Verbs in Learning Objectives – Trends in Australian Undergraduate Engineering Education

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Introduction

Many tertiary education institutions have adopted an outcomes-based approach to education. Outcomes-based education makes use of learning objectives or learning outcomes to outline the skills and competencies students are intended to develop while progressing through courses (individual units of study, often one semester in length) and programs (entire degree structures, typically 4 years for Bachelors of Engineering in Australia). Learning objectives or outcomes are statements that provide direction to the skill and competency development of students (Wallace, 2015). The distinction between learning objective and outcome varies with interpretation of the two phrases. However commonly 'objectives' is used to describe intended learning, while 'outcomes' is used to describe the skills demonstrated to indicate that learning has successfully taken place (Meda & Swart, 2018; Wallace, 2015).

Despite the subtle difference in their definition, 'outcome' and 'objective' are often used synonymously particularly in the university context. Many universities infer that on successful completion (achieving a 'passing' grade) of a course of study or program a student would have successfully demonstrated all learning outcomes associated with that course or program. This inference is demonstrated in the statement commonly preceding the learning outcomes, often similar to "*At the successful completion of this unit you will be able to*" (Monash University, 2019).

It is possible to imply successful completion of assessment tasks would correlate with students developing or demonstrating learning objectives if a constructive alignment model is assumed to be used. Constructive alignment describes the relationship between learning objectives, learning activities and assessment tasks (Biggs & Tang, 2011) as seen in Figure 1. In theory, these three should be aligned such that the learning activities support the development of the skills outlined in the learning objectives while competency of said skills is assessed or demonstrated through the assessment activity to validate the successful development of the intended learning objective (Biggs & Tang, 2011). Some institutions and individuals demonstrate the link between course learning outcomes and assessment tasks explicitly (RMIT University, 2019).

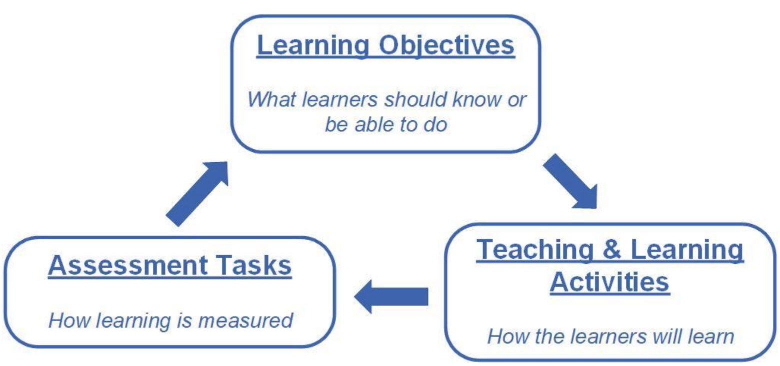

Figure 1: **Constructive Alignment Model demonstrating the relationship between learning objectives, learning activities and assessment tasks, adapted from (Biggs & Tang, 2011)**

There are many perspectives on what constitutes the make-up of learning objectives. Some describe learning objectives as needing to be clear, specific, observable and measurable to be effective such that they can be understood and assessed (Biggs & Tang, 2011; Wallace, 2015). Anderson and Krathwohl (2001) describe learning outcomes as having a noun and a verb component which correlate with a knowledge dimension and cognitive process respectively. Glasson (2009) suggests the use of 'success criteria' statements to validate the required standard of skill demonstration at different levels. Mager furthers this, describing a well-written learning objective as having three elements – an action, a condition the action is performed under and a criterion outlining acceptable performance. At a fundamental level, these definitions are underpinned by including an element describing something having been done, a verb.

Published frameworks provide scaffolds of observable and measurable verbs for use when developing learning objectives. There are three frameworks which dominate the tertiary engineering education literature when discussing learning objectives – Bloom's Taxonomy (Bloom, 1956), Revised Bloom's Taxonomy (RBT) (Krathwohl et al., 2001) and Biggs' Structure of Observable Learning Outcomes (SOLO) Taxonomy (Biggs & Tang, 2011). All three of these frameworks also incorporate categorization of verbs into increasingly difficult levels of cognitive function from lower levels, representing basic understanding, to higher levels, representing skills like critical thinking and synthesis.

