Concept-of-Prototype: Selecting Software for Tertiary Animation Courses

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ABSTRACT

Contemporary animation is almost exclusively produced using computers, and so for students of the discipline, software tools are a critical component of their higher education. However, a methodical process for comparing and selecting programs for use in the classroom is noticeably absent. It is thus hypothesised that the observed struggles in graduate employability are, in part, a consequence of ill-advised software procurement decision-making.

This dissertation contributes to the discourse by presenting a predictive software selection concept-of-prototype which accommodates a range of functional and qualitative judgements. The methodology deployed in its development is a synthesis of the TAES-COTS multi-stage filtration process, the criteria formulation techniques of Parker, Ottaway and Chao (2006), and the subjective appraisal approach demonstrated in Parker (2010). The decision support system is actualised as a Microsoft Excel spreadsheet and includes a suite of original domain-specific selection criteria. This practical tool respects a range of pedagogical, operational and disciplinary considerations, and is thus expected to generate quality and cost-effective outcomes.

Certification of Thesis

I certify that this work is original and has not been previously submitted for any other award. I certify that the ideas, analyses and conclusions presented in this thesis are my own effort entirely, except where otherwise acknowledged.

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Signature of Candidate	Date

ENDORSEMENT:

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Signature of Supervisor	Date

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AHP	Analytic Hierarchy Process
AQF	Australian Qualifications Framework
AR	Augmented Reality
AT	Activity Theory
CG	Computer Graphics
CGI	Computer Generated Imagery
CI	Consistency Index
CR	Consistency Ratio
COTS	Commercial-Off-The-Shelf
MCAP	Massive Collaboration Animation Projects
MCDM	Multi-Criteria Decision-Making
RI	Random Index
TAES-COTS	Thorough Approach for Evaluation and Selection of Commercial Off-The-Shelf products
VFX	Visual Effects
VR	Virtual Reality

1. INTRODUCTION

The computer animation industry is a vibrant and lucrative powerhouse of production, and the escalating household consumption of entertainment content promises continuing growth in this sector. Such expansion necessitates a robust workforce with a steady flow of new talent to sustain it. In-kind, tertiary admissions in this field is increasing as the prospect of expanding employment opportunities, as well as the appeal of working in the creative industries, attracts people to the discipline. However, the transition from study to the studio is not always a smooth one. A significant body of literature reports that graduates often lack the necessary skillsets to operate at a commercial level. This criticism is indicative of a misalignment between tertiary education provision and the expectations of the industry.

1.1 Research Background

An examination of undergraduate animation education reveals the prevalence of commercial software tools as instruments for training and production. However, there is limited research on the pedagogical suitability of these products and an absence of evaluative frameworks suitable for this unique domain. Accordingly, this topic of dissertation pertains to education reform via improved technology decision-making and implementation.

1.2 Research Aim

The objective of this research is to develop a predictive software selection tool to support comprehensive, efficient and cost-effective decision-making. Towards this aim, the concept-of-prototype draws on the didactic principles of adult education, operations research, and organisational sustainability.

The methodology deployed in this research is the *Thorough Approach for Evaluation and Selection of Commercial-Off-The-Shelf products* (TAES-COTS) developed by Basir et al. (2014) which is a multi-stage framework that uniquely supports both functional and subjective appraisal. However, given the generic nature of the TAES-COTS method, it is complemented with the criteria development techniques enunciated in Parker, Ottaway and Chao (2006), and the qualitative comparison demonstrated in Parker (2010), to derive a more specific model.

1.3 Dissertation Structure

Chapter 2 presents the literature review which is divided into two sections. The first portion begins with an examination of the graduate employability issue and enunciates the recurrent efforts towards education reform. From there, Engeström's (1987) Activity Theory is used to decipher the mesh of social, pedagogical and technological factors involved in animation instruction, and highlights the decisive role of software in the achievement of learning goals. The research will then trace the lineage of software evaluation techniques. Consequently, Multi-Criteria Decision-Making, a branch of operations research, will be proposed as the optimal platform to develop the evaluation prototype. However, to develop a specialised tool, discipline-specific criteria are needed.

Accordingly, the second segment of the literature review will be dedicated to a thematic survey of computer animation principles and techniques, and the landscape of tertiary education in an Australian context. Providing this vignette establishes the groundwork for the selection criteria which are codified in the methodology.

Chapter 3 presents the concept-of-prototype which is assembled based on a composite method derived from Basir et al. (2014), Parker, Ottaway and Chao (2006), and Parker (2010). The selection process is charted against the architecture of the Microsoft (MS) Excel spreadsheet, and the criteria are organised categorically into functional, non-functional and operational clusters. The Analytic Hierarchy Process, which is the mathematical bedrock of the qualitative comparison, is also demonstrated with illustrations from the spreadsheet.

Having explained the mechanics of the decision support system, Chapter 4 explores the anticipated outcomes of its implementation. This section enunciates the benefits to the various stakeholders and to the overall sustainability of the institution, in addition to a consideration for areas of improvement.

Finally, Chapter 5 will conclude by summarising the research trajectory and finding. It offers a commentary on the scope of the project and accordingly makes recommendations for testing, development and potential diversification of the prototype.

1.4 Conclusion

The goal of this dissertation is to show a practical outcome which has real, tangible benefits for animation education. Its pragmatic, intuitive structure is designed to accommodate a diverse range of users irrespective of their expertise in animation or software procurement. Although the scope of this project does not accommodate pilot testing, this research initiates the dialogue for continuous improvement.

2. LITERATURE REVIEW

Computer animation is integral to film production, game design, advertising and media, and the emerging domain of immersive technology. Market research reveals that the animation industry is one of the fastest-growing segments in the global economy, with streaming content and eSports enjoying remarkable expansion, tracking at an annual incline of 8 per cent and 30 per cent respectively (*Global animation and VFX industries: strategies, trends & opportunities* 2019). These successes mean that the global value of this sector is projected to reach US$270 billion by 2020 (*Global animation and VFX industries: strategies, trends & opportunities* 2019).

The continuing prosperity of the animation industry translates to a corresponding demand for skilled artists in the labour market. Statistics from the United States predict a 4 per cent increase between 2018 and 2028, equivalent to the creation of 3000 new jobs (Bureau of Labor Statistics 2019). Australian employment data, although more general in its categorisation, reports similar findings with 9.1 per cent growth in film and video production segments between 2012 and 2016 (Australian Bureau of Statistics 2017). Synchronously, the industry is also increasingly competitive with tax-incentives and labour costs driving a globally dispersed production model (Research and Markets 2019). Though creative industries are typically geographically concentrated, the animation sector has relied heavily on international outsourcing since the 1970s (Yoon 2017, pp. 634-5).

This decentralisation has had two important consequences. The first is the corresponding increase in the accessibility of education. Statistics from 2011 indicate that there were 1151 animation schools internationally, excluding those in China, and that these institutions were distributed across 64 nations including the United States, India, Canada, and Europe (Su & Wang 2013). So, not only does this afford opportunities for aspiring animators throughout the globe, but it also means that universities not currently offering animation studies should not be discouraged by their distance from production hubs. Secondly, it reinforces the importance of tuition consistency and workflow standardisation as the division of commercial production necessitates the sharing of project assets between studios.

The implications of these findings for the education sector are significant. Evidence suggests that the typical education standard for entry-level employment is a Bachelor's

Degree (Bureau of Labor Statistics 2019; Ozanimate 2019) and thus, universities play a crucial role in cultivating human resources. However, an examination of the literature reveals an ongoing aberration in tertiary graduate employability.

2.1 Industry Perspectives on Graduate Employment

There are recurrent accounts within the digital creative industries, including animation, that graduates are inadequately prepared for the demands of commercial production. Among the earliest Australian accounts was a 2005 report by the Australian Interactive Media Industry Association in which it was observed that:

> Universities, and TAFEs in particular, were not considered to produce students with sound technical, creative, business or team skills. Graduates were viewed to have been taught a range of software packages – some of them out of date – and required intensive on the job training to reach an acceptable minimum standard… Companies felt that graduates tended to over-estimate their own capabilities and had not been adequately prepared for the fact that technicians needed more than software competence to be effective team members. Graduates rarely had the requisite project skills – including deadline sensitivity. (AIMIA 2005, p. 47)

Despite having been published 14 years ago, the sentiment of this AIMIA report is repeated in the legacy of publications up to the present and across international research. In a 2007 survey of American industry professionals on animation in university found that almost three-quarters of participants believed that the principles of animation (including acting, anatomy, motion studies and drawing) needed much more emphasis in the syllabus, as well as pre-production and design skills (Flaxman 2007). As the researcher highlighted it was remarkable that the curriculum areas needing the most improvements were non-technical skills, despite the intensely computerised production setting (Flaxman 2007).

Similar findings are evident in Asia, from which a significant proportion of literature on animation education, employment and reform originates. In 2007, a complaint of Malaysian recruiters was that university tuition was focussed on the technical aspects of animation, and so graduates rarely demonstrated a rounded education in storytelling, acting and mise-en-scene (Muthalib 2007, p. 288). Eight years later, in another Malaysian study, Abdullah and Ishak (2015) presented strikingly similar findings that an imbalance remains between technological execution and a solid understanding of the animation fundamentals and creative practice. Within Chinese scholarship, Zhang, Li and Fu (2017) noted that despite the rapid growth of the national animation industry, a lack of originality had bridled its potential. Elsewhere, Jin (2018, p. 201) explained that enterprises were often forced to provide on-the-job training to bring employees up to a professional standard: an expensive undertaking in an already turbulent and competitive industry.

Similarly, research from the United Kingdom suggested that graduates are compelled to pursue further study to improve their employability prospects. In the case study presented by Palmer, Ralley and Davenport (2016, p. 41), intensive post-graduate courses emerged to ‘bridge the gap’ between higher education and industry practice. Escape Studios, the focus of the article, described the composition of its student cohort as “[arriving] with undergraduate degrees in a related subject but [lacked] the required in-depth technical knowledge and skills to get their first job” (Palmer, Ralley & Davenport 2016, p. 41).

A survey of Australian design industry professionals showed there was a perception that university degrees offered little practical value in preparing students for professional careers (Bridgstock 2016, pp. 313-4). Instead, qualifications were more useful in recruitment as an indicator of a candidate’s work ethic (Bridgstock 2016, pp. 313-4).

These findings are cause for concern on several accounts. Firstly, the consistency of complaints across international reports suggests a common underlying problem in animation instruction, independent of cultural or social factors. Furthermore, since the problem was first documented, there have been significant shifts in the technological and educational landscapes in the elapsed time. Cloud-computing and subscription-based licensing means that new features are being pushed out to the end-user regularly, and so product currency is assured. Concurrently, the university sector has adopted a service delivery model placing greater emphasis on the student experience in support of quality assurance and organisational competitiveness. Despite these transformations, neither advancement seems to have had a meaningful impact on animation graduate outcomes. So this is suggestive that another, unrecognised factor is maintaining the status quo.

For students and graduates, the ambiguity surrounding stable employment can be disheartening. To exasperate the issue, unsuccessful candidates may feel compelled to pursue further study, resulting in additional personal expenditure and potential income forfeiture.

From a commercial standpoint, recruiters also face uncertainty as to whether new staff will ‘have what it takes’ to integrate quickly into the production workflow. In the probationary period, employers may need to provide extensive on-the-job training to upskill new team members. This is an unwelcome burden in an already time- and cost-pressured industry, and intellectual property safeguards may be undermined if the person is poached by a competitor. Alternatively, if the skills gap continues, and the current generation retires, the uncertainty of workforce replenishment endangers the stability of the industry.

Moreover, the perpetuating misalignment with the industry does not reflect favourably on the reputations of higher education institutions. It is disconcerting that an undergraduate program, with its minimum duration of three years, is apparently inadequate to teach the animation craft even to an entry-level standard. Evidently, there is some unique characteristic of animation instruction that requires a different approach to cultivate the necessary outcomes.

2.2 Educator Perspectives and Efforts Towards Reform

The academic sphere has not been inattentive to the criticisms from industry or the problems surrounding student qualifications and employability. Rather, educators have shared extensive dialogue in these matters and taken great interest in improving their own practice. Table 1 summarises the main themes of the discussion across a breadth of literature.

