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Assessment and Evaluation in Higher Education

DOI:
10.1080/02602938.2019.1676397

Published: 18/05/2020

Peer reviewed version

Degree Pictures: Visualizing the University Student Journey

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Abstract

The field of Learning Analytics is progressing at a rapid rate. New tools, with ever-increasing number of features and a plethora of data-sets that are increasingly utilized demonstrate the evolution and multifaceted nature of the field. In particular, the depth and scope of insight that can be gleaned from analysing related data-sets can have a significant, and positive, effect in educational practices. We introduce the concept of Degree Pictures, a symbolic overview of students' achievement. Degree Pictures are small visualizations that depict graphically 16 categories of overall student achievement, over the duration of a Higher Education course. They offer a quick summary of students' achievement and are intended to initiate appropriate responses, such as teaching and pastoral interventions. This can address the subjective nature of assessment, by providing a method for educators to calibrate their own marking practices by showing an overview of any cohort. We present a prototype implementation of Degree Pictures, which was evaluated within our School of Computer Science, with favourable results.

Keywords Learning analytics; visualization; student progression; learning gain

Introduction

This article reports on the work that we have been involved in which combines the concept of Learning Pictures (Lindsley 1977, All 1977) with contemporary Information Visualization techniques, such as Small Multiples, in order to provide enhanced, objective guidance to examiners when making adjustment decisions. Our goal is to improve the sense making process of examiners, during situations such as annual board of studies, where dozens, if not hundreds of students need to be evaluated in terms of their overall performance.

Towards this aim, our contributions are:

- The elaboration of Degree Pictures, a graphical depiction of a student's achievement trajectory, through the presentation of their theoretical foundation, design process and final concept;
- A prototype, interactive implementation, that is built upon contemporary open-standards tools and visualization libraries, and can therefore be integrated with larger Learning Management Systems;
- An evaluation of said tool, by participants of boards of studies and directors of teaching and learning, and student experience.

The resulting methodology and prototype tool are intended to complement existing Learning Analytics deployments, by providing the wide-angle view of a student's entire University career. By combining all the available information into one tool and presenting it visually, examiners are expected to be able to make quicker and more accurate decisions. By examining a wide range of student data in this way, it is expected that it should be possible to extract a set of common patterns. These patterns can then be organized into a taxonomy, similar to Lindsley and All's (1977) Learning Pictures. Once catalogued, it is hoped that a set of recommendations can be derived to objectively guide examiners with their decisions. This moves progression and adjustment decisions one step closer to data driven decisions, suggested for teachers by Wayman (2005). This approach will also allow educators to calibrate their own assessment practices to reduce discrepancies while marking, by allowing a benchmark across a cohort. These discrepancies can be the result of the evolving nature of marking any assignment, or near-unconscious factors, such as gender, perceived ability, or likeability as discussed by Malouff (2008).

The rest of this article is structured as follows; firstly, we review the concepts of Learning Analytics and Learning Pictures. Next, we extend Learning Pictures to encompass the entirety of a students' journey through Higher Education. We, then, present a prototype implementation of a Learning Analytics tool including our Degree Pictures. The prototype is then evaluated, discussing limitations and lessons learned.

Learning Analytics and Learning Pictures

One of the greater challenges of Learning Analytics is providing clear indications to educators on the need to remedy a situation that affects their students. This process, referred to as 'closing the loop' by Clow (2012), is a highly bespoke and delicate one, as each situation and each student may require a different approach. Rienties, Cross, and Zdrahal (2017) have proposed a framework and a set of 'recipes' for such remedial interventions but acknowledge that each must be tailored to student and situation.

Almost all academic assessment relies implicitly on the subjective judgments of the educator, with notable exceptions such as in mathematics. Nevertheless, educators constantly strive to reduce the impact of such variations. We employ rubrics, mark schemes, multiple-choice assessment, and other mechanisms in the pursuit of an objective individual grade for each student (Choinski, Mark, and Murphey 2003). This process, while potentially time consuming, can work on an individual assessment or module basis. As students progress further through their programmes, more and more subjectivity creeps in (Bloxham 2009). Additionally, despite all best efforts additional unconscious bias, of the marker, will also affect scores (Malouff 2008).

