student.

There are many processes to manage product development projects such as Stage-Gate®, Integrated Product Development (often taught as concurrent engineering), Lean Product Development, Waterfall, Agile (using Scrum) as discussed in the Product Development and Management Association (PDMA) Body of Knowledge (Anderson & Adkins, 2017). However, recent developments have focussed on hybrid processes with a focus on short iterative cycles within the phases or stages of a project such as Agile-Stage-Gate® (Cooper & Sommer, 2016). Since one of the critical success factors for product development is the work done at the front end of the project (Cooper, 2019) these hybrid processes help promote front end work where there is the least known about a project and reduce the uncertainty for those doing the project. A lesser known hybrid product development process has been titled Rapid Learning Cycles by its creator Katherine Radeka (Radeka, 2015). which combined short learning cycles from Lean Product Development (Ward, 2002) with Agile Software development methods.

Rapid Learning Cycles (RLC) combined these processes into a framework that uses regular learning cycles for project execution. At the beginning of the project the process identifies Key Decisions to be made and the Knowledge Gaps to be closed to be able to make those Key Decisions. The key elements in order of overarching hierarchy are the Core Hypotheses (the reason for doing the project or why the company believes in the product), Key Decisions (decisions that are high impact, unknown and must be made in order to complete the product or process but cannot be made with confidence yet), Knowledge Gaps (things the team needs to learn in order to make the key decision the knowledge is related to) and Activities (what will be done to close a knowledge gap or other processes in the product development process) (Radeka, 2015). These definitions fit well with the Activities, Information, Decisions (AID) model that has been used in Capstone Projects previously, where students define the decisions to be made in the project as the first step. The ‘kick-off event’ is used by the team led by a facilitator to determine the key decisions and the knowledge gaps and then plan these in a regular cadence of learning cycles and decision points as shown in Figure 1.

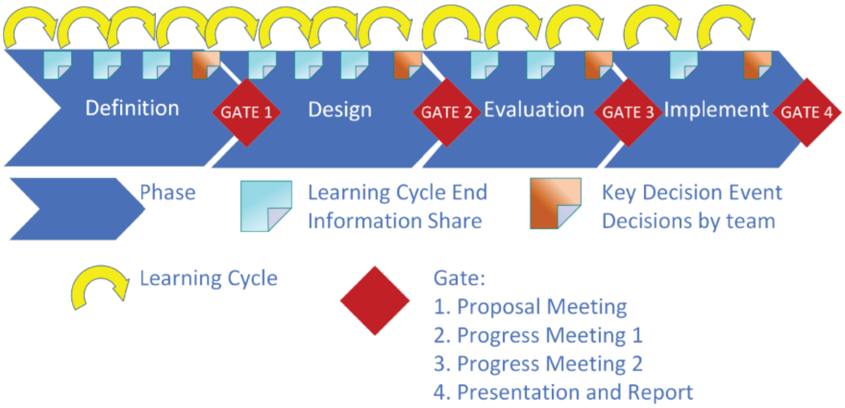

Figure 1 RLC interpreted for the BE (Hons) Capstone Project, based on Radeka (2015)

The knowledge gained is documented in a short A3 template (a single page) to be shared at the end of the learning cycle event (Information Share in Figure 1) to allow knowledge to be shared and easily found. Each key decision event is also documented with the decision(s) made on a short A3 template. The cadence of the learning cycle is set, dependent on the project, to 2 -4 weeks normally and the event for key decisions at every third or fourth learning cycle. Each event requires resetting and planning the next cycle. The use of documentation is seen as an important part of student capstone projects (Keogh & Venables, 2009) and this process promotes short and concise documentation that should reduce the workload on students when communicating project information and decisions.

In exposing the knowledge the team needs to make a decision, it encourages the team to use more time to build knowledge and make these decisions as late as possible. With the emphasis on learning and decreasing unknowns within a project this approach has the potential to be used where student projects are short (one or two semesters), allowing students to make better-rationalized decisions and complete projects with a disciplined framework as well as promoting the self-regulated behaviours that are desired in projects, particularly capstone projects as described by Lawanto et al. (2016).