Table 1: Critical Summary of Tertiary Animation Education

The quality of the teaching staff	Educators should demonstrate solid skills in the animation fundamentals as well as have professional experience and maintain currency with industry practice (Liu 2016).
Dated teaching methods and instructional design	Traditional teaching methods are not suited to the animation specialty. It is all too common for the instructional design to either be densely theoretical (Jin 2018; Liu 2016) or grounded in fictitious, drill-and-practice exercises which are incongruous with real workflows (Bernar & Torrents 2008). Perpetuating these techniques does not provide enough opportunity for practical application nor engages the student's interest.
Dated teaching resources	Despite the plethora of instructional materials available, few succeed in cultivating a sense of interconnectedness between the concepts, innovation and originality (Zhang, Li & Fu 2017).
Broad student recruitment	The typical class size in a university animation course can be 20 or more students. This arrangement means that the opportunity for individual mentoring is reduced (Changrong 2016). To exasperate this issue, institutional admission standards for the animation specialty are often quite relaxed, and subsequently many students 'blindly' enrol (Changrong 2016, p. 928). So, within a class cohort, there can be vastly different levels of artistic aptitude and enthusiasm for the discipline, which presents a significant challenge for teachers.
Mixed student concentrations	Even before students customise their degree programs with their chosen major and minor studies, university curriculums require the uptake of core general units (for example, communication studies or statistics). This reduces the time which can be dedicated to the animation specialty (Holladay & Adams 2017). Students may also be studying quite different subjects concurrently with their animation courses.
Practical limitations imposed by the university structure	The university setting rarely emulates the studio environment, meaning that learning behaviours are often at odds with professional practice. Standard university timetabling is modularised, designating classes into 2-3 hour time slots which may be at opposite ends of the week (Marshall & Meachem 2007). Attendance is also non-compulsory. These characteristics foster a culture of independence, spasmodic engagement, irregular working hours and compartmentalised creative practice. Together, these make it difficult to instil professional rigour and consistency in the learning environment.
Poor integration of technology with the curriculum	Although the enrolment pattern may align computer courses with complementary theoretical units, the fact that the skills are taught independently means that intersection between them can become 'wooden' and fractured. Consequently, students may struggle to make connections between the concepts and application (Cumbie-Jones 2001).

In reviewing these topics it is clear that university programs rarely succeed in emulating an authentic animation workflow. Of course, there will be differences between learning and work environments as the former is designed to be a ‘safe space’ for trial-and-error, experimentation and self-expression (Leung & Bentley 2017). Nevertheless, training without some semblance to the studio setting does little to prepare students for professional work. So, it is unsurprising that the cumulative effect is a cohort of graduates who are unable to adapt to the intense demands of the industry.

2.3 Curriculum Reform

In response to these systematic weaknesses, and in recognition of the unique instructional requirements of the craft, there have been many attempts towards curriculum reform. Generally, these approaches have involved the reorganisation of the social learning structures, three of which will be discussed here.

The first of these is the introduction of interdisciplinary group projects which are usually completed as part of a capstone course in the final year of the undergraduate program. Students form medium-to-large teams to produce a cohesive creative article such as a short film, and in doing so develop their specialist skills in an intensely collaborative, self-managed setting. Some advocates enhance this method by enlisting external experts to provide mentoring and critical feedback and add authenticity to the task (Fleischmann 2010; Holladay & Adams 2017). Because of the intensity of the production environment, and the heightened focus on the transition to work phase, many of the traditional university structures are reconfigured or bypassed. This includes operating to a production schedule rather than to a specific class timetable, and including individual work effort and participation as components of the assessment. The success of these projects relies on a reasonably-sized student cohort to distribute the workload within the timeframe of the semester, and sufficient teaching staff for supervision. So for schools that do not have the resources or student numbers to sustain such an endeavour, there has been a recent move towards Massive Collaboration Animation Projects (MCAP) in the discourse (Joel et al. 2018). These are international projects which bring together students and teachers from around the globe by utilising current communication and file-sharing technologies such as video-conferencing and cloud services (Joel et al. 2018). This ambitious undertaking is compelling and changes the education paradigm for animation because it eliminates geographical barriers to learning opportunities, and it simulates the intensely digital and distributed production model of the industry.

The second approach is independent research projects which is suitable for more internalised delivery. In this case, students are given the freedom to produce individual computer graphic productions that complement their specialisation and interests. These courses are designed to engage the high achieving students who are capable of more challenging work beyond the standard courseware and have demonstrated a capacity for independent study. These types of projects serve to develop the student's confidence and resilience within the research process, as well as prepare them for career outcomes (Lopatto cited in Joel 2016). Research projects also have the added benefits of bolstering the reputation of the institution via academic publications, and the enrichment of the professional knowledge of the faculty staff through collaboration with the student (Anderson, Adzhiev & Fryanzinov 2016).

The third example is the introduction of peer learning techniques into the computing classroom. Here, students are encouraged to cooperate and problem-solve with one another; thereby taking a more active role in refining their own understanding. The format may be a formalised process, as documented in Wang and Chern (2013) where students formed groups and were required to present a software technique or tool to the class. Alternatively, Coorey (2016) implemented a more casual approach where, during technical exercises, students were expected to seek help from others before consulting the teacher. These just-in-time learning strategies and knowledge sharing behaviours are essential in commercial workflows (Bridgstock 2016). Unfortunately, this system is vulnerable to variances in work effort, given the diversity of student ambition and motivation. Disinterested students may invest themselves very little in the process, meaning that other students do not enjoy a productive collaborative dialogue.

In each of these three cited examples, the researchers observed improvements in student performance and satisfaction. However, deploying these methods does not satisfy the greater endeavour of animation education reform. The emphasis on social change, particularly in the first and third examples, does not address the practical factors of instructional design and delivery identified in Table 1. Furthermore, it is difficult to translate these methods into a generalisable practice because of the specific resourcing and cultural constraints presented in these case studies.

Indeed, the social dynamics of the learning environment is only part of the overall educational experience. So in the next section, Activity Theory will be used to understand the domain of the scenario and the interrelationships between the various factors to student learning.

2.4 Activity Theory

Activity Theory (AT) originated in early 20th Century German philosophy and is a descriptive framework for modelling goal-based behaviours within a social context. The contributions of Yrjö Engeström in the 1980s and 1990s, however, expanded the tool so that a more complex network of constraints could be articulated and managed (Murphy & Rodríguez-Manzanares 2014). Consequently, AT has become widely accepted in both education and information technology research because it distinguishes how human and functional parameters impact task completion and performance. Animation education is a unique intersection between these two domains, and so AT is therefore well-suited to the present analysis.

Engeström's model is depicted in Figure 1 and shows the six essential components, and their interrelationships, that contribute to the activity outcome. As the black arrows indicate, each element is directly influenced by the adjacent factors.

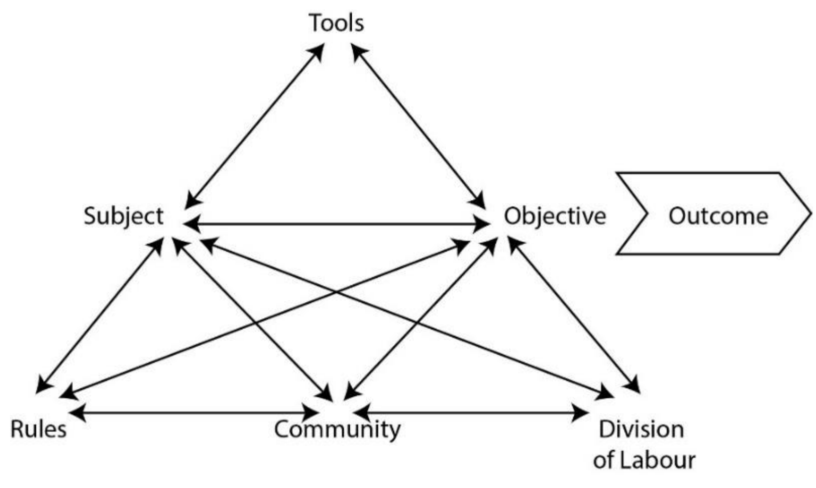

Figure 1: Activity Theory Triangle adapted from Engeström, (1987)

Adapting the narration given in Murphy and Rodríguez-Manzanares (2014), the following dot points will describe each AT element, and provide linkages to the equivalent concept in credentialed animation education.

- The *subject* is the person undertaking the activity (that is, the student) and is the central unit of analysis in the AT model.

- Activities are motivated and given meaning by an *objective*, and understanding this underlying aim is essential to comprehend the whole activity system. In this instance, the objective is the development of animation knowledge and skills. The exact nature of this object will differ, however, according to the adopted viewpoint. This fact may account for variances in perception between students, educators and industry on the purpose and value of tertiary education.
- The attainment of the objective transitions the activity into one or more *outcomes*. These include the attainment of the qualification, developed graduate skillsets and the production of works which may contribute to their portfolio.
- *Tools* are the artefacts which mediate interactions between the subject and the objective. In educational settings, tools may include textbooks, equipment or other instruments used in the classroom. Software is arguably the most critical tool in the given setting because it dictates how students engage with the learning materials and assessment projects.
- The *community* is the social collective to which the activity has meaning. Members may include student peers, the teaching and support staff, potential employers and professional networks. The perceptions and behaviours of the subject are shaped by interactions with these groups.
- The activity *rules* govern how these interactions occur. The classroom etiquette imposed by the teacher, behavioural expectations articulated by the institutional ethos and the broader conventions of society are just a few of these social norms.
- Lastly, the relationship between the community and the objective is negotiated by the *division of labour*. This element dictates the horizontal division of tasks and the vertical allocation of responsibility across the participants. In the present context, the authority exercised by the educator and the degree to which peer collaboration is permitted are the most influential structures.

As is evident, one of the benefits of AT is its combined micro and macro frame of reference. The researcher is able to embody the subject's viewpoint as well as interpret the system from an aerial perspective (Engeström & Miettinen cited in Murphy & Rodríguez-Manzanares 2014, p. 22), allowing an empathetic and holistic assessment.

With this understanding, it is possible to examine the undergraduate animation studies more precisely and recognise new opportunities for reform. Reflecting on the methods summarised in Section 2.2, the elements at the bottom of the triangle - the rules, community and division of labour - have been the pivots for change. The formation of teams, the introduction of independent research and peer-learning strategies shuffle the roles and authority in the classroom and therefore change the social dimensions within the activity. These concentrations, however, do not appreciate the network of variables and deny the significance of those elements on the outcome. Furthermore, there is little consideration for the bilateral relationships between the nodes and the reciprocal nature of their influence.

For example, consider the peer-learning studies of Wang and Chern (2013) and Coorey (2016). Here, the researchers acknowledged a relationship between social factors and technology tools and thus sought behavioural solutions to improve student usage of software to promote overall engagement with the discipline. This approach, however, assumed an immediate and unidirectional relationship between the constraints whereas the AT shows a two-stage pathway, with the subject and objective elements as intermediaries. Accordingly, in the cited examples, the contribution of tools to the improvement of graduate outcomes are not dealt with adequately in methods of reform. There needs to be more attention placed on the role of software tools in the network as they not only serve in the accomplishment of the task but also shape how the goal is perceived by the subject (Abouelala, Janan & Brandt-Pomares 2015, pp. 81-2). Using this logic, well-implemented software will foster productive learning behaviours and positive outcomes, whereas tools incompatible with the activity will be an impediment to progress and development.

This analysis is consistent with the symptoms described in the industry criticisms given in Section 2.1. There are numerous references to technology and software competence in these commentaries, and there are anecdotal linkages made with deficiencies in other aspects of the animation skillset. So the implication is that software is not effectively deployed in the classroom and that this is a wide-spread issue given the volume and geographic distribution of the feedback. Crucially, the proposition is not that there is a lack of quality software tools available, but rather that there is a misalignment with the activity system. Over the trajectory of a student's education, therefore, it is plausible that the technology barrier undermines their learning and subsequent post-education opportunities.

2.5 Animation Software in Tertiary Education

Producing computer animation requires the use of specialised software, the characteristics of which are explained further in Section 2.8.1. For this reason, many education providers insist on using commercial tools to enhance the employability of their students. For example, the acclaimed Studio of Audio Engineering (SAE) in Australia proudly advertises its use of "industry-standard software such as Maya, Autodesk 3D MAX [sic] and the Adobe Creative Suite, to prepare [students] for a career in the industry" (Bird 2015).

However, Commercial-Off-The-Shelf (COTS) products may not be suitable for education because the professional domain for which they are intended assumes different product outcomes and user groups. As Tselios, Avouris and Komis (2008, p. 56) explain, for technology to be considered educational it must support the *process* of learning not merely the performance of a task. This is in contrast to the objective of industrial tools which are optimised for complex workflows, multidisciplinary application and commercial output. Tselios, Avouris and Komis (2008) therefore caution that the enhanced usability offered by industry products may, in fact, be counterproductive for learners if important mechanisms and conceptual relationships are disguised behind automated tools.

Evidence from the discourse highlight two areas in which software and its perceived role in animation skill development have interfered with learning outcomes. Firstly, in some cases, the students themselves are driving an imbalanced emphasis on technical instruction. In a case study of a Computer Graphics Master's Degree, Larboulette (2009, p. 1) recounts that "when [students] are asked at the beginning of the class what they want to learn, most of them answer *Maya!"* Although this example is in a post-graduate setting, it illustrates learner priorities. If students believe that digital skills are equivalent to mastery of the discipline, then they may belittle or ignore other aspects of the multidisciplinary craft. This problem may be exasperated when animation theory and technical instruction are presented in separate courses and so timetabling risks diluting the connections between concepts and practice.