High level cognitive processes, such as critical thinking, are often reported as being dependent on having sufficient amounts of the underpinning knowledge (Swart, 2010, Facione, 1990). As more underpinning knowledge is acquired, larger proportions of the high level cognitive processes are able to be undertaken. It has been implied previously that this would suggest for engineering tertiary education that lower academic levels (years 1 and 2) would focus more heavily on the lower order levels of cognitive processes, that is developing understanding and knowledge domains. The higher academic levels (years 3 and 4) would feature higher levels of cognitive processes more prominently (Swart, 2010). Engineers Australia (EA) also implies that with program progression there should be an increasing emphasis on higher order cognitive functions in the accreditation users guide (Engineers Australia, 2019a). EA states that programs of study should '*contain progressive emphasis on … critical review as the program progresses'* (Engineers Australia, 2019a) and *'promote a graded transition of learning experiences from a structured beginning to a more independent learning approach…"* (Engineers Australia, 2019a).

Due to a constructive alignment model, learning objectives can be suggested to be indicative of the curriculum content they represent. This allows mapping between curriculum and frameworks through the use of learning objectives. For example, Australian engineering learning objectives have been reported as mapped to the Engineers Australia Stage 1 Competencies (EAS1C) framework (Halupka, Nguyen, Woo, & Lamborn, 2018; Holmes, Sheehan, Birks, & Smithson, 2018). This type of analysis is also commonly used as part of the EA accreditation process by institutions wanting to demonstrate the links between curriculum and EAS1C. Mapping can also be done between learning outcomes and a learning outcome taxonomy to correlate curriculum with level of cognitive function. In engineering, Meda and Swart (2018) have undertaken a curriculum review of the electrical engineering degree offered by University of Technology South Africa as categorized using the Revised Bloom's Taxonomy (RBT). Elsewhere, Biggs' SOLO Taxonomy has been used to analyse science programs in Denmark (Brabrand & Dahl, 2009) and the RBT has been used to benchmarking business programs in Australia (Lau, Lam, Kam, Nkhoma, & Richardson, 2018).

The mapping procedures between learning outcomes, curriculum and level of cognitive function are predicated upon the assumptions of the constructive alignment model being effectively implemented and the learning outcomes being correctly designed to represent the relevant curriculum content and assessment task. However, it has been observed that in practice there is a misalignment of learning objective and assessment activity in the Australian engineering education context, contributing to students failing to demonstrate the expected level of cognitive function (Nightingale, Carew, & Fung, 2007). The divergence between the ideal case and practice is therefore a limitation of any mapping projects that are undertaken.

Aims and Objectives

This study investigates if trends are present in Australian undergraduate engineering core unit learning objective's verb choices and the subsequent implied cognitive function. It aims to answer the question – how does year level and engineering discipline of study influence the verbs used in learning outcomes and their implied cognitive function?

Theoretical Framework

The theoretical framework for this study is guided by the principles of constructive alignment (2014) and the RBT (Krathwohl et al., 2001). Constructive alignment, see Figure 1, as defined by Biggs (2014) is

> *"an outcomes-based approach to teaching in which the learning outcomes that students are intended to achieve are defined before teaching takes place. Teaching and assessment methods are then designed to best achieve those outcomes and to assess the standard at which they have been achieved"*

Bloom's Taxonomy, presents a hierarchical structure of learning outcome verb suggestions based on the complexity of cognitive functions and thinking skills they demand. The RBT, proposed by Anderson and Krathwohl (Krathwohl et al., 2001), changes from the original Bloom's taxonomy by the terminology used to define the categories, reordering of the highest two levels and segregation of the lowest level to incorporate a knowledge dimension into all levels of the framework. It is the cognitive process dimension which is often referred to as RBT and is what is being considered here.