Methodology

Final year engineering students majoring in Engineering and Innovation Management (EIM) complete a double semester Industry-based Capstone project in small teams. An EIM team at one Massey University campus was introduced to RLC informally and encouraged to use the approach to manage their project at the start of the academic year. Other EIM teams (three in total) at a second Massey University campus were not introduced to RLC and used other product development processes to manage their projects. There were a total of 15 students in the four projects and no project was the same as the other. Each project had elements that required technical knowledge that was not part of the taught content of the programme. The student teams had weekly supervisory meetings with an academic staff member although there was some flexibility in this, and the student team managed their communication and contact with the project's industry sponsor as negotiated with the sponsor. An abridged version of the learning outcomes for the Capstone project are.

1. Manage a complex engineering design/development project in a "near to commercial context"
2. Complete a detailed design solution based on a complex engineering problem related to the specific major being studied, where the final solution requires full evaluation.

3. Work effectively as both team leader and team member to successfully complete a complex, multidisciplinary project.
4. Exercise professional judgment, self-monitoring, peer assessment and adherence to ethical principles and professional codes of practice.
5. Identify key stakeholders and effectively communicate key information that is appropriate to specific stakeholder requirements and expectations.
6. Evaluate the feasibility of a project from a commercial perspective.

The Capstone project has six assessments for group and individual assessment including a project proposal meeting to define the project, progress meetings, presentations, and a final report as well as self-assessment and evaluation of the team performance.

A full human ethics application was completed and approved (SOB 17/30). After final report submission (the last assessment) a post-project survey was sent to students using the course's Stream site with instructions to return to an independent administrator. The students had two weeks to return the survey though this was extended due to the low response rate. The administrator entered responses to the survey in a spreadsheet to anonymise the data collected. The data was available to researchers after the release of final grades. The purpose stated to the students was that the survey would 'allow a qualitative and quantitative determination of what areas the teams find successful or challenging in a Capstone project-based course before considering what improvements could be introduced to make project execution easier'.The survey used to review the project management methods considered these sections (number of questions): Getting started on the Capstone project (5), Capstone Project Planning (11), New Product Development Process (7), Knowledge gathering, storage and reuse (7), Ease of decision making (8), and Attainment of learning outcomes (6). There were 45 questions in total, with a mixture of open-ended and Likert-scale questions. The survey was sent to 15 students but only 4 responses were received, which meant that quantitative analysis was not tested for significance.

A statistical analysis of Likert scale questions was conducted. The responses were scored 1-5 (1 being strongly disagree or poor, 5 being strongly agree or excellent) for each question and averaged.) Open-ended questions were reviewed to provide qualitative analysis of the data to establish themes in the answers given by the students (identified as A, B, C, D).

Results and Discussion

The first five questions were aimed at understanding whether students had difficulty getting started on the project and what the key challenges were. The responses to the ease of getting started ranged from easy (A and D) to difficult (B). Although three of the four students said that understanding and engaging in the project took 1-3 weeks, Student B said it took 4-5 months. However, in identifying the key challenges faced in starting the project the responses were similar around understanding expectations from the client and the academic staff, and identifying the scope of the project, which are the normal activities identified as critical to success in a project at the front end (Cooper, 2019). The students were asked if any particular NP process was adopted to overcome the challenges in starting the project. Only one student (A) answered that:

> *Rapid Learning Cycles was adopted identifying key knowledge gaps, and distributing activities for filling these gaps amongst the team members. Each team member focussed on a key knowledge area from which they would then become the "expert" in the team on that particular area.*

However, other NP Processes included "double-diamond" and "relatively fluid (like Agile)" both of which are similar in their use of iterative cycles and focus on learning. Double-diamond refers to the process which was the UK Design Council's interpretation of Design Thinking (Design Council, 2007). All responses indicated adoption of an NP Process.