Secondly, the software interface and nomenclature can be confronting, especially for novice users. The nature of animation production necessitates a specialised digital literacy which maps geometric and spatial concepts with artistic expression, and navigating this vocabulary is a topic in itself. So deploying software to a cohort who are not conversant is an added burden to the identification and comprehension of tools. Koning (2012) describes this frustration in a case study of an advanced 3D animation class. The researcher recounts the difficulty students demonstrated in interpreting foundational geometric indicators, using and applying the standardised vocabulary and surmounting the complexity of the interface (Koning 2012). Elsewhere Mou (2018) concurs:

> In my teaching experiences of more than 10 years in 3D animation, many students are frustrated by complex interfaces and even lost their interest in creating animation because of difficulties in software… Therefore, there are few connections between art expression and technology support in current college education (Mou 2018, p. 2).

This quotation highlights the relationship between software and student performance and explains the effects of imprudent acceleration to high-end tools on proficiency and learner motivation. Mou (2018) goes on to expound that the arduous task of creating animated sequences using complex tools can greatly diminish student opportunities for iteration and experimentation, which subsequently affects the originality of their work (Mou 2018). Additionally, using software tools is only the first challenge students must overcome, as they also learn the universal animation skills such as performance, anatomy and the principles of motion and physics (Mou 2018, p. 4). Mou (2018) concludes that animation teachers can and should adopt better digital tools to support creativity, experimentation and overall improved learning outcomes.

2.6 Research Rationale and Aim

The above research strongly indicates that COTS products present many challenges when implemented in the classroom, for two reasons. Firstly, both students and educators can be swept away in revere of the software's sophistication, meaning that these applications are rarely chosen on their pedagogical merit. Secondly, the steep learning curves often associated with industrial tools can seriously demotivate or impede student development. Accordingly, students may dedicate disproportionate effort to merely learning the tools, at the expense of other essential animation concepts and principles, resulting in a skewed skillset upon graduation.

However, this is not to say that COTS programs should be avoided in education. On the contrary, confidence in using commercial tools is an important element in a graduate's repertoire and prepares them for professional work. Rather this dissertation asserts the need to choose classroom software more carefully, where options are evaluated on their compatibility with course objectives, theoretical instruction, and the learning needs of the student cohort. It is therefore hypothesised, that implementing improved software evaluation techniques would translate to a more fulfilling student learning experience, and therefore, stronger performance and employability prospects.

There is a general absence of literature on software tool comparison in higher education (Parker 2010). The reason for this is that software selection is generally an informal process, where through a series of faculty meetings, options are debated and a consensus is achieved (Parker, Ottaway & Chao 2006, p. 120). Therefore, whatever judgements or strategies previously applied have been largely undocumented and, at the time of writing, there is no apparent method for choosing animation software. This invisibility makes it very difficult to track progress and meaningful connections between software instruction and educational performance indicators.

Hence the research objective is to begin a formalised dialogue on this topic by developing a concept-of-prototype software selection tool. It will incorporate all the relevant pedagogical, technological and operational factors as well as provide a methodical evaluation process. Implementing this prototype is expected to improve the quality of decision-making and thus yield a healthier learning environment. Furthermore, its pragmatism will bolster organisational sustainability through increased cost awareness, transparent reporting, legacy management, and enhanced compliance with government and professional organisations. Towards this aim, the following section will elaborate on methods for performing software evaluations.

2.7 Software Selection Methods

Software evaluation is the process of comparing a pool of candidates against a set of established criteria. Within an educational context, the evaluation methods can be categorised into three classes. These are (a) evaluation during software development; (b) summative research of student software use; and (c) predictive analysis when investigating potential acquisition options (Mukherjee 2012). As the objective of this research aims to help educators make product choices, the third 'predictive' form is considered the most relevant approach.

Predictive evaluation methods for educational software have existed since the 1980s. The earliest technique was 'checklists' which required evaluators to respond Yes or No to a suite of functional criteria. Although these lists were methodical and easy to use, they struggled to measure the dimensions of software usability (Mukherjee 2012). Checklists were later challenged by the 'heuristics' approach in the 1990s, which maintained a greater focus on pedagogy and supported decision-making based on educator experience and intuition (Mukherjee 2012). Nevertheless, the qualitative nature of this evaluation left it open to unrecognised bias and meant that selection reporting was less transparent.

Both functional and usability concerns are relevant to educational software decision-making, and yet neither the checklist nor heuristics models adequately capture both domains. Accordingly, some scholars have turned to the field of management science in search of more comprehensive methodologies. For example, Multi-Criteria Decision-Making (MCDM) was the grounding framework employed in Parker's (2010) research regarding methods for choosing programming languages for an Information Technology degree course. As a field of operational research, MCDM is designed for complex scenarios and compares options according to diverse and sometimes conflicting criteria. Within this classification, it encompasses several derivative methods (Ishizaka & Siraj 2018). Among these is the Analytic Hierarchy Process (AHP), a weighted judgement system, which Hülle, Kaspar and Möller (2011) contend is the most common analytics tool in multifaceted management decision-making. The mathematical grounding of AHP will be discussed at length in Chapter 3.

So MCDM is a compelling option and in fact, embracing a pragmatic, commercial attitude to software selection is advantageous given the increasingly competitive landscape of tertiary education. Institutions face significant uncertainty as public funding allocations decline and social expectations of training provision shift (Agasisti 2017). Student populations are also more transient and comfortable with external study arrangements, intensifying the competition with private, inter-state and international providers (Salmi 2001). Accordingly, procurement decisions must always mitigate risk in support of operational sustainability and the 'bottom-line'.

In the literature, it is commonplace for researchers to customise generic software selection methodologies for specific domains. While the value of these remodelled tools should not be understated, Basir et al. (2014) nevertheless contend that there are recurrent flaws in how they are formulated. To summarise their criticisms, methods often:

- make undue assumptions about user requirements
- rely on single criteria to make assessments
- give insufficient consideration of 'non-functional' (qualitative) requirements
- provide an insufficient description of how the analysis is performed, or
- are procedurally too complex to be practicably carried out (Basir 2014, p. 92).

Accordingly, Basir et al. (2014) offer-their own derivative MCDM framework called the *Thorough Approach for Evaluation and Selection of Commercial Off-The-Shelf Products* (TAES-COTS) to address these shortcomings. The appeal of this method to the present research is threefold. Firstly, it accommodates both functional and non-functional evaluation, promising a rounded and thorough analysis. Secondly, it supports the precise handling of qualitative factors by combing the AHP with a quality model developed by Alvaro, Almeida and Meira (2006). This device converts qualitative characteristics into quantitative metrics and thus simplifies analysis standardisation. Lastly, TAES-COTS works on a multi-stage filtration process in which software candidates are gradually expelled from the investigation. This means that even if the evaluators start with a large pool of potential applications, incompatible options are quickly removed, minimising the time and effort needed to complete the procedure.

Despite these benefits, the TAES-COTS is still fractious in its handling of the AHP comparison. To describe briefly, Basir et al. (2014) propose a technique where qualitative attributes are individually assessed, composed into classes, and from there the cumulative values of each class are processed through an if-then analysis to discern the optimal software product. Practically, the conversion from individual to class scores is complex and represents a deviation from the original mechanics of the AHP method. Accordingly, it is proposed that the Likert Scale measures employed by Parker (2010), which is comparatively much simpler and a more familiar method, be synthesised into the TAES-COTS model.

Furthermore, the general nature of TAES-COTS requires that a custom list of selection criteria be defined for the proposed concept-of-prototype. Faced with a similar challenge, Parker, Ottaway, and Chao (2006) extracted recurrent themes from the discourse to inform their programming language benchmarks. Emulating this technique, the remainder of the literature review will be dedicated to a discussion of the two key research pillars relevant to the study. These are computer animation and the Australian education landscape. Exploring these domains will foreground relevant topics for the selection criteria as well as establish the context in which the prototype will ultimately operate.

2.8 Computer Animation

Computer animation has permeated most forms of advertising and entertainment, including film, television, visual effects, motion graphics and gaming. It is also found in digital technologies such as mobile applications, education, and the scientific fields of criminal forensics and engineering simulations. Given the diversity of its applications, the definition of animation can be elusive. In the following section, the concept of computer animation is approached from numerous perspectives, and this is helpful to understand the various ways it can be characterised and produced.

2.8.1 Computer Animation Categorisation

Animation can be described as 'imagery [which] is recorded frame-by-frame, and [where] the illusion of motion is created, rather than recorded' (Furniss 1998, p. 5). This definition distinguishes the two characteristics which separate animation from other forms of filmmaking: that is, (a) the decisive formulation of individual frames, and (b) the separate consideration of the motion in the construction of the sequence. There are, however, many different methods and styles of computer animation which will be presently discussed.

Firstly, animation can be categorised according to how the sequence is generated. Kainz, Jakab and Kardoš (2013) offer a three-tier classification system – artistic, data-driven and procedural - based on the role of the artist and the nature of the input. The *artistic* class represents the situation where the artist exercises complete control over the sequence and manipulates the motion on each frame to achieve the desired look. The second category is *data-driven* animation, whereby motion from another source is translated into a digital format. Although Kainz, Jakab and Kardoš (2013) do not offer an example in their research, animation through performance capture seems to be the implied meaning. Lastly, *procedural* animation is where motion is generated through computation. Here, simulations are produced from a set of input parameters defined by the artist. This technique is typically used for massively populated scenes such as rain effects or battle sequences where the scale demands significant reliance on digital processing.

Computer animation can also be distinguished stylistically into two systems: *ink and paint*, and *automated in-betweening* (Robertson cited in Fekete et al. 1995, p. 2). The *ink and paint* approach is a line art style which is a descendant of the traditional hand-drawn format. The artist may digitise paper sketches or work directly within a drawing application and create pen strokes using a stylus. The subsequent bounded regions of the graphics are then filled using digital paint tools. Once completed, these illustrations constitute the individual, consecutive frames which make up the animated sequence. Popular software tools within this category include Adobe Animator (previously Flash), OpenToonz, TVPaint and even Adobe Photoshop.

In contrast, *automated in-betweening* programs operate on a puppet system where the animator poses the figure on major keyframes, and then the computer automatically interpolates the frames 'in-between' based on the skeleton rig. Because positional information is attached to the rig, the motion can be expressed as a graph and used to control the speed, easing and exaggeration of an action. The editability and flexibility of this workflow make it the preferred method for commercial production, and thus the majority of animation software tools support this function. Examples include Autodesk Maya, Adobe After Effects, Smith Micro Moho, Cinema 4D, Blender and Toon Boom Harmony.

Further distinctions can be made based on the 'depth' of computer animation, that is, the number of dimensions that the software emulates. *2D animation* is planar, operating in a flat world contained by the X and Y axes of the canvas, and is often associated with cartoon-style production. *2.5D animation* is an extension of this format which enables the artist to displace 2D planes in the z-axis, thus supporting focal-length control and parallax. Finally, *3D animation* simulates a fully three-dimensional environment in which objects can be modelled with depth and volume. Unlike 2D and 2.5D styles, the 3D production pipeline requires the addition of modelling, texturing, rigging, lighting and rendering.

2.8.2 Applications and Trends

In an industry characterised by rapid change and task-specific workflows, conceptions of animation will continue to evolve to accommodate emerging technologies. Augmented Reality (AR), Virtual Reality (VR), intelligent performance capture and automation (such as lip-sync), and machine learning are among the most compelling recent advances in the industry. As these technologies transition from developmental to established tools, increased accessibility will reinvent media production. Not only that, but the way content is broadcast and consumed is also changing. According to a report from the Australian Bureau of Statistics, online content creation showed impressive growth and represented almost A$93 million in non-television production costs (Australian Bureau of Statistics 2017). This indicates that traditional broadcast is quickly being overtaken by on-demand services which are more accessible to both creators and consumers. A notable example is the success story of the children's cartoon 'Bluey' which is produced in Brisbane. As of April 2019, the program had achieved over 23 million downloads, becoming the most-watched show on ABC TV, and had been adopted by the British Broadcasting Corporation in the United Kingdom (McCutcheon 2019) and Disney (Harmon 2019).

In the independent sphere, platforms including YouTube and Vimeo present new opportunities for artists to publish their work in a public forum and gain exposure. Aspiring animators now have the means to produce and upload content freely without the need for institutional backing. Hence, one anticipates that increased exposure to home-grown, amateur content will translate to a shift in the entering university cohort. It is predicted that students will be keen on 'hit-the-ground' running curriculums which enable them to learn the necessary skills in an accelerated pathway so they can advance to content production more quickly. Use of automation techniques is therefore also expected to be in demand by students as opposed to traditional methods which are time and labour intensive.