There are also some milestones, where a summative appraisal of a student's overall performance takes place. In UK Higher Education, this takes place during boards of studies, often in the presence of external examiners. These boards are often placed in a privileged position, able to apply adjustments to a student's assessment metrics under institutional regulations. These adjustments are intended to provide a balance to mitigate exceptional circumstances, such as pastoral crises or academic missteps in delivery or assessment as discussed by Konur (2006). Most often this activity is completed using dense tabulations of marks that can blend into one another. In addition, each HEI will have their own particularities in their regulations, practices, and methods when considering final grades, adjustments, and degree outcomes. Therefore, factoring in adjustments and regulations places an extra burden on examiners, in addition to making and confirming judgments on their students.

However, visually, extensive tables of similar data do little to aid the viewer to distinguish rows and columns. This a recognized problem in the Information Visualization field, with solutions already proposed (Rao and Card, 1994). Banding, division lines, colours, or more exotic methods add emphasis to assist the reader, who are nonetheless fundamentally left to interpret the data on their own. Introducing these highlights may not always be possible, due to either extra printing costs (such reports are typically produced in low resolution black and white) or lack of support in the reporting software itself. Where these tools are available, the support for visualizations is limited to simple charts (Bergin et al., 1996). Furthermore, any commercial offering would certainly lack the customization needed to encode all nuances of the institutional environment, regulations, etc.

Within the Education and Behavioural Psychology fields, there is a well-established practice known as Precision Teaching. Pioneered by Lindsley (1977) and developed over the next 13 years (Lindsley (1990), this practice examines quantitative measures to evaluate and improve teaching interventions. The primary tool is known as a Standard Celeration Chart. This is an often hand-drawn graph measuring both positive and negative behaviour frequencies on a logarithmic scale (and example is shown in Figure 1). Lindsley's work gave rise to the term 'Learning Pictures', describing common patterns observed in these charts. In his (unpublished) Masters thesis, All (1977) - supervised by Lindsley - described 17 unique learning pictures. Each picture demonstrated an established pattern, and an accompanying intervention.

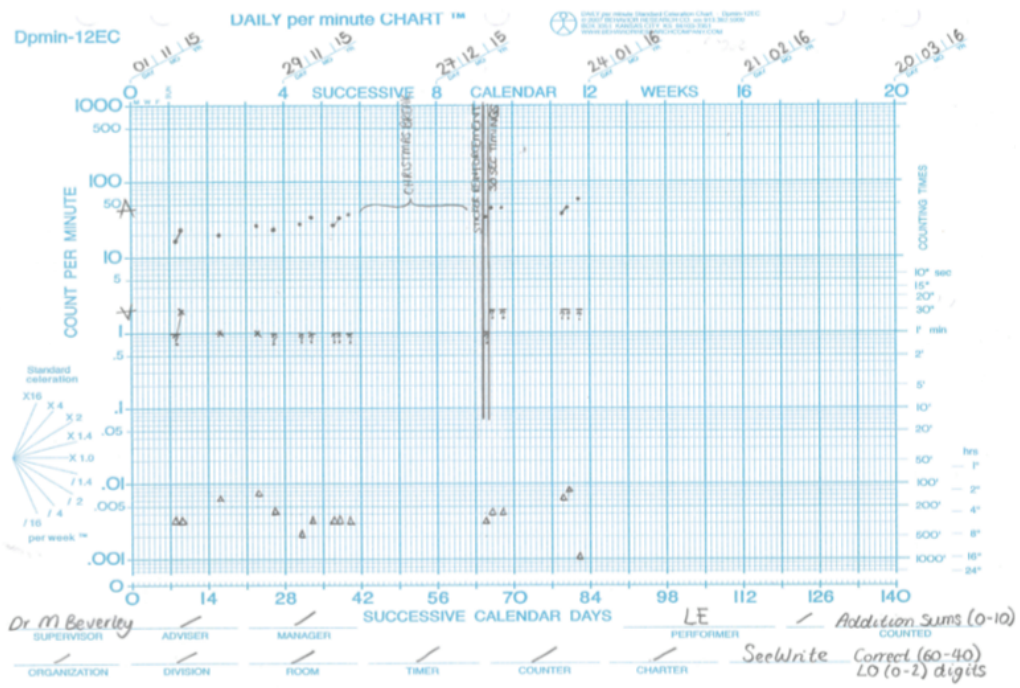


Figure 1. An example Standard Celeration Chart completed by hand. This example comes from a Precision Teaching intervention carried out by the School of Psychology at Bangor University.