The next eleven questions were focussed on Capstone Project Planning – a summary of the responses is shown in Figure 2 where the response to the question "We created a project plan at the beginning of the project" was strongly agree from three students and Student B, the one that indicated 4-5 months to understand the project, put 'neutral." Students mostly maintained a plan that they were mostly all responsible for and reduced the scope during the project to maintain delivery of the project at the end of the course. Interestingly all students planned task delivery on regular cycles, although regular cycles was not defined in the question. One student (A) commented that there was constant recognition that "the plan was 'just a plan' and was likely to change as the project progressed".

When asked about NP Process (seven questions) the responses were mixed in their agreement to them – there was agreement that all adopted an NP Process, though the use was not necessarily maintained throughout the project. Students C and D, who identified the Agile and Double-Diamond processes for getting started, used these throughout. However, Student A, who identified RLC to get started identified Stage-Gate® as the NP Process used – this suggests that RLC was used as a tool or method in their overall management of the project. The majority agreed that they adapted the NP process used for their project.

With respect to knowledge management the seven questions were aimed at teasing out an important aspect of RLC use. However, all students agreed that there was a process to gather knowledge, there was access to knowledge, it could be easily retrieved and reused. Students used Google Drive and communicated updates to information stored although Student A using RLC communicated detail on the structure used. This student did not communicate that initially knowledge was stored as one page A3 briefs as shown by Radeka (2015) but this documentation decreased as the project progressed.