In this turbulent landscape, the fundamental principles of animation remain a constant; transcending technology and style. These mechanics are widely acknowledged as the *12 Principles of Animation* (Thomas & Johnston 1981) which encapsulate the concepts of squash and stretch, anticipation, timing, follow-through and overlapping action, among others. Some authors have sought to modernise these tenets – Lasseter's (1987) article on the *12 Principles of Computer Animation* is a notable example – but they remain mostly unchanged since their invention in the 1930s. For this reason, many educators and professionals alike assert the importance of learning these fundamentals.

2.8.3 Computer Animation Education

With the evolution of computer graphics to its multidisciplinary composition and diverse applications, the educational and professional community recognised the need for standardisation and a baseline for academic instruction. In 2006 the *Computer Graphics Knowledge Base* (Alley 2006) was published which outlined seventeen domains, including animation, which were considered to be the essential skills and concepts. Looking at the adapted extract provided in Table 2, the volume of knowledge is striking. An accomplished animator must have a spectrum of expertise across technological, psychological, and artistic spheres and also demonstrate proficiency in team collaboration, problem-solving and project management. The guidelines also suggest that students within this specialisation should not only be skilled in the technical production and essential mathematics of the process but also have an eye for performance, cinematography and mise-en-scene. So, it is unsurprising, that educators often struggle to cover all of these topics in enough depth as well as deliver practical production experiences (Joel et al. 2018).

With this in mind, education will be the focus of the following sections; examining academic quality assurance via the Australian Qualifications Framework and the contribution of Minimalist Instruction in understanding how users interact with new technology.

Table 2: The Computer Graphics Knowledge Base adapted from Alley (2006)

Category	Sub-Topics (abbreviated)
CG Fundamentals	Overview of the field including the history, vocabulary, knowledge of hardware and software systems, knowledge of representations of visual systems, and foundational art concepts.
Professional Issues	Teamwork, project management, ethical considerations, intellectual property, accessibility, and business planning and analysis.
Physical Sciences	The laws of motion, light, fluid dynamics and biological systems.
Mathematics	Coordinate systems, transformation and deformation, random numbers, geometry, algebra, complex numbers, parametric and non-parametric representations and numerical methods.
Perception and Cognition	Visual, special, motion, interactive environment, psychology and human factors.
Human Computer Interaction (HCI)	Including information technology design, task analysis, and interface design.
Programming and Scripting	Data structures, object-oriented programming, languages, and graphics API.
Animation	Concepts including time and motion, interpolation, rigging, forward and inverse kinematics, texturing, modelling and rendering, characterisation, cinematography, motion capture, rigid body dynamics, procedural animation and particle dynamics.
Rendering	Scanline rendering, global illumination, algorithms, shading, anti-aliasing, camera operation and settings, and colour management.
Modelling	Including polygonal and NURBS techniques, subdivision surfaces, normal, animation and architectural modelling, level of detail for real-time and rendered graphics.
Graphics Hardware	Output and input devices, graphics cards, storage, networking, virtual and augmented reality.
Digital Images	Image processing and enhancement, compression, file formats, HDRI, and computer vision.
Communications	Technical and creative writing, storyboarding, presentation skills and improvisation.
Cultural Perspectives	Genres, socioeconomic effects, global aspects, age and gender.
Art and Design Foundations	Aesthetics, visual language, colour theory, composition, the historical development of art and design, two and three-dimensional expression, media as a social, cultural and political force.
Real-time Graphics	Requirements and optimisation of performance, hardware, software, rendering pipeline, applications in gaming, simulation, VR and AR.

2.9 The Australian University Environment

Bachelor's degree programs attract a diverse post-secondary school cohort of applicants who have a mixture of employment and life experience. Some may be exiting school and entering higher education for the first time, while others may be mature entrants who are seeking to upskill or pursue a career change. Within the degree structure, each student selects an area of specialisation with an expectation of gaining a robust knowledge base in that field to enable them to work across a range of roles and advance their career opportunities. In this pursuit, there is a significant financial and time commitment which must be acknowledged.

To provide some context to the learning scenario, undergraduate animation programs are typically divided into a suite of modular courses which can be undertaken as a minor or major area of study. These courses are usually stratified to progressively build on previously learned concepts and organised according to a central theme. Unlike art schools which offer highly specialised curriculums, universities have an obligation to achieve and maintain a level of training integrity which often necessitates a broader scope of curriculum topics. In Australia, accreditation and compliance are measured according to the *Australian Qualifications Framework* (AQF). In the AQF, a bachelor's degree equates to a Level 7 qualification, and therefore universities must meet set expectations for course length, training complexity and graduate skills. These stipulations are outlined in Table 3. As the figure articulates, students exiting undergraduate study should demonstrate "a broad and coherent body of knowledge, with depth in the underlying principles and concepts in one or more disciplines as a basis for independent lifelong learning" (Australian Qualifications Framework Council 2013, p. 48). It is also expected that candidates will have well-developed critical thinking skills to discern and synthesise knowledge, demonstrate autonomy towards work and learning tasks, be adaptable and able to problem-solve in complex scenarios, observe the precepts of professional practice and accountability, and exercise thoughtful decision-making skills. A bachelor's degree thus denotes a rounded and sophisticated skillset suitable for entry into professional work.

In teaching to this standard, universities may require students to undertake several generalist units such as an academic writing course. Some members of the industry see this as a point of competitive advantage, as Australian university graduates have been praised for their higher-order conceptual skills and contextual awareness in comparison to their vocational education counterparts (Doloswala, Thompson & Toner 2013, p. 416). However, others perceive generalist studies as an unnecessary distraction; consuming valuable time which might otherwise be spent perfecting an animation skillset. In either case, it is essential for the observer to recognise the unique composition of undergraduate study and that students may have a mixture of competencies entirely separate to their discipline concentration.

Table 3: AQF Specification for Bachelor's Degrees (Australian Qualifications Framework Council 2013, p.48)

Bachelor Degree qualification type descriptor	
Purpose	The Bachelor Degree qualifies individuals who apply a broad and coherent body of knowledge in a range of contexts to undertake professional work and as a pathway for further learning
Knowledge	Graduates of a Bachelor Degree will have a broad and coherent body of knowledge, with depth in the underlying principles and concepts in one or more disciplines as a basis for independent lifelong learning
Skills	Graduates of a Bachelor Degree will have: • cognitive skills to review critically, analyse, consolidate and synthesise knowledge • cognitive and technical skills to demonstrate a broad understanding of knowledge with depth in some areas • cognitive and creative skills to exercise critical thinking and judgement in identifying and solving problems with intellectual independence • communication skills to present a clear, coherent and independent exposition of knowledge and ideas
Application of knowledge and skills	Graduates of a Bachelor Degree will demonstrate the application of knowledge and skills: • with initiative and judgement in planning, problem solving and decision making in professional practice and skills and/or scholarship • to adapt knowledge and skills in diverse contexts • with responsibility and accountability for own learning and professional practice and in collaboration with others within broad parameters
Volume of learning	The volume of learning of a Bachelor Degree is typically 3 – 4 years

Given the constraints of academic study, it is important to optimise the time available and therefore educators need to implement strategies for efficient delivery and learning. In the following section, the tenets of Minimalist Instruction will be explored to understand adult learning behaviours in technological settings, as a foundation for achieving this goal.

2.9.1 Minimalist Instruction and the Learning Habits of Adult Users

Developed in the early 1980s, Minimalist Instruction is a set of principles for introducing users to unfamiliar computer technologies (Carroll 2014). A crucial part of Carroll's (1990) enquiry involved the identification of adult learning behaviours from which five strategies for best practice where derived:

- Allow the user to get started fast and let them work on meaningful tasks as soon as practicable
- Give the learner opportunities to infer information and improvise as this supports a more in-depth understanding
- Use authentic scenarios which align with the goals the learner brought with them when they started the training
- Exploit the knowledge and experience that users already have, and
- Provide error recognition and recovery to minimise confusion and frustration during the learning activity (adapted from Carroll 1990).

In reviewing these attributes, Carroll (1990) implies a ternary relationship between student motivation, task accomplishment and timeliness. Therefore, the best technology learning experiences occur when software tools are well matched to the activity goals, the cohort's digital competency and the timeframes for learning. Conversely, tool ambiguity and undertaking technically arduous tasks can jeopardise the engagement of the student and inhibit their progress. Equipped with this information, one can extrapolate tactics for software selection.

Firstly, the interface and navigation systems of animation applications should be assessed based on their usability and intuitiveness. Similarly, programs must have a semblance to authentic workflows and norms. Systems that deviate from standardised practice may contradict the student's prior knowledge, and thereby create confusion and detract from the activity purpose. Lastly, tools that offer in-built help and recovery mechanisms are attractive teaching instruments because learners are empowered to derive solutions independently.

2.9.2 Organisational Management and Sustainability

Having addressed the pedagogical aspects of animation, it is needful to consider the supporting operational background of the tertiary education sector. As previously mentioned, the education market is characterised by global competition, resourcing constraints, and stipulations for compliance and quality assurance. Accordingly, institutions must strategically manage their operations to navigate this environmental uncertainty. This extends to software procurement because of the financial expense, time investment and implications for technology infrastructure. For this reason, it is relevant to apply the principles of risk management (RM) in this research.

According to the revised *Risk Management – Guidelines ISO 31000:2018,* the concept of risk is the "effect of uncertainty on objectives", denoting that incomplete knowledge has an impact on decision-making and performance (Tranchard 2018). However, implementing RM principles (listed in Figure 2) can help to identify and mitigate risk through the process of data gathering and scenario planning. In thinking about the domain of software selection there may be risks associated with: the cost of ownership, compatibility with existing architectures, acquisition of new hardware, departmental staffing and professional development, classroom design, trouble-shooting and technology support, data storage and security, asset management and maintenance, licensing options, and student access rights and privileges. Although this list only offers a cursory glance of RM in this context, it illustrates the scope and specificity needed for the software selection prototype discussed in Chapter 3.

1. Creates and protects value
2. Be an integral part of organisational processes
3. Be part of decision making
4. Explicitly address uncertainty
5. Be systematic, structured and timely
6. Based on the best available information
7. Be tailored to the internal and external operating environment
8. Take into account human and cultural factors
9. Be transparent and inclusive
10. Be dynamic, iterative and responsive to change
11. Facilitate the continual improvement of organisations

Figure 2: The Eleven Principles of Risk Management (Comcover 2010)

2.10 Literature Review Summary

In examining the issue of animation graduate employability, this literature review has derived that a contributing factor to these outcomes is a lack of procedural software selection methods in the academic environment. Given the unique, multidisciplinary and evolving nature of computer animation, it was determined that a custom evaluative tool was needed to complement other efforts for reform.

Towards this aim, the research considered various decision-making tools and identified Multi-Criteria Decision-Making as a compelling platform for prototype development. However, recognising that selection criteria would need to be founded on a knowledge of the craft and the educational setting, the latter part of the discussion scoped these contextual factors.

The next chapter will further the research by presenting the modified TAES-COTS methodology, articulating the list of original criteria, and modelling the concept-of-prototype in Microsoft Excel.

3. METHODOLOGY

Quality decision-making requires the input of complete and accurate information. Thus, this research establishes a procedural framework which aspires to assist educators to gather and organise relevant data, and derive reliable solutions. The prototype will be constructed by synthesising the TAES-COTS methodology described in Basir et al. (2014) with the criteria development techniques of Parker, Ottaway and Chao (2006), and the AHP workflow presented in Parker (2010). The template will be generated in Microsoft Excel to facilitate mathematical analysis, shareability, and editing. Importantly, the predictive evaluation tool presented will be designed for commercial-off-the-shelf products, and not specialised or custom derivates, to maintain consistency with the TAES-COTS method.

To establish the groundwork for the prototype, this chapter will begin by describing the original TAES-COTS filtration system proposed by Basir et al. (2014). Following this, the selection criteria list will be expounded before being assembled into the prototype framework. The evaluation process will then be explained through a detailed commentary of each phase, the activities performed by the decision-making team, and the architecture of the Microsoft Excel template.

3.1 The TAES-COTS Framework

The unique quality of the TAES-COTS method is that the process of decision-making is divided into multiple stages of filtration. This means that in a potentially large pool of software candidates, incompatible contenders are promptly eliminated, leaving only a handful of viable options to undergo the full evaluation cycle. Thus, the overall effort to complete the analysis is minimised. The process is illustrated in Figure 3.