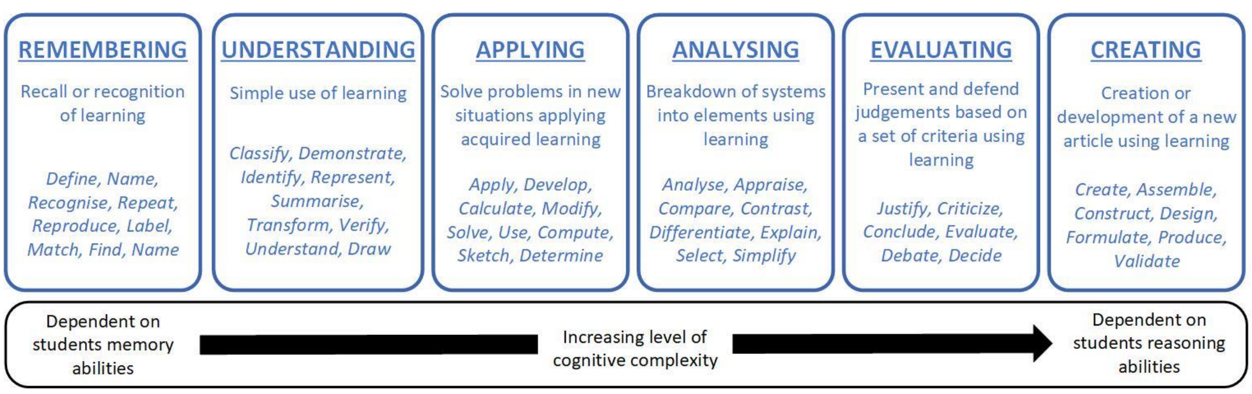

Figure 2: **Revised Bloom's Taxonomy Cognitive Process Dimension, adapted from Anderson & Krathwohl (Krathwohl et al., 2001) and Meda & Swart (Meda & Swart, 2018).**

Methodology

Data Set Development:

A list of four year undergraduate bachelor of engineering and bachelor of engineering (honours) degrees accredited by Engineers Australia (EA) at the level of Washington Accord (as of 2019 (Engineers Australia, 2019b)) was compiled by the first author in early May 2019. These were organized by university and categorised by discipline classification group (see Table 1 for details) based on a hybrid classification structure of that used in EA's current methods (ASCED classification (Kaspura, 2017) and discipline explanations (Engineers Australia, 2019c)). Where a program was classified by two disciplines, the courses were included in both discipline analysis. Discipline classifications groups which had 2 or more degree programs at 2 or more universities were included in this study. For each university, an Excel document was compiled between May and August 2019 containing (where found to be publicly available):

- a sheet for each accredited degree program outlining the units described as "core" (or mandatory) requirements in the publicly available 2019 program outline (where found),
- a summary sheet documenting all unique units for that university, their learning outcomes from publicly available 2019 handbook or course outline entries (where found), which degree programs they were core for and which year level they were typically being delivered at in single degree course outlines (year 1-4)

A summary Excel document was compiled for all universities' units that were found to be available at the time of data collection. A sample of universities was selected and summary Excel documents by discipline classification group were produced with an individual segregated page for each year level. This sample data set represents 232 program outlines, 2,628 unique course outlines or handbook entries containing a total of 15,629 learning outcomes from 30 Australian universities. The statistical breakdown of the used data set has been included below:

Table 1: Statistical breakdown of sample data set used for the purpose of this study

Discipline Group	Included Disciplines	Number of Universities	Number of Programs	Number of Core Units by Year Level with found LOs			
				1	2	3	4
Aerospace	aeronautical, aerospace	6	7	42	36	32	36
Chemical	chemical	11	15	99	72	74	78
Civil	civil, architectural, construction, mining, surveying	27	53	213	242	240	221
Environmental	environmental, agricultural, sustainable systems	12	17	131	119	114	97
Electrical	electrical, electronics, computer, software, telecommunications	26	72	245	266	274	227
Mechanical	mechanical, automotive, manufacturing	29	39	218	220	207	162
Mechatronics	mechatronics, robotics, control	20	27	165	160	127	120
Materials	materials, metallurgical, petroleum	8	14	72	78	76	69
Medical	medical, biomedical	9	10	87	76	67	53
Renewable	photovoltaics, solar, renewable, sustainable energy	4	7	38	30	21	32