Figure 2 shows the set of Learning Pictures describing students that are improving. This can mean an increase in positive/correct behaviours, a reduction in negative behaviour, or both. The most desirable of these is the 'Jaws' picture where both the conditions occur. In this case, All simply suggests the teacher monitor the situation and continue whatever practices have led to this situation. However, with the 'Uphill' picture the advice alters with educators being asked to teach specifically those aspects the student struggled with. This is because the student is already improving the desirable aspects on their own.

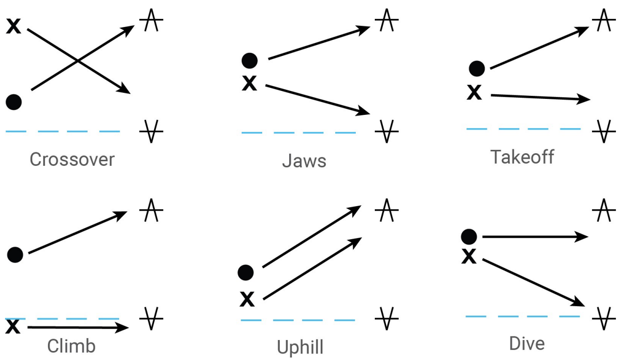


Figure 2. The 'Improving' set of Learning Pictures, Lindsley and All (1977). Lines annotated with circles represent 'good' behaviours, and 'x' those that are undesirable. The arrows to the right of each chart, show the intended direction of the lines. Image credit: Rick Kubina, Chartlytics.

There is a move toward progress tracking within Learning Analytics applications. Examples include Mastery Grids created by Loboda et al. (2014), and Study Paths created by Buser and Semmler (2017). However, this still remains basic, using bar charts to show achievement (Duval, 2011) on an assessment- by-assessment basis. However, DeCotes (2014), a University of Tennessee student, proposed in their thesis a method of tying some elements of a course and student data together. DeCotes' method, however, focused on unifying student cohorts rather than individual achievement.

While the focus of this work is primarily graphical, presenting the outcome from an analytic process; it is important to keep sight of the ultimate goal. There are significant issues when examining education on a temporal basis (Chen, Knight, and Wise, 2018). Designers and users alike need to have a keen understanding of how time fundamentally affects activity in the population measured. This is why in most learning analytics studies, the effect of time is obfuscated or ignored. There have been proposals to model these effects correctly (Mahzoon et al., 2018). As the level of analytic tools available remains quite small, the impact of these models is also small.

Our work is underpinned by an information visualization method, the Small Multiples (MacEachren et al., 2003). Small multiples are a set of juxtaposed data representations that together support understanding of multivariate information. The technique of Small Multiples was introduced as a data analysis method by Bertin in 1967, which he termed ‘collections.’ Small multiples were later popularised by Edward Tufte (Tufte and Graves-Morris 2014). They are a series of graphics, much like movie frames, showing the same combination of variables, and depicting changes in another variable. They have also been discussed as Trellis displays Becker, Cleveland, and Shyu (1996), due to their resemblance to a trellis fence. Both Tuftee and Bertin emphasize the potential that small multiples have in providing insight from simultaneously seeing and comparing patterns, relationships and trends.

From learning pictures to degree pictures

The aim of this work is to produce a symbolic and iconic overview of a student’s progress. This view does not necessarily need to be accurate to the exact numeric percentage or mark but must be representative and comparable between students. These representations are then abstracted to form a category or similar patterns in the same way Lindsley and All’s Learning Pictures have been.

There are two use-cases envisioned for these representations. The first is during Assessment Board meetings, where the representation will assist by displaying achievement graphically. Following the acclaimed visualization mantra “overview first, zoom and filter, then details on demand” Shneiderman (1996), Degree Pictures are coupled with an additional representation of the component marks and augmented with any other (usually textual) relevant detail. The second use-case is intended to assist with Pastoral Care systems. Personal Tutors are often called upon to offer advice and guidance to students, without much support on how to do so. This often results to a divide in the quality of responses due to varying factors, such as experience level. The Degree Pictures are expected to assist by allowing standardised responses and interventions. This should end the potential discrepancies of care, benefiting all students.