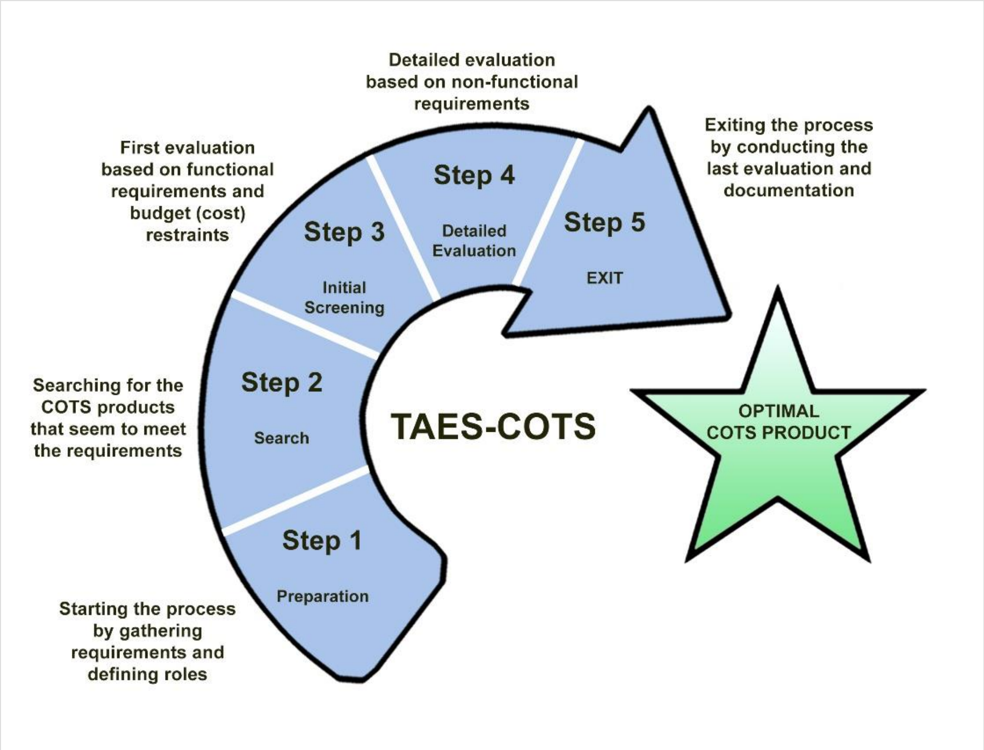

Figure 3: TAES-COTS Process (Basir et al. 2014)

The stages can be summarised as follows:

- *Step 1* involves the identification of stakeholders, the assembly of the evaluation team, establishment of roles and responsibilities, and the definition of objectives and priorities.
- *Step 2* is the gathering of various software candidates that appear to fit the identified need. This is typically undertaken by persons with expert knowledge, and may include product research and consultation with peers, industry professionals and software providers.
- *Step 3* is the first filtration phase and can be completed relatively quickly as candidates are assessed on basic mandatory functional requirements and overarching cost limitations.
- *Step 4* demands a more thorough examination by evaluating candidates on their qualitative features. In preparation for this phase, evaluators determine the criteria weights using the AHP method.
- *Step 5* is the conclusion and exit from the process. In tiebreaker situations, Basir et al. (2014) recommend a final comparison based on vendor credibility.
- The *result* is the optimal COTS product for the given situational parameters.

The benefits of the TAES-COTS model are its awareness of supporting activities in the decision-making process, precise consideration of both operational and usability factors, a ranking system embedded in the AHP analysis, and the provision of mechanisms to handle tiebreaker situations. Furthermore, the procedure can accommodate different types of evaluators who have a stake in the overall outcome. So the needs of educators, technical and administration staff, and the institution itself can all be taken into account. It is, however, is a general framework and thus requires customisation and expansion to meet the needs of the present research. Part of this modification is the inclusion of discipline-specific selection criteria, which will be the focus of the next section.

3.2 Animation Software Selection Criteria

Selection criteria are the bedrock of any software evaluation because they define the minimum performance and featuring standards needed for successful integration of the application into the given setting. Historically, educators have obviously made decisions on software selection, but a formalised record of the parameters used in their analyses may not exist. This research will address this gap by proposing a preliminary register and to do so, the methods described in Parker, Ottaway and Chao (2006) will be emulated. Their methods have been chosen because of the similarities in their research domain with the present study, albeit their focus was on computer programming languages.

In the research, they described a criteria formulation process which involved extracting significant and recurring concepts from the scholarly corpus, and then translating the data into usable metrics. The generated criteria were then seasoned by a pilot study conducted in Parker, Chao et al. (2006). Similarly, this dissertation will draw on the topics discussed in Sections 2.8 and 2.9 of the literature review, to assemble a baseline suite of criteria. Although the limited scope of this research does not allow for pretesting, validity trials would be a necessary step in the real-world implementation of the tool and recommendations for conducting this activity are given in the conclusion of the paper.

Four criteria classes have been devised and these are: (A) mandatory functional requirements, (B) optional functional requirements, (C) non-functional requirements, and (D) operational requirements. Following the TAES-COTS phases (see Figure 3), categories (A) and (B) correlate to the quantitative assessment in *Step 3*, while (C) invokes the qualitative appraisal of *Step 4*. Crucially, in respect of the operational constraints and considerations addressed in Section 2.9.2, a new fourth division is included in (D). The revised and expanded model used in the present research is given in Figure 4.

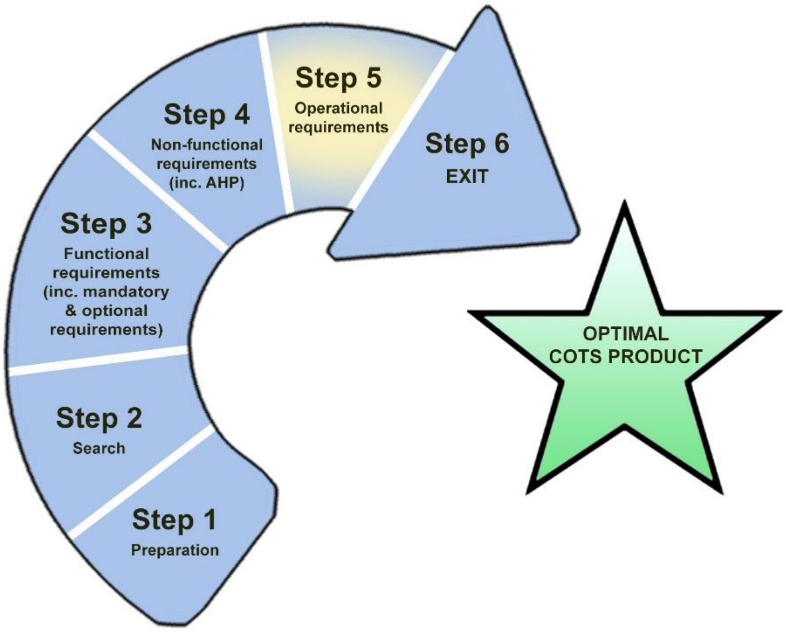

Figure 4: Prototype Evaluation Process

These phases, and the associated criteria, are illustrated in Table 4. As is shown in the fourth column, the response format will be different depending on the criterion type. The legend presented in Table 5 maps the response format to the metric descriptor. These codes are based on those proposed by Alvaro, Almedia and Meira (2006), which were used in the research by Basir et al. (2014). The original code set were comprised of P and IV. The rationale for the addition of AHP and S is that, in the prototype model, only some criteria are considered in the Analytic Hierarchy Process and the corresponding scalar assignation of suitability. Furthermore, the R parameter has been included to promote dialogue about the judgement, and therefore support decision-making transparency.

Table 4: Summary of Selection Criteria

	Category	*Criterion*	*Metric Type*
A	Mandatory Functional Requirements	Operating System Dependence	P
		System Requirements	P
		Support of Curriculum Domain	P and R
		Motion Visualisation	P
B	Optional Functional Requirements	4K Export	P
		Software Independence	P
		Motion Blur	P
		Scripting Capabilities	P
		Manuals and Training Resources	P and R
		Asset Library	P
		Particle Effects	P
C	Non-Functional Requirements	Versatility	AHP then S
		Industry Penetration	AHP then S
		Development Environment	AHP then S
D	Operational Requirements	Cost of Ownership (Institutional)	IV and R
		Cost of Ownership (to the Student)	IV and R
		Staff Training Provision	IV and R
		Time to Learn	R

Table 5: Metric Codes

Metric	Description
Presence (P)	A Boolean metric which identifies whether the feature is present or not.
Response (R)	A short-written response which expresses how the criterion is or is not met.
Analytic Hierarchy Process (AHP)	Indicates that the criterion must be evaluated and given a priority weighting before the candidates can be assessed against it.
Scale (S)	The degree of fit described as a scalar response.
Integer Value (IV)	The precise numeric value of a characteristic

In the following sections, each baseline criterion will be described in more detail. The discussion will articulate the relevance of the parameter to the evaluation, how it affects candidate advancement to the next phase and their preferential rankings, and denote mechanisms for scoring product features.

3.2.1 Mandatory Functional Requirements

The following criteria are mandatory requirements and are therefore considered essential for integration into existing classroom structures and to meet course learning objectives. When implementing this phase, evaluators must reach consensus on what are the minimum standards in their unique learning space, and include the specifics of the technology platform and curriculum structure in the Microsoft Excel template. Software candidates that fail to meet all of these requirements should be immediately culled from the pool.

Operating System Dependence

This criterion refers to the software compatibility with the hardware operating system used in the faculty. Many applications are platform-independent, affording the greatest flexibility to students and staff who may work across multiple devices. However, in situations where the software is incompatible, evaluators have the choice to either dispel this candidate or separately consider the procurement of new computing devices.

System Requirements

This specifies the minimum system requirements such as computer memory, processing and graphics capability, and hard disk space needed for optimal performance. Furthermore, specific animation techniques such as motion capture may need additional componentry such as cameras, microphone inputs, or drawing tablets.

Support of Curriculum Domain

This criterion assesses how well the application featuring meets the demands of the course specifications. Thinking about the stylistic needs of a particular study unit, evaluators need to match the software categorisation (that is: artistic, data-driven, or procedural; ink-and-paint or automated in-betweening; 2D, 2.5D or 3D) to the style of animation identified in the course synopsis. For example, 3D application may not be suited to a 2D character animation class. Some software does support multiple animation methods, and so these should be carried forward in the evaluation to further investigate their potential.

Motion Visualisation

Computer animation requires a way to visualise the change in motion over time so the artist can interpret the arcs, pace and exaggeration of the sequence. Ink-and-paint workflows typically use an ‘onion-skin’ technique where a set of drawings before and after the present frame are visible at a reduced opacity. In contrast, automated in-betweening software uses motion graphs which displays parameter change linearly over time. Most commercial software has a motion visualisation feature, but evaluators should check the presence of the desired system.

3.2.2 Optional Functional Requirements

The following optional criteria may support instructional design and enhance the creative opportunities afforded to the student. Nevertheless, these are not essential, and candidates need not fulfil any or all of the categories to progress to the next evaluation stage successfully.

4K Export

With 4K definition becoming increasingly popular for production, it is beneficial to have technology tools which support this workflow. This is especially relevant for students nearing the completion of their studies who are transitioning to work and are focussed on producing quality artefacts for their portfolios. Therefore, evaluator preference for this criterion may be relative to the skill level and objectives of the student cohort.

Software Independence

This criterion indicates whether the software is a stand-alone product, or if it requires partnering applications to complete its primary functions. Adobe Character Animator is one such tool that requires Photoshop, Illustrator and After Effects to be fully functional (although these particular products can be purchased as a suite). Working with a self-contained tool is preferable because it simplifies the installation process and minimises the number of applications which the students need to learn. Importantly, this category is only concerned with animation production and not auxiliary activities such as audio editing which requires its own specialised tools and workflows.

Motion Blur

Motion blur is useful for enhancing the realism and visual appeal of an animated sequence. However, it is neither a standard inclusion across animation software packages nor an essential feature for education outcomes. This criterion is mainly relevant for automated in-betweening software, as hand-drawn styles usually use ‘smear’ techniques, where transitioning frames are stretched or distorted, to simulate fast motion.

Scripting Capabilities

Having scripting capabilities enables students to customise the toolset, automate tasks and create procedural effects. So, scripting features offer the opportunity for more advanced workflows and diversification of the technical skillset.

Manuals and Training Resources

This category indicates the availability of quality software documentation and training resources. The majority of software developers provide comprehensive literature about their products although the language, scope and the clarity of the content (in terms of readability, organisation and use of jargon) may vary. Access to reputable materials assists the educator in preparing their teaching resources, gives the student an avenue for personal research and offers help for troubleshooting problems.

Asset Library

In like manner, the availability of pre-built character rigs and assets is an attractive feature and can reduce overall production time. Given the complexity involved in building custom elements, having a template which is ready to use enables the class to jump straight into their project. This is in support of the first principle of Minimalist Instruction.

Particle Effects

While commercial settings generally use specialised tools to generate particle effects, many software programs have in-built systems capable of simple simulations. The ability to create rain, snow or other replicating patterns natively within a program supports the creation of special effects without learning additional tools.

3.2.3 Non-Functional Requirements

The following three criteria are non-functional requirements which relate to the qualitative dimensions of the software. Given their subjective nature, they need to pass through the AHP model so that evaluators can assign numerical values to indicate their relative importance.

Versatility

Some institutions may prefer to teach multiple software applications in their curriculum, whereas others choose to deploy a single versatile program across multiple, threaded units. This criterion describes how well the tool can be adapted for other courses which may demand different animation styles or more advanced workflows.