Analysis Method:

Analysis for fit of learning outcomes to taxonomies like the RBT is commonly done by identifying the verb itself used in the learning outcome and then classifying said verb by structural level manually (Brabrand & Dahl, 2009; Lau et al., 2018). Here, due to the size of the data set a software program (KH Solver run with Stanford POS tagger) was employed to undertake the frequency analysis and verb identification in place of manual analysis. The identified verbs were classified against a predetermined sample list of learning outcome verbs that had been already classified by the RBT. English and American spellings were included where necessary. The frequency of each verb was then assigned to the relevant RBT category for summation and plotting.

The frequency lists were analysed qualitatively through comparative analysis. Textual analysis was also performed to categorise a sample learning outcome verb ‘apply’ for a single discipline, mechanical, for four key elements of a well written learning outcome – action, condition, criteria and specificity as defined by Mager (1984).

Findings and Discussion

All RBT levels were present in each discipline classification group and year level for the sample data set used, although on two occasions this was as low as a frequency of 1. The proportion of RBT level shifted for all discipline groups with change in year level as expected. For most discipline classifications, with each increase in year level, there was a decrease in the proportion of the lowest level of the taxonomy, ‘remembering’, and an increase in the three top levels, ‘analysing’, ‘evaluating’, and ‘creating’. Considering only those verbs which are found to match the RBT sample list, this trend can be seen in Figure 3 for the representative example from the mechanical classification group. The correlation between proportions of higher order RBT levels and year level suggests increased prevalence of higher order cognitive functions with progression through degree program structures for most disciplines.

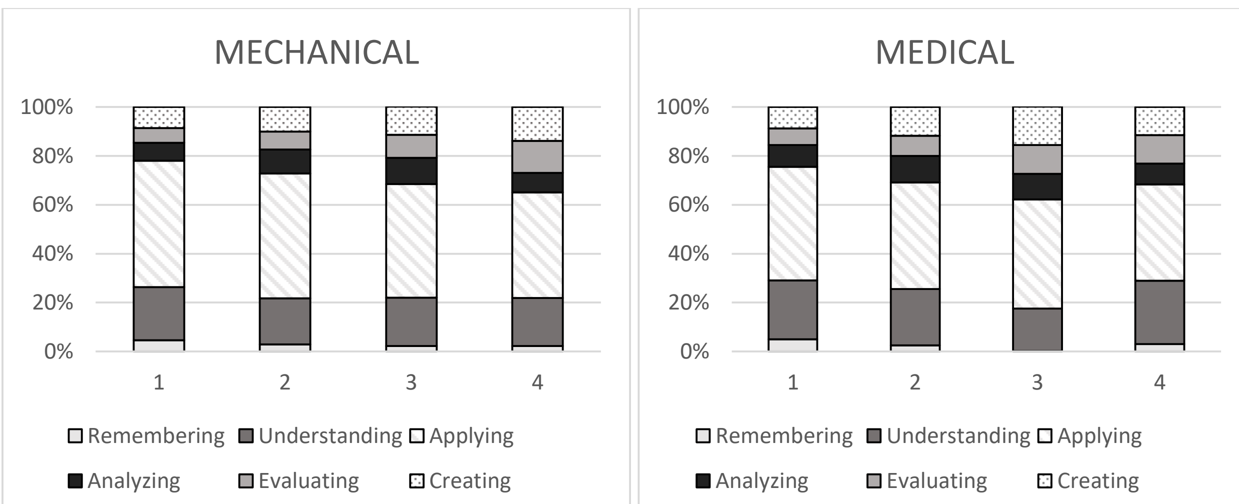

Figure 3: **Stacked bar graphs (percentage of stack’s total) by year level and Revised Bloom’s Taxonomy level for the mechanical classification group (left hand side) and medical classification group (right hand side)’s learning outcome verbs that were categorized with a Revised Bloom’s Taxonomy sample verb list**

At most for any discipline, the top three levels, ‘analysing’, ‘evaluating’, and ‘creating’, represent 40% of the total verbs for a given year level. This suggests that there is a primary focus on the lower levels of the RBT and consequently, lower orders of cognitive function at all year levels. For every year level for all discipline classifications, the peak frequency was at the middle ‘applying’ RBT category. This further suggests there is a disproportionately high emphasis throughout all year levels on developing low to middle order cognitive function of students.