As a first stage, a formal requirements analysis exercise was completed. Input was integrated from relevant stakeholders, all experienced lecturers from within the School of Computer Science at Bangor. These requirements are all compatible with the aim and intent of this work. The stakeholders noted that they wished to see at-a-glance two points; the general standing of a student, and an indicator of any regulatory or special circumstances that needed to be discussed and considered.

As special circumstances can be dealt-with as a highlight, the authors concentrated on providing the summary representation first. Following a process similar to the one suggested by Munzner (2009), we generated a series of prototypes utilizing simulated student achievement data. Most used the raw achievement percentages for each module and/or component. However, this was deemed too visually overwhelming for a summary representation. An initial round of testing, based on informal interviews with a subset of the interested stakeholders, showed that the most popular design drew inspiration from the UK Degree Classification system. This sees the institutional honours split into four classes; First, Upper Second, Lower Second, and Third. (There are other non-honour exit awards possible, but these are used as a last resort.)

Using a simple line-chart, we devised a set of fifteen potential paths through these classifications. These are shown in Figure 3, where each line represents a majority or final classification. This set was created as an educated best-guess from the authors' experience of student achievement patterns. The x-axis represents time, there are six data points to each picture corresponding to the weighted averages at the end of each of the six semesters (for a 3-year undergraduate program). The y-axis represents their achievement level split into the classifications, or 'F' meaning fail.

We quickly came to realize that the horizontal axis (different achievement) was not the only 'movement' in the pictures that could occur. Students may enter or complete a pattern at different times as well, in effect sliding the picture left or right. This effect is incidental when examining an individual's performance for discussion and/or comparison purposes, however when deciding on an intervention - it can confound the issue. Therefore, the patterns were abstracted to relative rises and falls in a sequence. Borrowing from Lindsley's vocabulary, we termed these sequences/patterns 'Degree Pictures'.

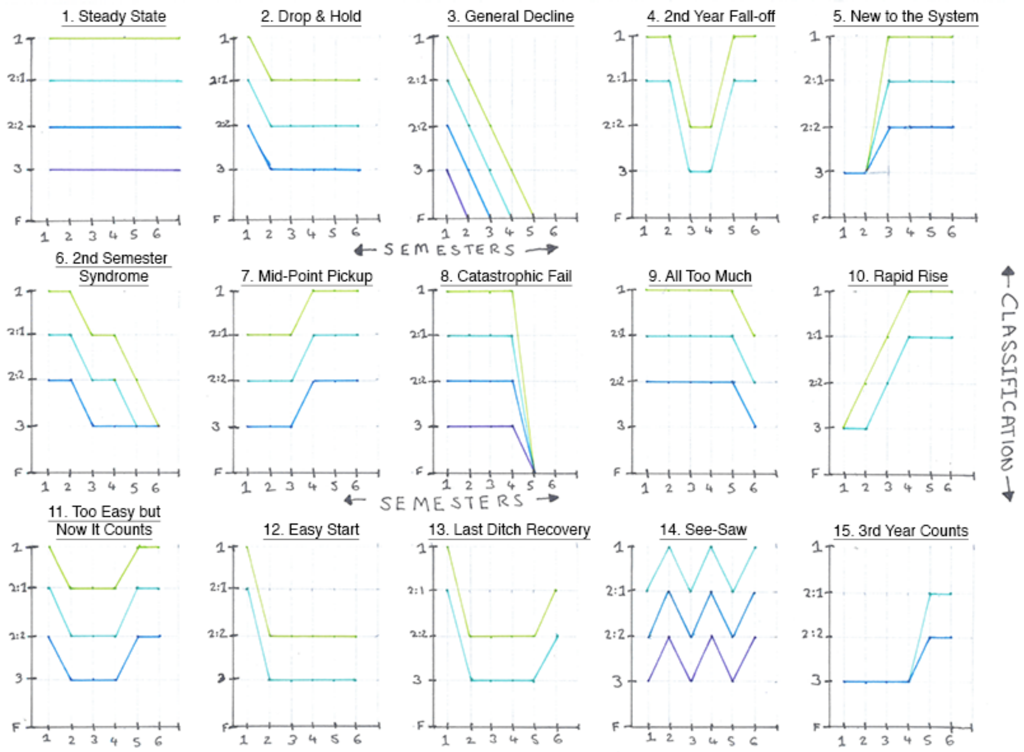


Figure 3. Simple line-chart representations of the initial set of achievement patterns. Each graph shows a potential achievement trajectory with time, 6 semesters, shown on the horizontal axis and achievement on the vertical. Achievement is divided into five ranges based on the UK degree classification schemes; Fail, third class, upper and lower second class and first-class honours. The individual lines show how the pattern scales with the starting achievement level. The set was created based on educator's intuition.