Industry Penetration

This criterion refers to the acceptance and uptake of the application in commercial settings. If a university is preparing students for a particular industry sector, or expects that specific animation studios will employ a significant proportion of its graduates, it is crucial to use the associated software tools to promote employability. This is typified in industry partnership arrangements such as the collaboration between the University of South Australia and Rising Sun Pictures (University of South Australia 2019). In this scenario, the industry penetration category will be rated highly in the AHP. Alternatively, it may be of lesser concern for entry-level courses or generalist curriculum structures.

Development Environment

The development environment is the workspace in which the user operates (Parker, Ottaway & Chao 2006) and has a direct impact on their performance and understanding. The suitability of a software program is relative to the user's confidence and experience level. Therefore, the learning needs of novice users will be different to students who are well-advanced in their studies. So, the evaluator should consider the usability of the software interface and navigation such as the presence of context-sensitive menus, common short-cuts and movable panels and their support of the learner experience.

The student's prior knowledge and the learning goals will also be factors in this appraisal. Interface familiarity is important when teaching animation concepts as it enables learners to transfer technical knowledge and strategies into the new platform. Conversely sophisticated software tools, which by nature have more complicated and intimidating workflows (Jensen cited in Parker, Ottaway & Chao 2006), may demand a totally different mental schema of the user to understand its ways of working. A suitable example is the comparison between the animation and compositing programs, Adobe After Effects and Houdini. The former uses a layer-based system, which is a common structure across photo-editing, video and illustration tools. On the other hand, Houdini operates via a node-based system which is comparatively less prominent, but offers the unique benefits of a different and highly specialised workflow. So, evaluators need to understand the software intricacies and their impact on learners, and weigh the learning curves against course objectives and time constraints.

3.2.4 Operational Requirements

These final four parameters serve to ground the evaluation, and examine the surviving software candidates based on the practicality of their deployment. This fourth 'operational requirements' stage is an addition to the original TAES-COTS model, and has been situated at the end of the evaluation process so as to not distract from the learning focus. It is an important inclusion as it acknowledges the managerial and governance obligations involved in procurement decision-making.

Cost of Ownership (Institutional)

This criterion includes the expenses associated with the purchase and installation of the software. Many providers offer volume or enterprise licencing arrangements, and acquisition is based on the number of 'seats' needed for concurrent access. Variances in software plans may also include offering perpetual licenses and time-based subscriptions. To reconcile these different structures, it is recommended that the cost of ownership be considered over the hardware renewal lifecycle as determined by internal institutional protocols.

Cost of Ownership (To the Student)

The second dimension of the cost of ownership is the expense to the student. This criterion may be more significant for universities that have a large external student cohort where engagement with the courseware requires the use of personal technology devices.

Staff Training Provision

This item refers to staff competence in using the software, and determining the level of professional development needed to upskill as part of the deployment preparations. Training should be provided to meet the needs of educators, course examiners and technical support staff, and considered in the context of recruitment and succession planning. In this analysis, there are both temporal and financial commitments.

Time to Learn

At this stage in the evaluation, there should be one or more compelling software options. However, they should be tempered against the time constraints imposed by class timetable and the demands of the course activities. So programs should be chosen based on anticipated learning curves and the accomplishment of exercises and assessment items.

3.3 Animation Software Selection Prototype

Having now established the selection criteria, the remainder of this chapter will be dedicated to the architecture and operation of the prototype. Reflecting on Sections 3.1 and 3.2, the prototype has evolved from the original TAES-COTS procedure, introduced in Figure 3, to the modified version as represented in Figure 4 respectively. The evaluation was expanded to include the Operational Requirements stage, to accommodate the animation and educational setting. The discussion will now alliterate the chronological completion of activities, the organisation of the selection criteria into the separate filtration stages, the ancillary tasks performed by the evaluation panel and the alignment of the supporting Microsoft Excel template to the process (see Figure 5). Throughout the discussion, the research will highlight and explain any deviations from the standard model.

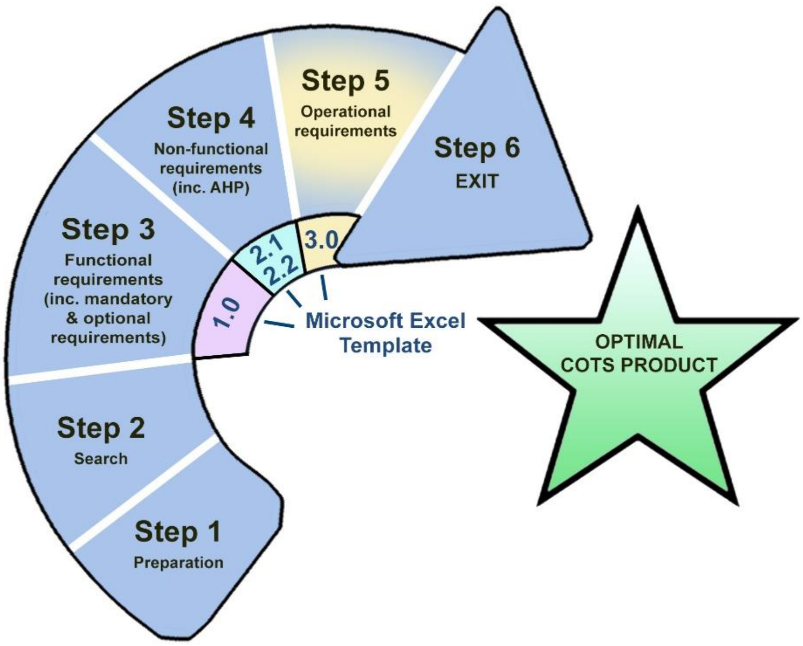

Figure 5: Prototype Alignment with Microsoft Excel Spreadsheets

It is important to note that the Microsoft Excel template, which is referenced graphically numerous times in the subsequent sections, has been populated with data from a fictional scenario. This has been done to demonstrate the operation of the tool and areas of customisation. Evaluators using the framework in a real scenario would need to supply parameters, such as the operating system of their student computers, that match their needs and circumstances.

Furthermore, the template is divided into four spreadsheets which correlate to stages of the evaluation process, and the relationships between them are illustrated in Figure 5 and coded in Table 6.

Table 6: Software Selection Steps Mapped to the Template Spreadsheet Tab

Evaluation Stage	Spreadsheet Tab
Step 1: Preparation	N/A
Step 2: Search	N/A
Step 3: Functional Requirement Filtering	1.0 Functional Requirements
Step 4: Non-Functional Requirement Filtering	2.1 AHP Criteria Weighting 2.2 Non-Functional Requirements
Step 5: Operational Requirement Filtering	3.0 Operational Requirements
Step 6: Exit	N/A

Throughout the process there are several ancillary activities performed by the evaluation panel that support decision-making but are not directly executed in the template. To understand how these parallel tasks fit within the overall system, an illustration is provided in Figure 6.

	Supporting Tasks	Filtration Activity
Step 1: Preparation	Team Assembly Assignment of Roles and Responsibilities Requirement Gathering	
RESULT:	Decision panel and evaluation protocols	
		↓
Step 2: Search	Software Candidate Search	
RESULT:	Pool of software candidates	
		↓
Step 3: Functional Requirement Filtering		Mandatory Functional Requirements Optional Functional Requirements
RESULT:	Filtered and ranked pool of candidates	
		↓
Step 4: Non-Functional Requirements	Assignment of Criteria Weightings AHP Consistency Check	Value Comparison
RESULT:	Ranked pool of candidates	
		↓
Step 5: Operational Requirements	Sourcing of software quotations	Cost of Ownership Staff Training Provision Time to Learn
RESULT:	Candidate profiles	
		↓
Step 6: Exit	Panel intervention on variance to resourcing limitations	
RESULT:	Optimal COTS product	
		↓
		Initiation of procurement, departmental restructures and professional development. Reporting and distribution.

Figure 6: Prototype Animation Software Selection Process

3.3.1 Step 1: Preparation

Team Assembly

The process begins with the assembly of the decision-making team. The group is expected to be a small complement of people (up to ten) and be composed of a range of stakeholders from within the institution. Members may include heads of department, academic staff, technicians, procurement and other administrative officers. Once the members have been established, the addition of new participants is discouraged as the change in roles may disrupt the evaluation.

Assignment of Roles and Responsibilities

The next step is to determine the team roles according to the individual's professional appointment and domain of expertise. Responsibilities may be shared with regards to reporting activities, gathering software candidates, and trialling application features. However other tasks may be delegated to the relevant expert on the panel.

One of the goals of the prototype is to improve decision-making and accountability in the software procurement process. Consequently, there should be a dedicated assignment for documenting discussions and judgements made throughout the evaluation. While the Microsoft Excel template serves to capture the comparative analysis, other communications such as meeting minutes and correspondence with external vendors should also be recorded. This is important data for assessing risk, upholding managerial best practice, performing summative post-deployment evaluations, and to provide a baseline for future iterations.

Requirement Gathering

Upon finalising the roles of panel members, consensus should be reached on the goals and parameters of the evaluation. Points for consideration include the learning objectives, the animation style to be delivered in the syllabus, the number of software licenses needed, and the hardware specifications.

3.3.2 Step 2: Search

Software Candidate Search

Having defined some basic parameters for the product, the participants can begin researching and compiling a list of possible software options. Towards this aim, they may look to the following sources:

- Software currently in use within the faculty
- Internal information about COTS products, such as documentation about past acquisitions
- Software used by team members in personal or other professional spaces
- Online reviews and product demonstrations
- Resources from professional conferences or technology conventions
- Direct enquiries to software providers
- Research into or direct enquiries to commercial studios.

Collection through these avenues should present a reasonably comprehensive list of software programs. As part of this process, the key features and product specifications should be documented as these will be the input for the first comparative analysis.

All plausible candidates should be included in the pool because undocumented judgements can undermine the transparency and reliability of the decision. The panel can be confident that the filtration system will fairly measure the product suitability and quickly eliminate incompatible options. With this sentiment, emerging and avant-garde applications should not be ignored as there may be unforeseen features and competitive advantages in using these products. Likewise, options that initially do not seem to fit expectations should not be dispelled.

3.3.3 Step 3: Functional Requirement Filtering

This represents the first evaluation phase is performed by completing worksheet '1.0 Functional Requirements' in the Microsoft Excel template (see the example in Figure 7). This stage is divided into two classes, mandatory functional requirements and optional functional requirements, according to criteria importance.

Mandatory Functional Requirements

This stage is the simplest level of comparison and assesses applications based on their compatibility with existing computing hardware and the defined learning objectives of the course. The criteria include:

- Operating System Dependence
- System Requirements
- Support of Curriculum Domain
- Motion Visualisation.

Evaluators start by inserting the parameters defined in the *Requirement Gathering* stage under the respective Mandatory Requirement headings and list the candidates for evaluation. From there, the table is completed by comparing product specifications to each topical area using a Boolean response. For the *Support of the Curriculum Domain* criterion, it is also recommended that a short annotation be recorded to indicate the reasoning for the score.

At the conclusion of the mandatory requirement stage, only candidates that satisfy all dimensions of the strict and divisive criteria set progress to the next evaluation stage. This is shown in Figure 7 by the orange *Satisfactory?* row. Candidates that fail in one or more fields are eliminated from further consideration.

Optional Functional Requirements

The narrowed candidate pool progresses to the optional featuring analysis, and are assessed against a list of compelling but nonessential criteria. Using the technique demonstrated by Basir et al. (2014), products that exhibit all the features are demarcated with an asterisk. This flag may be used as a tiebreaker towards the end of the evaluation. The criteria in the optional functional requirement class include:

- 4K Export
- Software Independence
- Motion Blur
- Scripting Capabilities
- Manuals and Training Resources
- Asset Library
- Particle Effects

Result

Candidates should be listed under the *Successful Candidates* heading in order of their compatibility. These products will progress to the third stage of filtering which appears on the 2.2 Non-Functional Requirements spreadsheet.

Functional Requirements

		Software Candidates								
		Harmony Essentials v16.0	Harmony Advanced v16.0	Moho 13	Adobe After Effects	Adobe Animate CC	Adobe Character Animator	OpenToonz	TV Paint Standard Edn	Clip Studio Paint EX
Mandatory Requirements	**Operating System Dependence** Macintosh iOS 10.14.0	Yes	Yes	Yes	Yes	Yes	Update to 10.14.1 req.	Yes	Yes	Yes
	System Requirements 8GB RAM 3.1GHz 6-core Intel Core i5 Radeon Pro 575X, 4GB GDDR5	Yes	Yes	Yes	Requires 16GB RAM	Yes	Yes	Yes	Yes	Yes
	Support of Curriculum Domain 2D Automated In-betweening Character Animation	Yes	Yes	Yes	Yes	No. Ink-and-paint only	Yes	Yes	No. Ink-and-paint only	No. Ink-and-paint only
	Motion Visualisation Graph Editor	Yes	Yes	Yes	Yes	Yes	No. Performance capture only.	Yes	No. Frame-by-frame only	No. Frame-by-frame only
	Satisfactory?	Yes	Yes	Yes	No	No	No	Yes	No	No
Optional Requirements	**4K Export**	No	Yes	Yes				Yes		
	Software Indepedence	Yes	Yes	Yes				Yes		
	Motion Blur	No	No	Yes				Yes		
	Scripting Capabilities	Yes	Yes	Yes				Yes		
	Manuals and Training Resources	Yes	Yes	Yes				Limited		
	Asset Library	Yes	Yes	Yes				No		
	Particle Effects	No	No	Yes				Yes		

Successful Candidates

- Moho 13*
- OpenToonz
- Harmony Advanced v16.0

Stage 1 Instructions

• Input the custom Mandatory Requirements under each of the criteira.Complete the matrix by answering Yes/No beside each selection criteria. Provide annotations if applicable.