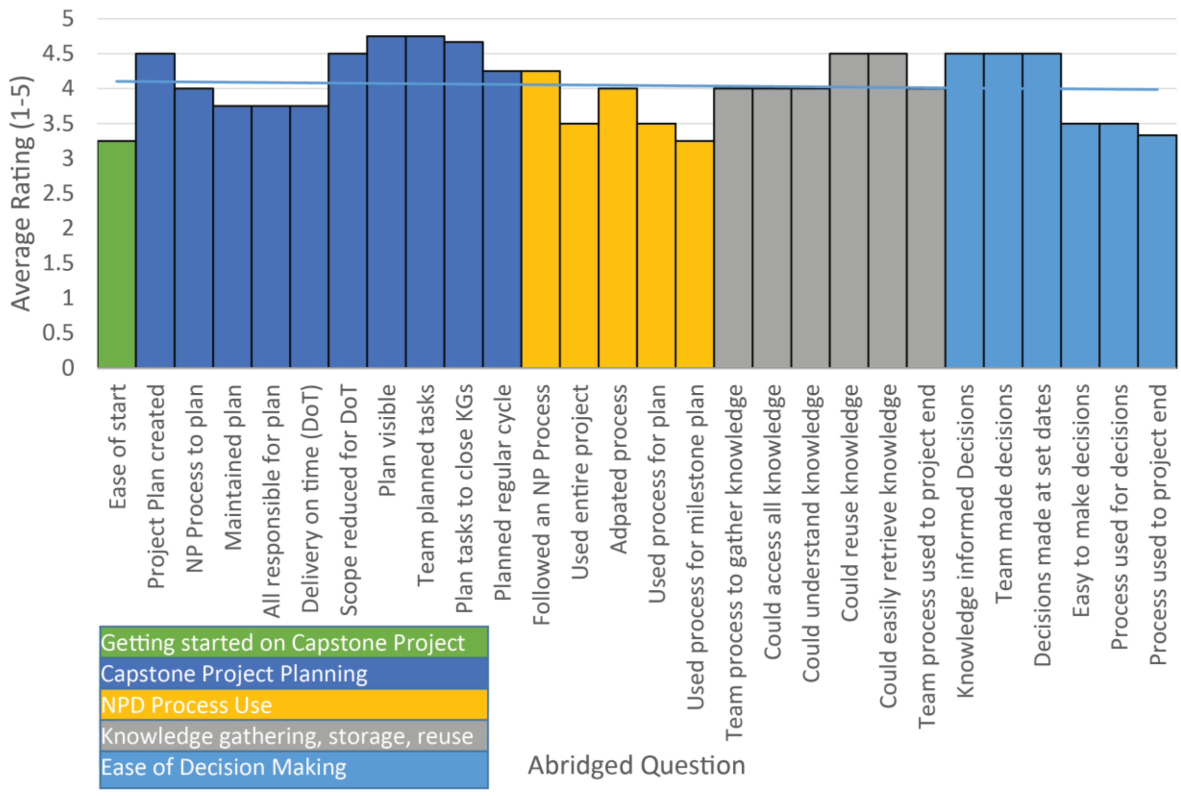

Figure 2 Student Responses (Averaged) to Survey Questions (N=4)

The last section of questions (8) was around the ease of decision making, another key aspect of RLC. Students agreed that the knowledge found informed their decisions and was made by the team at set dates. Students A and C, who identified as using RLC/Stage-Gate® or Agile, agreed that it was easy to make decisions and only the former agreed that there was a process used to make decisions and it was used throughout the process. Yet all identified they used some form of Decision Matrix with weighted criteria but not necessarily for all decisions. The students also commented that discussion of the decisions as a team was important as sometimes decisions were made without closing off the relevant knowledge gap.

In reviewing the responses, it became clear that the original purpose of the study being to identify if RLC was a more suitable method for the student management of their Capstone projects was not evident. It was evident that the students had success in managing their projects and that they used processes largely throughout the project. This was evident in how the students rated themselves when assessing their achievement of learning outcomes for the course. The responses are shown in Figure 3.

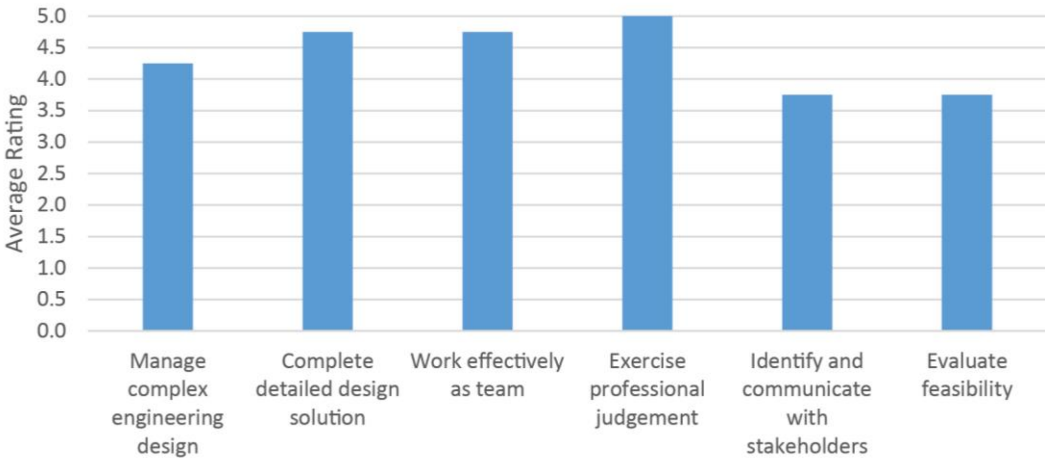

Figure 3 Student self-assessment of learning outcome achievement (N=4)

Manage a complex engineering design, working effectively as a team and exercising professional judgment encompass project management activities and students were largely in agreement that they had achieved these outcomes. This is similar to the results seen from an evaluation of the redesigned engineering degree where graduates of the redesigned programme rated themselves higher in the attributes of Societal considerations, Ethics, Teamwork, Communication and Management than graduates of the replaced programme (Tunnicliffe & Brown, 2017). However, the student comments clearly identified that there were issues in communicating with the company or other major stakeholders sponsoring the project and also having the knowledge to complete an effective evaluation of commercial feasibility of the project.