To ensure that there were no edge or corner cases that had been inadvertently missed, we constructed the line charts from two full academic years data. This set was reduced from 118 to 53 unique patterns. These 53 were then grouped by eye, creating the 16 descriptions below from the common features.

Steady State - The student, from the outset in Semester 1, achieves a level and remains at that level for their entire degree.

New to the System - The student establishes a flat trajectory and remains there by the end of semester 2, there may be a delayed achievement of this level.

One-Step - The student achieves a given level, maintains that for at least one semester, then improves maintaining the higher level until the end of their program.

One-Step with Drop-off - As with a standard One-Step; however, the final year full average drops by one classification.

Two-Step - The student increases their achievement each year creating three flat aspects. This occurs as semester 1 and 2 of each year will be at the same level.

Two-Step with Drop-off - As with Two-Step but includes a one classification drop in the final semester.

Single Spike - At one point during their studies, a single semester has an upward spike. Their results return to the previous level the following semester.

Spike and Drop - The student shows a single semester upward spike in their results, however the following semesters drop further than the level prior to the spike. There may or may not be a flat section where the lower result is held.

One Dip - The student achieves a given level and maintains it, with the exception of a single semester where their achievement decreases.

Unbalancing Dip - The student achieves a given level and maintains it, and a decrease for semester occurs. The student recovers but only to a maximum of one classification below the previous level.

Wake-Up Call - The student establishes and maintains a level, but then their performance decreases for a semester. Following the decrease, the student then establishes a new level higher than the previous one.

Last Ditch Effort - This Degree Picture is typified by an at least two classification drop, with or without sustain and a final semester increase of one classification.

Oscillating - The student appears to be on a boundary between two classifications, where there is a repeated pattern of at least two rises and falls.

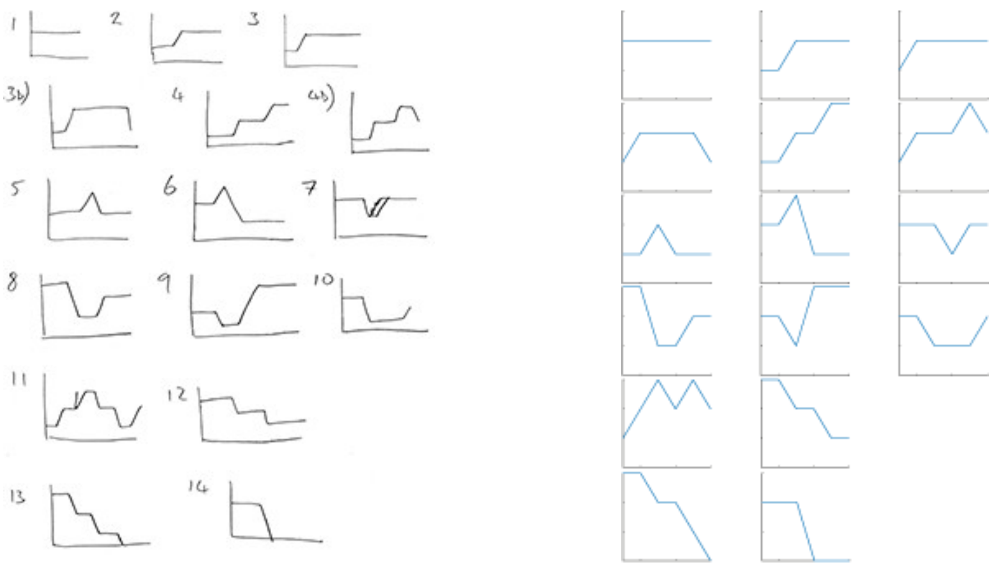
Step Down - The student starts out at whichever level but will decrease by a single classification. They will then sustain that level for at least a semester. This pattern may repeat, as long as they do not drop far enough to fail their program.