• Indicate in the orange 'Satisfactory?' row if the software meets all of the mandatory requirements. If they do not meet these minimum standards then the investigation of these tools can be discontinued.

Figure 7: Functional Requirement Filtering in 1.0 Functional Requirements spreadsheet

3.3.4 Step 4: Non-functional Requirement Filtering

Step 4 involves the assessment of the qualitative 'non-functional' aspects of the software. Before continuing the evaluation, however, panel members must assign priority weightings to the three sectional criteria according to their comparative preference. In the Microsoft Excel template, this is separated into two sub-stages designated by the '2.1 AHP Criteria Weighting' and '2.2 Non-Functional Requirements' spreadsheets.

Importantly, given that these criteria require some depth of software familiarity in order to make informed judgements, the evaluators may need to experiment with trial versions of each application to understand its layout and workings. Accordingly, a block of time should be allocated in the evaluation schedule for this testing process.

Assignment of Criteria Weightings

Both Basir et al. (2014) and Parker (2010) recommend the Analytic Hierarchy Process (AHP) as the grounding framework to assign criteria weightings, although there is some variance in their comparative methods. Prior to addressing this distinction, however, this section will begin by illustrating the mathematical logic beneath the AHP value comparison and how this is implemented in the prototype.

The Mathematics of the AHP

Developed by Saaty (1980), the AHP is a general theory of measurement which uses discrete and continuous paired comparisons to formulate ratio scales (Saaty 1987). This method thus empowers evaluators to make meaningful preferential distinctions between selection criteria and articulate trade-offs in decision-making. The process begins with the compilation of the criteria list, which in this case are the three non-functional parameters:

- Versatility
- Industry Penetration
- Development Environment.

It is recommended that criteria be kept to a minimum, as the number of comparative judgments increases dramatically for each additional item. This relationship is shown in Table 7. Large numbers of categories (that is, more than seven) intensify the complexity of the comparative assessment and make it challenging to detect inconsistency later in the AHP (Saaty 2013).

Table 7: The Number of Comparison Judgements per Criteria

Number of Criteria	1	2	3	4	5	6	7	n
Number of Comparisons	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

The AHP method pivots on a pair-wise comparison matrix, where the criteria are organised along both the horizontal and vertical axes, with the number of rows and columns dictated by the criteria count. The matrix employed in the prototype is provided in Figure 8.

2.1.1 Pair-wise Comparison Matrix

	Versatility	Industry Penetration	Development Envmnt
Versatility	1.00	0.33	5.00
Industry Penetration	3.00	1.00	7.00
Development Envmnt*	0.20	0.14	1.00
Column Sum =	4.20	1.48	13.00

**Note that 'Development Environment' has been abbreviated for formatting reasons.*

Figure 8: Pair-wise Comparison Matrix in 2.1 AHP Criteria Weighting spreadsheet

The evaluator proceeds to input their preferential scores in the upper triangular matrix as highlighted in yellow in Figure 8. This is achieved using Saaty's Fundamental Scale (Table 8) which translates qualitative judgements into fractional scores. Criterion in the left column are progressively compared with criterion listed in the header row. Where the column criterion is preferred over the row criterion, an integer is assigned to the cell, with higher values indicating a greater priority. So, using the example in Figure 8, *Versatility* [left column] is considered strongly more important than *Development Environment* [header row], and so scores $\frac{5}{1}$ or 5.00. Conversely, a positive value less than one is given where the header row criterion is dominant.

The logic of the tabular layout means that each comparison is repeated in reverse (depicted as the white cells in Figure 8) and therefore, the intensity of importance is transposed as the reciprocal fraction. That is, the reverse judgement of *Development Environment* to *Versatility* renders a score of $\frac{1}{5}$ or 0.20. As shown in the illustration, the diagonal fields (in grey) are always a value of one because the criteria are being assessed against themselves.

Table 8: The Fundamental Scale adapted from Saaty (1987)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement moderately favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	Experience and judgement very strongly favour one activity over another
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	

After the pair-wise comparison, the AHP method requires the scores to be converted to a percentage. This is achieved by dividing each cell by the column sum, shown in light grey in Figure 8. Once the judgements are normalised, the row average is calculated to compute the 'Criteria Weight' (see Figure 9).

2.1.2 Normalised Pair-wise Comparison Matrix

	Versatility	Industry Penetration	Development Envmnt	Criteria Weight
Versatility	23.8%	22.6%	38.5%	28.3%
Industry Penetration	71.4%	67.7%	53.8%	64.3%
Development Envmnt	4.8%	9.7%	7.7%	7.4%
Column Sum =	100%	100%	100%	100%

Figure 9: Normalised Pair-wise Comparison Matrix in 2.1 AHP Criteria Weighting spreadsheet

Examining the sample values in Figure 9, one can see that *Industry Penetration* has the highest importance with a value of 64.3 per cent followed by *Versatility* at

28.3 per cent, and lastly the *Development Environment* at 7.4 per cent. These fictional scores are suggestive that software is being chosen for a skilled student cohort who are preparing for entry into the workforce, hence the variance between the *Industry Penetration* and *Development Environment* weightings.

AHP Consistency Ratio

Due to the subjective nature of the qualitative assessment, and the intangible parameters, evaluator inconsistencies can be present in comparative judgements. This can be symptomatic of having an unmanageable number of criteria in the pair-comparison or can simply occur because human judgements are not always perfectly logical. To explain, rational deduction states that if a person values A > B and B > C, it is inherently expected that A > C. Therefore, a preference score of A < C would be an illogical response. Nevertheless, a degree of inconsistency is acceptable in the AHP because of the subjective nature of the assessment. As Saaty (1987, pp. 164-5) describes, where judgement values differ from the expected score, the corresponding apogee of the reciprocal calculation lessens the overall aberration. To keep irregularity within a reasonable margin and therefore sustain outcome validity, Saaty (1980) formulated a Consistency Ratio (CR). This measure expresses the uniformity of the decision-making by computing an approximation of the Principal Eigenvector for the matrix. Importantly, as this is an estimated value, there is a chance of rank reversal, although small matrices (with up to three criteria) mitigate this risk (Saaty 1987).

Consistency calculations are almost entirely automatic in the Microsoft Excel template, making the tool accessible to nontechnical users. Nevertheless, it is advantageous to describe here the underlying mathematical architecture. Generating the CR is a four-step process. It begins by multiplying each cell from the original pair-wise comparison (Figure 8) by the relevant criteria weight (Figure 9). This gives the Weighted Sum Vector given in Equation 1; where W_S is the vector, C represents the pair-wise comparison matrix, and W is the Criteria Weight. The W_S vectors for the fictional scenario are given in the white cells in Figure 10.

Equation 1: Weighted Sum Vector Formula

$$\{W_S\} = [C] \times \{W\}$$

2.1.3 Consistency Check	Versatility	Industry Penetration	Development Envmnt	Weighted Sum	
Versatility	0.28	0.21	0.37	0.87	3.06
Industry Penetration	0.85	0.64	0.52	2.01	3.12
Development Envmnt	0.06	0.09	0.07	0.22	3.01
				λ max =	3.066
				C.I. =	0.033
	R.I. =	0.58		C.R. =	0.056

Figure 10: Consistency Check in 2.1 AHP Criteria Weighting

From there, the summation of each row produces the 'Weighted Sum' values depicted in grey (Figure 10). The Weighted Sums are further divided by the Criteria Weights (referenced from Figure 9) to give the values highlighted in orange in Figure 10. These are then averaged to determine λ_{max} (the purple cell in Figure 10), which represents the Eigenvector estimate.

From here, the Consistency Index (CI) is calculated using the formula given in Equation 2, where n is the number of criteria. Equation 3 demonstrates the CI calculation using the fictional values from Figure 10, rounded to three decimal places.

Equation 2: Consistency Index Formula

$$\text{CI} = \frac{\lambda\,\text{max} - n}{n - 1}$$

Equation 3: Sample Consistency Index Calculation

$$\text{CI} = \frac{3.066 - 3}{3 - 1} = 0.033$$

The last step is to compute the CR. This is achieved by dividing CI by the corresponding figure given in Saaty's Random Index (Table 9). This calculation is given in Equation 4. These Random Index (RI) values were obtained through a simulation which averaged 500 randomly generated reciprocal matrices (Saaty 1987).

Table 9: Saaty's Random Index (Saaty 1987)

Number of Criteria (n)	1	2	3	4	5	6	7	8	9	10
Random Index (R.I.)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The prototype simply requires that the user determine the RI relative to the number of matrix criteria (n) and input it into the pink cell (shown in Figure 10). Equation 5 provides the CR calculation for the scenario given in Figure 10. If the CR value is less than 10 per cent (that is, 0.1) then the judgement inconsistency is tolerable. If not, the evaluator should be prompted to reconsider their initial preference scores in the pair-wise comparison matrix.

Equation 4: Consistency Ratio Formula

$$\text{CR} = \frac{CI}{RI}$$

Equation 5: Sample Consistency Ratio Calculation

$$\text{CR} = \frac{0.033}{0.58} = 0.056$$

At this stage, the evaluator has completed the '2.1 AHP Criteria Weighting' spreadsheet and finalised their preferential scoring. The Criteria Weights derived from the AHP are carried forward to the '2.2 Non-Functional Requirements' spreadsheet where the software candidates are assessed against the three qualitative criteria.

Value Comparison

At this point, the research deviates from the original TAES-COTS method. In the Basir et al. (2014) model, due to the high number of criteria, a clustering system was used to categorise parameters and then candidates were ordinally rated. The limitation with this approach, however, was that the conversion process was complex and distinctions between options were not clearly defined.

The prototype instead adopts an AHP value comparison technique proposed by Parker (2010), where the evaluator rates each application according to its perceived suitability with the row criteria using a ratio scale. This *Satisfaction Value* (the blue columns in Figure 11) is then multiplied by the respective criteria weight to generate the *Weighted Score* (the white columns in Figure 11). These figures are then averaged to give an overall score for each candidate. The in-built conditional formatting of the spreadsheet automatically colour-codes these results to highlight the best performing products. Looking at the sample in Figure 11, Harmony Advanced v16.0 is the strongest performer in this stage, closely followed by Harmony Essentials v16.0. While these are compelling options for acquisition, *Step 5* will differentiate the candidates according to affordability and the practicality of deployment.

Non-Functional Requirements

		Moho 13*		OpenToonz		Harmony Advanced v16.0		Harmony Essentials v16.0	
Criteria Weight	*Criteria*	*Satisfaction Value*	*Weighted Score*	*Satisfaction Value*	*Weighted Score*	*Satisfaction Value*	*Weighted Score*	*Satisfaction Value*	*Weighted Score*
28.3%	Versatility	5	1.41	4	1.13	7	1.98	7	1.98
64.3%	Industry Penetration	3	1.93	2	1.29	7	4.50	5	3.22
7.4%	Development Envmnt	6	0.44	2	0.15	4	0.30	4	0.30
			2.37		1.43		4.80		3.51

Likert Scale						
1	2	3	4	5	6	7
Extremely Unsatisfactory	Very Unsatisfactory	Unsatisfactory	Neutral	Satisfactory	Very Satisfactory	Extremely Satisfactory

Candidates (in order of Non-Functional preference)

- Harmony Advanced v16.0
- Harmony Essentials v16.0
- Moho 13*
- Opentooz

Figure 11: Value Comparison in the 2.2 Non-Functional Requirements spreadsheet

3.3.5 Step 5: Operational Considerations

This final filtration stage, which is an addition to the original TAES-COTS format, introduces essential operational constraints via consideration of the three selection criteria:

- cost of ownership
- staff training provision
- time to learn.

These have been purposely left to the end of the evaluation so as not to interfere with the pedagogical analysis of candidates, and to deliberate on overarching activities which may impact faculty structures and finances. At this stage, the candidate pool should be considerably reduced, and the surviving options ranked according to their appeal. This phase, then, serves to differentiate products according to resourcing and timetabling constraints. Unlike the previous comparative analyses which have been sequential and produced ordinal outcomes, *Step 5* requires a holistic viewpoint where the cumulative data across the three metrics contribute equally to the final decision.

