CASE STUDY A: Traffic lights and interventions: Signals at Purdue University

The most frequently cited institutional deployment of learning analytics is the Signals project at Purdue University in Indiana. Research showing considerable enhancements to both student achievement *and* retention has been widely hailed in the educational media. It has also been the inspiration behind a number of learning analytics products and many initiatives in other institutions. The findings from the various studies around the use of Signals are not however without controversy, and some of the conclusions drawn by Purdue staff have subsequently been thrown into doubt by other researchers. Here we examine the rationale for the initiative at Purdue, describe the product, the interventions taken with students, and the effects of those interventions. We also look at what staff and students think of the product itself and its effects on motivation and performance.

Key takeaway points

- Signals' predictive algorithm is based on based on performance, effort, prior academic history and student characteristics
- Problems are identified as early as the second week in the semester
- Students are given feedback through traffic lights – and from messages tailored by their instructors
- Students using Signals seek help earlier and more frequently
- One study showed 10% more As and Bs were awarded for courses using Signals than for previous courses which did not use Signals
- 89% of students in one survey considered Signals a positive experience; 74% said their motivation was increased by using it
- There was some confusion among students about the multiplicity of types of intervention that were being taken

Rationale

Signals is built on the premise that students do not have a good understanding of how they are progressing in their courses. This can be for various reasons. They might for example have only a few assessments during their course so may not have much of an idea of where they are until seeing their final grades. By the time they do realise that they are not progressing well it may be too late to withdraw from the class so they end up failing. Signals therefore aims to help students understand their progress early

enough to be able to seek help and either increase their likely grade or withdraw from the module and take something else.

The aim for Purdue at an institutional level was to apply the principles of business intelligence to enhancing student success at a course level, thus contributing to overall retention and graduation rates. Purdue developed their approach to 'early warning systems' which show at-risk students over a number of years, initially capturing on paper-based forms the views of staff on which of their students were at risk. While considered helpful, the warnings often came too late to be effective, and the approach did not help students to change their behaviours adequately. Meanwhile the warnings sent to students were too general and not specific enough to the course they were taking.

While there were other early warning systems on the market, they were based on demographic, personal and grade data, and did not take into account students' behaviour and efforts on their courses. These systems could become self-fulfilling prophecies by labelling students as at-risk based on certain characteristics such as low income or being the first in their family to attend higher education. Signals reduces this bias by incorporating dynamic data on performance and behaviour. This 'real-time' data is considered essential in being able to predict academic success. The resulting analytics aims to produce actionable intelligence, providing detailed support materials and positive steps for students to take.

Description

Signals takes data about attendance and students' use of the VLE, together with grade information held in the VLE gradebook. The product is 'behaviourly-based': more weight is given to interaction with the VLE and 'help-seeking behaviour' than on past academic performance. No evidence is provided in the sources reviewed here for this weighting and how it was decided on – possibly because this is seen as proprietary information which is core to what is now a commercial product. Other studies have shown that past performance is a strong indicator of future academic success. The Purdue researchers assert however that "a student with average intelligence who works hard is just as likely to get a good grade as a student that has above-average intelligence but does not exert any effort".

Signals aimed to avoid the problems of early warning systems which flag up at-risk students after mid-term grades are issued – generally too late to make a difference. These also often require attendance data to be captured, something which is difficult to ensure takes place in large lectures. Meanwhile Signals is argued to be less labour-intensive and costly than other systems where students bring frequent grade reports to academic advisors with the hope of improving their grades. Help-seeking behaviour e.g. visiting a professor or attending a review session is an indication of effort shown outside of the class so is regarded as important. A key part of the philosophy is to allow students to compare what they are doing with what others are doing and showing how these activities (e.g. submitting assignments or attending help sessions) correlate with success.

Signals mines data from the SIS, the VLE and the gradebook. This is then transformed and processed to produce a 'traffic light' indicator showing how at risk each student is considered to be. A range of interventions can then be taken by the instructor. The predictive algorithm has four components:

1. Performance – based on points earned on the course so far
2. Effort – interaction with the VLE compared with other students
3. Prior academic history – including high school GPA and standardised test scores
4. Student characteristics – e.g. age or credits attempted

These components are weighted and fed into the algorithm which produces the appropriate traffic signal. Red indicates a high likelihood of being unsuccessful, yellow potential problems, and green a high likelihood of success.

Interventions

Potential problems are identified as early as the second week in the semester. Instructors can decide to intervene through posting the signal on the student's home page, emailing them, texting them, referring them to an academic advisor or resource centre, or scheduling a face to face meeting with them.