There are two additional Degree Pictures, which were in the initial ideas but do not figure in the actual data. Both of these deal with failure modes.

General Decline - The student begins a gradual decreasing trajectory, falling by one classification per semester until finally reaching a failing level. There may not be a sustaining step of one or more semesters.

Catastrophic Fail - Students in this category would otherwise be described by another picture, however in whichever semester their achievement immediately falls to the failing level.

As part of the definition of the Degree Pictures we undertook a validation exercise using ten lecturers within the School of Computer Science, who were unfamiliar with the work. They were set the task to sketch a version of the Degree Picture from the description alone. All, but one (Oscillating), were correctly reproduced. Figure 3 shows a sample compared with the idealized equivalent. Upon reflection, while the response does differ from the picture we originally intended, the sketch of the Oscillating picture is still reasonable.



(a) Sample response from a lecturer in the School of Computer Science.

(b) Ideal representations

Figure 3. Output of the validation exercise, where participants were asked to sketch the graph from the Degree Picture descriptions. Inset (a) shows a sample response from a lecturer within the School of Computer Science and (b) shows the canonical or idealised representation. Corresponding descriptions/responses are laid out in the same positions in both.

Prototype implementation

Having defined the Degree Pictures, we have implemented them into a tool for use by Boards of Examiners. This tool uses the Small Multiples technique to display an overview or comparison of an entire cohort. An extract from this view is shown in Figure 4. Instead of a straight line to connect the values, we have chosen to use a polynomial line of best fit. The curves can accentuate the trends present in a student's pattern. This gives viewers/tutors a hint as to a potential intervention and/or likely future occurrences.

This information is taken directly from Bangor's Student Information System (Ellucian Banner), and is implemented using open, web-friendly technologies (JavaScript, D3.js, and SVG), facilitating easy integration with a variety of learning management systems. By utilizing this architecture, tutors can be made aware of any and all students' situations as soon as marks are collated.

The prototype has also been integrated, to provide additional detail, with Bangor's Student Journey tool Gray and Perkins (2018). This provides an interactive view of all achievement down to a module level. In this context, examiners in the School of Computer Science have been able to use the Degree Pictures to visually reason about potential regulatory actions, such as border-line cases and impacts of special circumstances.

A preliminary usability evaluation of our prototype tool was carried out using the standard System Usability Scale (SUS) Brooke et al. (1996). A total of 16 examiners, familiar with the institution's practices but not all regulations, were surveyed. This specific questionnaire uses a Likert scale and arrives at a score out of 40 but is commonly multiplied by 2.5 to achieve a score out of 100. (It should not be treated as a percentage however.) Subsequent testing of the scale (using over 500 trials) has established that the average score is 68 Sauro (2011).