Little variation existed between discipline classification groups. This is expected as each discipline is considered against the same generic set of competencies, the EAS1C, in the accreditation process by EA. However, in the case of medical and renewable classification groups between years 3 and 4 there is an observable regress in proportion of the top three levels (‘analysing’, ‘evaluating’ and ‘creating’) and an increase in the lowest level (‘remembering’), Figure 3. Overall, an increase in the highest three orders RBT categories was still seen between year 1 and 4, 7% and 20% for medical and renewable respectively, however this was different to the rise observed in other disciplines, 13% for mechanical for example. The regress may indicate a misalignment in learning objectives and assessment, or a misunderstanding of the relational nature of learning outcome verb choice and the implied cognitive function. Similarly, this may speak to scaffolding problems across the degree program.

Between 60 and 72% of the verbs detected per year level of each discipline classification group are from the RBT sample learning outcome verb list. However, 28-40% were not. As verbs with higher frequencies did tend to be verbs found in the RBT sample verbs list used, we can gain a good overview of evident trends in the learning outcomes. This is however a limitation of using inquiry based on matching as opposed to manual analysis. Verbs are identified and categorised without any allowance for synonyms or discipline specific verbs, like ‘de-bug’ which could be seen to be fitting category descriptions but is not part of the sample list used. Manual categorization may yield additional insights in future works. Some verbs, namely ‘reflect’ and ‘appreciate’, suggest the use of another framework, Biggs’ SOLO Taxonomy, would yield additional insights. This is beyond the scope of the current study.

The data set had a high degree of homogeneity in the most frequently used verbs across disciplines and year levels. When the 10 most frequently used verbs for each year level are collated into unique lists by discipline, we can see that there is only 28 unique verbs across all disciplines, Table 2. This is despite the RBT list of sample verbs used having 235 unique verbs. The high degree of homogeneity suggests a propensity or preference for certain verb types and thus by implication a high degree of commonality in current engineering education practice. These verbs were mostly able to be categorised by the RBT sample list used with the highest proportion of these terms falling under the applying category level. This also supports previously discussed findings, that there is a focus on lower order cognitive function of students.

Table 2: The 28 unique verbs resulting from comparative analysis of the 10 most frequent learning outcome verbs from each year level of each discipline presented by the number of discipline classification groups they were found in the most frequently occurring list.

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Most frequent learning outcome verbs from each year level of each discipline found:</th></tr>
<tr><th>In all 10 disciplines</th><th>In 9 of 10 disciplines</th><th>In 8 or under disciplines</th></tr>
<tr><td colspan="2" rowspan="4">None</td><td>Be</td><td rowspan="4"></td><td>Base</td></tr>
<tr><td rowspan="3">Include</td><td>Communicate</td></tr>
<tr><td>Perform</td></tr>
<tr><td>Reflect</td></tr>
<tr><td rowspan="15">Revised Bloom’s Level Classification</td><td>Remembering</td><td></td><td></td><td>Find</td></tr>
<tr><td rowspan="3">Understanding</td><td>Demonstrate</td><td rowspan="3">Identify</td><td rowspan="3"></td></tr>
<tr><td>Describe</td></tr>
<tr><td>Understand</td></tr>
<tr><td rowspan="5">Applying</td><td>Apply</td><td rowspan="5"></td><td>Calculate</td></tr>
<tr><td>Develop</td><td>Determine</td></tr>
<tr><td>Solve</td><td>Interpret</td></tr>
<tr><td rowspan="2">Use</td><td>Write</td></tr>
<tr><td>Relate</td></tr>
<tr><td>Analysing</td><td></td><td>Explain</td><td>Analyse</td></tr>
<tr><td rowspan="2">Evaluating</td><td rowspan="2">Evaluate</td><td rowspan="2"></td><td>Assess</td></tr>
<tr><td>Implement</td></tr>
<tr><td rowspan="3">Creating</td><td rowspan="3"></td><td rowspan="3"></td><td>Design</td></tr>
<tr><td>Formulate</td></tr>
<tr><td>Manage</td></tr>
</table>