Feedback can be categorised as *motivational* or *informative*. Motivational feedback provides basic comments such as "Well done". When the feedback is informative, the learner can obtain a better idea of their progress, and how it compares to where they were previously or to others in the class. Implicit feedback is sent via the traffic signals, accompanied by explicit feedback in the form of messages.

Feedback enables students to see how far they are from the required outcome. Positive or negative feedback can be provided on the *outcome* (the result) or their *performance* (the activities they carried out). Positive feedback on performance can reinforce existing behaviours while if it is negative it should encourage them to do something differently. Excessive positive feedback may have detrimental effects however, boring students and failing to challenge them. Meanwhile continual negative feedback can reduce the motivation to learn.

With Signals, positive feedback is sent as a green traffic signal, which the instructor can reinforce with a positive message. Negative feedback is yellow or red and can be sent with a warning message. Instructors were concerned that they were setting the right criteria to determine the appropriate traffic light. One instructor did not want to give students a "false sense of security" through the provision of a green light. Meanwhile there were, confusingly, various reasons why a student might be given a yellow light, such as unsatisfactory scores for exams, quizzes or homework. Another instructor thought it was important to send appropriate and specific feedback based on the reason for their performance.

Some staff were concerned not to overdo the sending of messages, and particularly to avoid giving false positive or negative feedback too early. One instructor said that they did not want students to become overconfident by providing early positive feedback; another found that many students were anxious by being given red lights after the first test. In summary there was no clear consensus around the timing for and frequency of feedback, and the optimum balance of positive and negative comments.

Evaluating the interventions

Signals was evaluated on student *performance*, measured by final grades, and *behaviour*, indicated by interactions with the VLE and help-seeking behaviour. Using two semesters of data it was seen that, in those courses which deployed Signals, there were consistently higher levels of Cs and Ds obtained than Ds and Fs. Meanwhile students receiving the automated interventions sought help earlier and more frequently than those who did not receive them.

Results were monitored between Autumn 2007 and Autumn 2009, and appeared promising. In a biology course, the signals pilot produced 12% more B and C grades than among students not involved in the pilot, and 14% fewer D and F grades. There was also a 14% increase in students withdrawing early enough for their grade point average (GPA) scores to be unaffected. This was despite the withdrawal rate from the course remaining the same.

It also appeared that when students became aware of their risk level, they tended to alter their behaviour, with resulting improvements to their performance. For example in one course of 220 students, there were 45 high risk students. By the end of the course only 10.6% of these were still in the high risk group. Meanwhile 69% of those in the moderate group had risen to the low risk group. Students in pilot groups sought help earlier and more frequently than those not taking part. Even after the interventions stopped, these students were seeking help 30% more often than those in the control group.

In order to establish whether there was a relationship between interventions through Signals and student success, 522 messages sent to students via Signals were analysed anonymously in conjunction with results data. No relationship was established between student success and the frequency of feedback sent in Signals messages. While some of the instructors in the previous study thought that motivational feedback was important, it did however seem that instructional feedback was more effective than motivational feedback. Explicit feedback comparing students to their peers seemed to be more effective than comparing students to standards. Succinct messages also appeared to have a more positive impact than longer ones.

Some instructors used Signals to communicate messages such as "the next assignment is in two weeks". The study suggests that these sorts of message are a distraction and should be communicated through other means. Finally because the messages are perceived by students as personalised communication with instructors it is important to take care in how they are formatted. One instructor failed to fill in the gaps in a templated message with the result that an email was sent saying "please continue to work and if you have any questions, I am in my office, [office location], each day from [h:mm]AM to [h:mm]AM."

Overall there was a 10.37 percentage point increase in As and Bs awarded between Signals users and those in previous iterations of the course which were not using Signals. There was a 6.41 percentage point drop in those awarded Ds, Fs and withdrawals. There was also a significant increase in retention for those taking one of more courses which deployed Signals. The suggestion was therefore that the earlier a student took a Signals course the more likely they were to be retained. Meanwhile if they took two or more courses that used Signals they were even more likely to be retained. A further interesting finding was that lesser-

prepared students taking Signals-based courses did better than better-prepared students on courses that did not use Signals.

Mike Caulfield disputed some of Purdue's claims of the improved retention of students using Signals, and in particular that those taking two or more Signals courses were 21% more likely to be retained. He pointed out a selection bias: those taking *two* classes, whether Signals-based or not, were already more likely to be retained than those only taking one. Conversely, those who dropped out were taking fewer Signals courses because they weren't taking any classes at all. So students are taking more Signals courses because they are continuing; they are not continuing because they are taking more Signals courses.

Purdue does not appear to have responded in detail to these claims and their subsequent exposure in the media. They relate to claims of improved retention – the improvement in grades does not appear to be being questioned. However Caulfield points out that it is retention that has real financial implications for institutions rather than improved grades.