Given that resourcing can be malleable, according to changes in funding allocations and institutional strategic direction, there may be opportunities for negotiating these factors internally and externally. Accordingly, there may be some flexibility in the solutions derived from this analysis. To give an example, if the most compelling software option is over budget then team members may decide to seek additional funding from within the university or via external sources such as government grants. Where this is not feasible, the panel can nominate alternatives based on the candidate rankings generated by the tool.

Cost of Ownership

As previously articulated, the cost of ownership relates to the expense incurred in procuring and implementing the application. Part of the challenge, however, is reconciling the different software pricing structures, namely subscription versus perpetual licencing, as well as currency conversion.

The Microsoft Excel template handles the first problem by calculating the cumulative subscription costs over a designated period, such as the anticipated hardware renewal lifecycle, and uses this value as the basis for comparison. As shown in Figure 12, the template enables users to input their own ‘Estimated Time of Institution Ownership’ data (see the orange cells) which automatically feeds into the cost calculations. With respect to the second issue, the template prompts users to provide exchange rate information, where applicable, and the values are automatically converted to Australian Dollars. The conditional formatting features of the spreadsheet ranks options according to the total adjusted cost, from least to greatest. Free applications, such as Opentoonz shown in Figure 12, are attributed a zero cost.

Operational Requirements

Cost of Ownership (To the Institution)				
	Software Candidates			
	Harmony Advanced v16.0	**Harmony Essentials v16.0**	**Moho 13***	**Opentooz**
Cost (21 Licenses)	$ 5,289.90	$ 2,923.31	$ 4,183.20	$ -
Currency	AUD	AUD	USD	n/a
Currency Conversion (to $AUD)	n/a	n/a	$ 6,149.30	n/a
License Duration	*Yearly Subscription*	*Yearly Subscription*	*Perpetual*	*Perpetual*
Cost of Ownership	*$ 15,869.70*	*$ 8,769.93*	*$ 6,149.30*	*$ -*
Cost of Ownership (To the Student)				
Cost of a Single (Academic) License	$ 9.00	$ 6.00	$ 239.99	$ -
Currency	USD	USD	USD	*n/a*
Currency Conversion	*$ 13.23*	*$ 8.82*	*$ 352.79*	*$ -*
Licence Duration	*Monthly*	*Monthly*	*Perpetual*	*Perpetual*
Cost of Ownership	*$ 79.38*	*$ 52.92*	*$ 352.79*	*$ -*
Exchange Rates (as at 5 Sept 2019)	USD to AUD:	1.47		
Est. Time of Institution Ownership	Years:	3		
Est. Time of Student Ownership	Years:	0.5		

Figure 12: Financial Comparison in 3.0 Operational Requirements spreadsheet

Volume licensing enquiries should be directed to the relevant software provider, and this correspondence must describe the specific departmental hardware configurations so that accurate quotations can be given. Notably, enterprise products may include additional benefits and applications, and this should be recognised in any panel discussions.

In preparing the sample cost inputs shown in Figure 12, estimates were sought from the Smith Micro and Toon Boom corporations based on a computer laboratory with 21 iMac devices. The response quotations are provided for reference in Appendix 1 and Appendix 2.

Concerning the cost of ownership for the student, unless otherwise stated in the vender quotation, estimates can be typically retrieved from online stores and retail outlets. The template calculations operate in a similar way to the institutional section, with one important point of difference. A separate field has been provided for the 'Estimated Time of Student Ownership' based on the understanding that the duration of student software usage is variable depending on their study specialisation.

Equipped with these statistics, it is up to the evaluator to make trade-offs between these two categories according to the budget constraints of the organisation and the expected personal uptake of the software by the student cohort.

Staff Training Provision

Training may be necessary to maintain currency with industry practice and new technology releases, and where academic or technical staff are unfamiliar with candidate products. Accordingly, the financial and time investment of professional development must be considered in procurement decisions. These dimensions are integrated into the prototype (see *Figure 13*).

There are multiple avenues for learning the featuring and maintenance of software tools. The most accessible means is via online tutorials or paid services. However, opportunities to attain vendor accreditation through specialist courses may also be available. In this case, there may be additional expenses for travel, accommodation and employee wages. Training schedules should also be reviewed to coincide with the expected deployment date and staff availability.

Staff Training Provision				
	Software Candidates			
	Harmony Advanced v16.0	**Harmony Essentials v16.0**	**Moho 13***	**Opentooz**
Number of Trained Staff	3	3	1	0
Staff Training Required	No	No	Yes	Yes
Cost of Training Provision (not including Cost of Wages)	n/a	n/a	Free video tutorials available from developer. Udemy course $55.00	Limited English instructional resources from developer. Udemy course $65.00
Estimated Training Days Required (per person)	0	0	10	17
Additional Expenses Per Person	n/a	n/a	n/a	n/a
Time to implement before semester commencement?	Yes	Yes	Yes	No

Figure 13: Staff Training Requirements in 3.0 Operational Requirements spreadsheet

	Software Candidates			
Time to Learn	**Harmony Advanced v16.0**	**Harmony Essentials v16.0**	**Moho 13***	**Opentooz**
Does competence in the software seem reasonably achievable for weekly activites? For assessment projects? Describe any factors that may forseeably impact learning or the completion of course objectives.	[Annotation]	[Annotation]	[Annotation]	[Annotation]

Figure 14: Time to Learn analysis in 3.0 Operational Requirements spreadsheet

Time to Learn

This category is unique in the evaluation process as it is the only element that requires a brief written response. Here evaluators are asked to reflect on their professional experience and comment on the anticipated time students will need to functionally engage with the application, and whether it is reasonable to expect that the competence level for assessment can be achieved within the study duration (see Figure 14).

3.3.6 Step 6: Exit

At the conclusion of the evaluation, the optimal software application should be evident and procedures for procurement, departmental restructures and professional development should be initiated. Team members responsible for reporting should finalise, compile and distribute the documentation to the relevant stakeholders, before archiving the materials for reference in future evaluations.

3.4 Methodology Summary

This chapter has demonstrated the application of the modified TAES-COTS methodology, in the development of the animation software selection prototype. By combining the MCDM techniques of Basir et al. (2014) and Parker (2010), a software selection model was produced which offers an intuitive and thorough candidate sorting process. The suite of original criteria for animation software appraisal were derived from literature using the methods described in Parker, Ottaway and Chao (2006), and then organised into the relevant evaluation stages. Significant attention was also given to the Analytic Hierarchy Process to describe the underlying logic in the qualitative comparisons.

The discussion has been complemented with extracts from the Microsoft Excel template to illustrate the decision-making process and the use of this support tool. The focus of the next section will be a reflection on the anticipated benefits of the prototype, as well as some suggestions for template improvement.

4. DISCUSSION

Reforming animation education is an ambitious project and software selection tools alone cannot possibly address all the issues at hand. Nevertheless, the proposed prototype does direct evaluators to ponder variables that may not have been previously considered and perhaps this will spur on a new direction for improvement in the discourse. So, even in its current developmental phase, this tool has merit. This chapter will expound on those benefits and assert the framework's place in the academic domain.

The prototype was designed with a variety of decision-makers and stakeholders in mind, and so simplicity and practicality were the grounding principles of its development. The template was constructed so that the user can intuitively progress through the comparison process and enter requisite data in a straight-forward manner. Where possible, the results are generated automatically, and there are in-built error recognition mechanisms in the template so that inconsistencies can be identified and resolved. Furthermore, the panel can customise and shape criteria parameters to reflect their priorities and prominent elements relevant to their animation course.

Evaluators are encouraged to consider all COTS software applications, even those which are experimental or on the periphery of industry acceptance. The sharp filtration in *Step 3* means that these speculative options can be fairly assessed with the knowledge that any incompatible options will be quickly eliminated. The breadth of inclusion, however, opens up the investigation to be attuned to new trends and shifts in technology, and may highlight unexpected solutions or opportunities for innovation. Computer animation production is so changeable and dynamic, that this inclusive approach takes a responsible position and is true to the spirit of the discipline. The resulting documentation captures a comprehensive profile of the software landscape and becomes an artefact for ongoing reflection and iteration.

One of the strengths of the Microsoft Excel template is that it empowers decision-makers to perform quick 'what-if' analyses by trialling values and observing the impact on candidate scores and rankings. The implication is that the panel can use this to re-examine the faculty priorities, content delivery and ways of working in support of continuous improvement.

The prototype upholds operational best practice and promotes thoughtful decision-making. It enables evaluators to justify selections to stakeholders by providing accountability and transparency via the documentation. Where the situation arises, the panel is also equipped to negotiate structural changes or financial allowances if the cost-benefit analysis of the successful candidate cannot be ignored. Even when these changes are not feasible, the prototype equips evaluators to make trade-offs and consider other candidates in the final stages.

Evidently software selection is complex and can be challenging to make fair comparisons. While the prototype covers a breadth of parameters, its capabilities for reporting and data visualisation could be further enhanced to make the tool more accessible and meaningful for users. Recommendations include graphical representations of candidate performance, expanded summaries at milestone events, provision of timelines and dashboard services, workbook security features and shareability rights, additional data validation, and greater interactivity for conducting 'what-if' analysis. Furthermore, platforms support for real-time multi-user contributions would enable participation of the decision panel from varying locations.

Lastly, the carrying forward of preference judgement could be improved as the candidates transition from the *1.0 Functional Requirements* to *2.2 Non-Functional Requirements*. At present, it is up to the user to list succeeding candidates and their ordinal rankings at the end of each stage, and then translate them to the following spreadsheet. So, automation of this transfer would streamline some aspects of the analysis and reduce user input errors. However, the tool is functional in its current state and the Microsoft Excel platform facilitates adaptation on-demand according to the needs of participants.

5. CONCLUSION

This dissertation makes an original contribution to the animation education discourse in the development of a software selection prototype, and supports university reform and improved graduate employability. The research has taken an interdisciplinary stance – drawing knowledge from the computer graphics, management science and education fields – to provide a well-rounded discussion of the topic. Using Activity Theory as the initial lens to examine the education setting, it was found that software tools have a significant impact on performance, craft perceptions and student motivation. Based on this rationale, the research traced the legacy of software selection methodologies and concluded that an adapted Multi-Criteria Decision-Making framework – based on the works of Basir et al. (2014), Parker (2010) and Parker, Ottaway and Chao (2006) - would be the ideal tool to manage the complexity of the proposed evaluation. In the development of the prototype, a suite of selection criteria was devised and integrated into a multi-stage filtration system which included a Microsoft Excel template.

Given the limited scope, further research would be beneficial to test the construct validity of the individual selection criteria, and conducting a pilot study would evaluate the overall performance of the prototype. In like manner, a post-acquisition review would compare how well the chosen candidate operates in the classroom as an indicator of the prototype's accuracy. Longitudinal surveys would support continuous tool improvement, and may be achieved by harnessing existing data sets such as course evaluation feedback, student grading trends and technology incident reports. Furthermore, the diversity of the animation industry means that there are opportunities for the prototype to be adapted for other branches, such as motion graphics, animation for games, or immersive technologies. In these cases, the selection criteria would need to be modified to reflect the nuances of the domain, and so a similar investigation to that given in the literature review would need to be undertaken.

Apart from its practical aims, this research encourages further academic discussion and renewed enthusiasm to advance animation education. The prototype acknowledges the constraints of the university environment but helps educators to navigate these boundaries and optimise their resources to achieve sustainable, innovative solutions.

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APPENDICES

Appendix 1. Moho Pro 12 Full Version Volume Licence Enquiry

Sent: Saturday, 22 June 2019 5:34 AM
To: Amy Knie
Subject: FW: New submission on HubSpot Form "Sales & Partners"

Hello Amy,

Thank you for reaching out – we appreciate your interest. Here's a quote for 21 licenses of Moho Pro 12:

21, Moho Pro 12 Full Version (Mac/Win) Multi-Seat License = $4,183.20 USD.

The licenses are perpetual, therefore it will be a one-time cost. Please let me know if you have any further questions – I'm happy to help.

Best Regards,
[redacted]

Graphics Team
Smith Micro Software, Inc. | https://my.smithmicro.com/
SMITHMICRO SOFTWARE

Appendix 2. Toon Boom Harmony Essentials and Advanced Volume License Enquiry

STORMFX

Quote #	[redacted]
Date	21/6/2019
Expires	20/7/2019
Terms	Net 30

Bill To
Procurement Officer
Finance Department
University of Southern Queensland
Toowoomba QLD 4350

Ship To
University of Southern Queensland
Central Store (O2 Block)
West Street
Toowoomba QLD 4350

Item Name	Description	Qty	Unit Cost	GST	Total
HAALRSV000ELEDU...	Harmony Essentials - Annual Term license - Silver Support - Institution	21	126.55	265.76	2923.31
HAALRSV000ELEDU...	Harmony Advanced - Annual Term license - Silver Support - Institution	21	229.00	480.90	5289.90