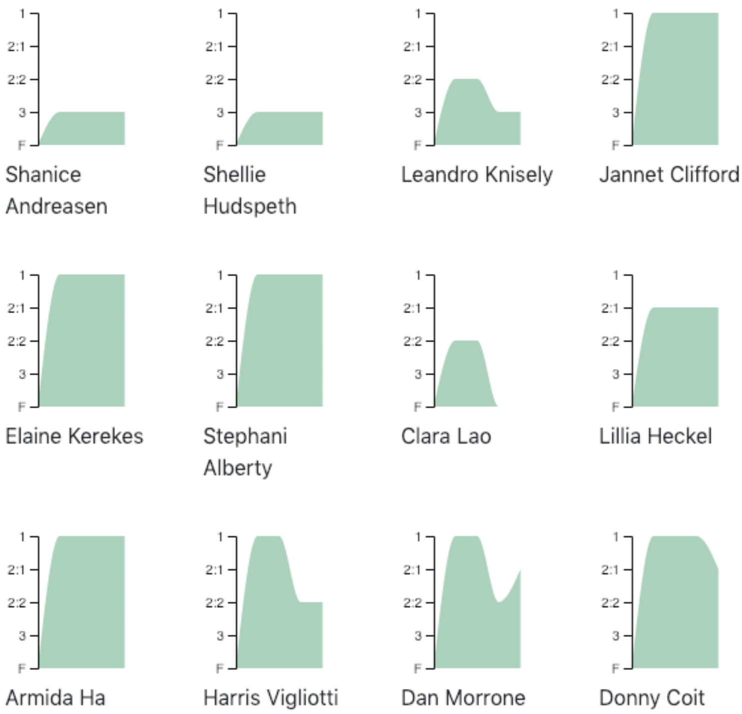


Figure 4. A selection of Degree Pictures from Bangor University. The horizontal axis represents time, with a data-point being taken at the end of each semester (therefore 6 total). The vertical axis represents the student's achievement, categorized into degree classifications. While the underlying data is taken from actual graduates, the corresponding names have been changed to fictitious ones.

The Student Journey visualization scored an average of 79.65 / 100 on the SUS. This score places it on the Good/Excellent boundary Bangor, Kortum, and Miller (2008). The cut-off for 'excellent' usability is 80/100. Examining those results ranking the tool below average (n= 5), the average score was 63 / 100. This score places the tool in the marginal section of the scale.

Respondents were also given the opportunity to provide free-form comments. Most of the negative-leaning remarks were requests for additional training/materials rather than suggestions or complaints. One positive comment stated that this tool was able to show the situation with a student which matched, almost exactly, examiners intuitions. These additional comments support the use of the summarization of a student with the Degree Pictures.

Discussion

At present, standardizing interventions is at a nascent stage. Directors of Student Engagement and tutors are being encouraged to become more involved at the earliest opportunity. This is the point in time where the trajectory starts to fall. Example interventions include an out-of-sequence tutor contact in the event of Picture 7 (‘One Dip’) at the point of the dip occurring. These contacts generally attempt to disclose any potential and unreported special circumstances. In addition, students could be offered tips and strategies to deal with whatever is the underlying cause. With Picture 13, ‘General Decline’, these contacts become more sustained and in-depth to try to avoid the potential failing or (most preferably) recover the situation before the student fails.

The most difficult Degree Picture to react to is the Catastrophic Fail (#14). The difficulty lies in its sudden onset, and the fact that by the time this Picture become available the damage may have already been done. Each institution will have regulations applicable to these emerging failures. Most institutions will allow supplementary assessment (colloquially ‘resits’ or ‘summer school’) to enable failing students to redeem a passing mark. Often, this work can be set as soon as a student has no mathematical route to passing a module. For example, the additional assessments from a failed first semester could be undertaken during the second semester. This allows the student to remain with their social and academic groups, and in the case of final year students graduate with their cohort. Anecdotally, there have been several cases, within Bangor, where the additional support has resulted in students continuing their studies and completing their programme with the most appropriate classification.

The initial tool is optimized for local conditions at Bangor University, especially the prototype small multiples tool and its link with the Student Journey. However, the wider work (Degree Pictures, and their use) should be general enough to be applied at any institution with similar regulations and program designs. The main limitation, as with other achievement-based Learning Analytics, is that Degree Pictures only become available after grades have been awarded. As a result, pre-emptive or corrective interventions are not available. The exact nature of the interventions will also change with the implementing institution due to differences in structure, student services offered, staff training, and pedagogical makeup of individual programs.

The prototype tool does not yet include extra annotations for special circumstances, emphasis for key events or contacts. Adding these options could allow faster identification of either problem cases or discussion points by tutors. The tool is currently a static representation. The Information Visualization field places an importance on interaction, which can reveal additional insights. A candidate interaction could be allowing reordering, whether by hand or fixed criteria such as achievement, program, cohort, etc.

Conclusions

This work introduces Degree Pictures, a graphical summary of students' achievements, intended to initiate appropriate responses, such as teaching and pastoral interventions. Our 16 proposed representations provide an intentionally typified view, rather than a grade-exact one. This concept is akin to Learning Pictures. Using Learning Analytics outputs in conjunction with Small Multiples, Degree Pictures give an at-a-glance overview of entire cohorts.

Our institution has used the prototype tool in its Board of Examiners where progression and award decisions are made. The examiners have found the tool very useful, and the formal usability evaluation has shown positive results. Future work will include adding interactions, such as ordering, as well as different depictions of student achievement. The hope is that educators will be able to use these tools to create interventions to benefit students who need help realizing their potential.

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