When the top 10 frequency lists are further analysed by year level for each discipline this high degree of homogeneity is carried through. A majority of the verbs being used at any year level are also present in other year levels, often in similar orders of prevalence, Table 3. This suggests that students are primarily performing similar, if not the same, cognitive tasks repeatedly throughout their programs.

Table 3: The position of the 10 most frequently used verbs in learning outcomes listed by year level and Revised Bloom's Taxonomy structural level for a sample discipline classification group, mechanical. Here italicized verbs indicates verbs found in the top 10 verbs for all 10 disciplines.

Revised Bloom's Level Classification		Verb	Year 1	Year 2	Year 3	Year 4
None		*Be*	5th	5th	3rd	8th
		Include	10th			
		Communicate				7th
Dependent on students memory abilities	Remembering					
↓	Understanding	*Demonstrate*	4th	4th	8th	3rd
Increasing level of cognitive complexity		*Describe*	6th			
		Understand	9th	10th	5th	
		Identify		9th	10th	6th
	Applying	*Apply*	1st	1st	1st	1st
		Use	2nd	2nd	2nd	4th
		Solve	3rd	3rd	4th	10th
↓		*Develop*	7th	7th	9th	2nd
		Write				9th
Dependent on students reasoning abilities	Analysing	Explain	8th	6th	6th	
	Evaluating	*Evaluate*		8th	7th	5th
	Creating					

Despite the homogeneity in the words themselves, there was a wide variety of ways in which these verbs were employed. Returning to Mager's (1984) framework for a good learning outcome requiring an action, a condition and a criterion as well as their assertion that they need to be specific, we can see that not all of the instances where the identified verbs were used would constitute an effective learning outcome. Some examples are provided in Table 4. Further work may analyse the effectiveness of learning outcomes employed in addition to the verbs themselves.

Table 4: Examples of learning outcomes containing the Bloom's Taxonomy verb "apply" from the mechanical classification group.

Elements and Specificity	Sample Learning Outcome
Action, Vague	*"Apply teamwork skills"* – 3rd year management and communications course
Action, Specific	*"Apply the conditions of static equilibrium to simple structures"* – 1st year engineering mechanics course
Action, Condition, Specific	*"Define and apply simple I/O methods using console and simple text files in the C and Matlab programming environment and to express data as information"* – 1st year programming for engineers unit
Action, Criteion, Specific	*"Competently apply principles of engineering project management for planning, organising and managing resources, and for prioritising competing demands"* – 4th year engineering project course

Conclusions

This study shows RBT is a useful tool to map increase in cognitive function in engineering programs. The verbs used in learning objectives in core courses from a sample set of 232

Australian undergraduate bachelor of engineering and bachelor of engineering (honours) degrees showed a high degree of fit with the RBT sample list used. The proportions of higher order verbs increased along with increases with year level. However, the majority of verbs were lower order across all year levels. This suggests a trend of primarily focusing on lower order thinking skills or cognitive functions throughout the course of engineering programs. Further, this suggests students are performing similar cognitive tasks repeatedly throughout their program. All bar two discipline classifications showed similar trends between year levels while all discipline classification groups showed similar trends overall. A level of homogeny in the most frequently used verbs between disciplines and year levels existed, suggesting a propensity or preference for certain verbs and therefore tasks over others. There is a wide variety of ways in which the verbs themselves are used in learning outcomes with differing levels of efficacy.

Further works may include works into academics' understanding of taxonomies and the constructive alignment approach, qualitative inquiry into the efficacy of learning objectives or developing a tool to use this kind of approach to adjust learning outcomes in higher years to a better balance for level of cognitive function.

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