Massey University's project spine's PBL courses use regular supervisory meetings of staff with student project teams, and also include progress (sometimes termed gate) meetings with the team within the assessment schedule for the course. For example, one of the learning outcomes of the second year PBL course Product Development is 'Recognise the inputs and processes required for project management and apply the key elements through a product development process' and this is assessed through a component 'project planning and management' as part of the project proposal, progress meeting 1 and progress meeting 2 assessments. The average mark at progress meeting 2 for this component of the assessment ranges from 71 to 81% (mean 75.6%, median 75%) for 2015-2021 with no pattern that shows improvement or otherwise. The criterion for >75% is given as 'Clear evidence of use of a plan and that the plan is a living document. The planning for the report includes key sections of the report to complete and a plan for their review within the team'. In Year 2 there is still significant guidance for the students in managing and directing their projects, which is recognised as necessary when students are unfamiliar with project management (Verderber & Serey, 1996). At Year 4 in the Capstone Project with an expectation that students are autonomous in their planning and management of projects the learning outcome is ‘Manage a complex engineering design/development project in a "near to commercial context"; requiring problem definition, scoping of system and sub-systems, planning to complete required deliverables and outcomes, sound decision-making based on well researched knowledge and definitive action’ and there are project proposal, progress meeting 1 and progress meeting 2 assessments where a component assessed is the Project Planning and Management. The marks for this component ranges from 70-80% with no pattern to show improvement or otherwise.

Although these results indicate students are performing above average at both Year 2 and 4 (and this is similar to the conclusions of Konings and Legg (2020) for a Year 3 project) the students often modify the scope of the project to meet the constrained time of the semester or double semester project as well providing only very high level detail Gantt charts and sometimes a Kanban system of task management. The responses by the students confirm that students are modifying the project scope but were able to mainly maintain processes throughout the project. Students often express concern over getting started in projects, lack of time, the workload, and the uncertainty of what needs to be done. Students are introduced to the Engineering Method and Project Management in Year 1, and the Product Development Processes and the Work Breakdown Structure in Year 2, which could be seen as giving them necessary tools to plan and manage projects and the lack of these concerns being evident in the responses to this study of Capstone Projects suggests a developing confidence in project execution.

Overall, in this study students used both a team management and time management approach, as defined by Lawanto et al. (2016), but did not use a resource management approach. This might be due to the resources being largely out of their control. The concerns expressed over lack of, and infrequent efforts to define, update and adhere to a project schedule were not evident in this study perhaps because of the small sample size and students whose major is focussed around product development and engineering management. Yet, when these students started their final year they had had only a small exposure to courses specific to their major. In the time since this study was conducted there has been a noticeable uptake in the programme of students using electronic tools for task and time management, largely Kanban systems (To do, Doing, Done) that fit within the Agile and Lean NPD processes. All of these processes can be viewed as tools that fit within an overarching Stage-Gate® process (Furr & Dyer, 2014), a process which is used throughout the ‘project spine’. In teaching project management there is an unanswered question as to whether staff have the experience and knowledge of project management tools to guide students though it is seen as moderately to highly important (Brown & Tunnicliffe, 2017).

Conclusions

The adoption of the Rapid Learning Cycles framework produced a project that was planned well, had a high degree of completion, had few issues getting started, and use of the framework decreased as the project neared completion. A similar conclusion can be reached with the use of the other processes adopted by students in different teams. With a low survey participation rate there was no evidence of RLC being better than other methods of managing projects. This might be because the other processes adopted (Agile, Double Diamond) are also processes that use regular iterative cycles emphasising flexibility, knowledge and learning and these all fit within a Stage-Gate® approach that is taught in the programme as an overarching management process. All methods allowed students to achieve the learning outcomes as self-assessed, which is supported by the grades the students achieved. The few responses received from students indicate that flexible methods of management help students with project delivery. The motivation is to help students earlier in the programme with project management and these methods will be considered further for PBL based courses including further study on project management in the Capstone project.

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