Opinions of students and staff

Stakeholders have generally welcomed the Signals initiative. Administrators were particularly interested in the potential for increasing retention and thus reducing spend on marketing and recruitment, as well as improving individual universities' positions in league tables. They also felt it was helping to alleviate the concerns of students' parents. One administrator who was interviewed in this study pointed to a need for "faculty to buy into the fact that students are here to succeed … and that the faculty's job is not only to just impart information but also to ensure that the information is being understood". Another interviewee noted messages "from students who said they really needed that kick to get me going, to get me started".

One problem identified was that in many humanities classes the final grade was based on only two assignments and use of the VLE was minimal. It was suggested that data from wiki participation could be used. This points to a potential need to redesign courses to have more frequent assignment points and more use of VLEs in order to generate more learning activity data.

A key benefit of Signals pointed out by one administrator was that subject help desks and additional tutoring sessions were often poorly-attended, however those using Signals took greater advantages of these services. Signals also appeared to improve communication between students and instructors. None of the administrators interviewed saw the technology as a "big brother" but they were worried about its scalability.

Instructors meanwhile agreed that students tended to show improvements in engagement after using Signals, and were thinking about their assignments earlier. They did express reservations about the number of emails from concerned students, and were worried that learners would develop a dependency on the system rather than developing skills in independent learning.

Learners' opinions on Signals were also sought. More than 1,500 students were surveyed anonymously across five semesters to gather feedback on their use of Signals. Most felt that the automated messages and warnings sent to them were a type of personal communication with their instructor, which reduced

their feelings of "being just a number". They found these messages and the traffic lights informative and helpful in changing their behaviour, though they would have liked even more detailed information on how to improve. Negative responses from a minority of students included two comments from students who reported being demoralised by the frequent messages. Many also felt that there were too many similar messages sent to them by email, text and on their VLE home page. Some also believed that their traffic lights were not updated frequently enough, and did not reflect their current status. Others wanted more specific feedback on how they could improve.

Students overall *liked* Signals. 89% of them considered it a positive experience and 58% would have liked to see Signals in all of their courses. They found the combination of the traffic signal and instructor feedback both informative and motivational. 74% of them said their motivation was increased by Signals.

Conclusions

Possible problems with Signals were anticipated: including maintaining the privacy of teaching performance and ensuring the validity of the algorithm. There were also concerns that appropriate staffing, technology and information resources would be put in place.

A number of additional issues emerged overall from the Signals project:

- Institutions need to be able to extract data from disparate systems efficiently and in a timely way. Much of this is dynamic and changing rapidly which adds further complexity.
- Students were confused by the multiplicity of interventions deployed by different instructors. Further research in required in refining the tone and frequency of messages, the methods of communication and the timing of interventions.
- Students did not express concerns about privacy of their data but that did not mean that the institution could neglect to protect it.
- Given the centrality of student success to the institutional mission, learning analytics initiatives might be better led from an education-focussed unit than from the IT department.

One final reported benefit of Signals was the increased interest on campus in retention and how best to help students.

References

Arnold, K. (2010, March 3) Signals: Applying Academic Analytics. *EDUCAUSE Review*. http://er.educause.edu/articles/2010/3/signals-applying-academic-analytics

Arnold, K. E., & Pistilli, M. D. (2012) Course Signals at Purdue: Using Learning Analytics to Increase Student Success. *Learning Analytics and Knowledge.* ACM.

Arnold, K. E., Tanes, Z., & King, A. S. (2010) Administrative Perceptions of Data-Mining Software Signals: Promoting Student Success and Retention. *The Journal of Academic Administration in Higher Education, 6*(2), 29-39. http://jwpress.com/JAAHE/Issues/JAAHE-Fall2010.pdf

Caulfield, M. (2013, September 26) *A Simple, Less Mathematical Way to Understand the Course Signals Issue.* Retrieved from Hapgood: http://hapgood.us/2013/09/26/a-simple-less-mathematical-way-to-understand-the-course-signals-issue/

Caulfield, M. (2013, Nov 12) Purdue Course Signals Data Issue Explainer. *e-Literate (blog)* http://mfeldstein.com/purdue-course-signals-data-issue-explainer/

Straumsheim, C. (2013, November 6) MIxed Signals. *Inside Higher Ed*. https://www.insidehighered.com/news/2013/11/06/researchers-cast-doubt-about-early-warning-systems-effect-retention

Tanes, Z., Arnold, K. E., King, S. A., & Remnet, M. A. (2011) Using Signals for appropriate feedback: Perceptions and practices. *Computers and Education, 57*, 2411-2422.