Proceedings Paper:

Rossiter, J.A. orcid.org/0000-0002-1336-0633 (2016) Using an understanding of feedback processes to improve student learning. In: IFAC-PapersOnLine. 1th IFAC Symposium on Advances in Control Education ACE 2016, 01-03 Jun 2016, Bratislava, Slovakia. Elsevier , pp. 57-62.

https://doi.org/10.1016/j.ifacol.2016.07.153

Using an understanding of feedback processes to improve student learning

J. A. Rossiter *

* *Department of Automatic Control and Systems Engineering, University of Sheffield, Sheffield, S1 3JD, UK (e-mail:j.a.rossiter@sheffield.ac.uk*

Abstract: The main purpose of this paper is to give some novel insights into the creation and use of feedback within a learning environment. The literature commonly puts all the emphasis for feedback on what staff do, but this paper will demonstrate using analogies with classical control feedback loops that it is in fact not staff who create feedback, but students. Consequently, rather than pressurising staff to create more, faster, better 'feedback' the onus should be on educating students, and staff, on how to create effective feedback from the myriad of information available to them.

Keywords: Feedback, measurement, student engagement, student responsibility, student satisfaction.

1. INTRODUCTION

The issue of feedback has routinely scored relatively poorly on National Student Survey (NSS) results and this despite huge efforts by Universities to address this. In the author's view, the poor student perception of feedback at University is much more down to their misunderstanding of what feedback should be, in effect an assumption that the type of feedback provided at school will continue to be available at University. This paper will give some evidence to support that view and specifically will give an insight into feedback processes which is less well publicised in the mainstream literature. The insights derive from a mathematical analysis of control feedback loops in engineering and these insights are a powerful methodology for showing the impact of different components within learning. The main conjecture of this paper is that University staff would be better putting more effort into helping students understand learning processes (Schaefer et al., 2012) rather than focussing on what students perceive to be poor staff feedback; indeed in many cases the real weakness is the student recognition and inadequate use of feedback (HEA, 2012; Hepplestone et al., 2010) rather than the feedback being poor quality, although of course it is accepted that occasionally staff do provide poor quality feedback.

Recent work has emphasised the need for students to be the prime movers. For example from Winstone and Nash (2015), *The very best feedback is sure to be futile if students do not use it, assimilate it, and implement it in their future goals.* A similar message is given by Brown (2014) and Sivasubramaniam (2014) where it is emphasised that students need to be supported in critiquing their own work, that is generating their own feedback; of course it is implicit that staff provide mechanisms such as online quizzes to help students to do this. A different view on the same message appeared in Benjamin (2012); Wheatley (2012); Wong et al. (2012) where the focus was on distinguishing between feedforward and feedback. The key point is that feedback from staff cannot or will not be utilised effectively by students unless they have an obvious, perhaps immediate, opportunity and motivation to use this for future assignments (Race, 2015). Within the control engineering community this issue has been well understood although again viewed from a different angle. Here there has been a lot of emphasis on game playing and interactive computer tools which encourage students to learn through trial, error, experimentation, reflection and so forth (Khan and Vlacic, 2006; Guzman et al., 2006; Rossiter, 2007, 2013). Again a key point is enabling the student to become active in generating their own feedback. A particularly relevant work in the literature has focussed on so called self-regulating learning (Duffy et al., 2012), whereby students are encouraged to be much more aware of their role in the learning process and the importance of actively reflecting on their own progress, feedback as available and their own needs. It is this thread which is pursued in the current paper.

Another popular tool for encouraging students to become active participants in feedback processes is peer assessment (Hughes, 2007; McConlogue et al., 2010; Orsmond, 2012; Rossiter, 2013b). The aim here is to get students to think deeply about the assessment criteria and the extent to which different pieces of work meet those criteria and to provide comment and justification for their marking. There are twofold benefits in that students receive detailed comments on that work, albeit from peers, and moreover students are emotionally and mentally prepared to think carefully about the quality and weaknesses of their own work given the effort gone into marking a fellow students submission; this should also help them become more targeted in seeking clarifications from academic staff.

A key focus of this paper is the message that feedback comes in many forms (Feedback Toolkit, 2012) and students need to be on the look out and to recognise the feedback when it is available. Too often students think they are getting no or poor feedback because they do not recognise the feedback being provided as feedback. It is well understood in the mainstream literature (Evans and Waring, 2011; Geyskens et al., 2012) that feedback comes in many forms, some of which are staff generated and some of which are self-generated (by the learner), but learners do not respond equally or recognise each form of feedback, irrespective of its quality. A key point is the emphasis on active student engagement with the feedback in order for it support learning effectively. One popular method for improving student engagement is regular assessment, for example with small computer based quizzes which provide instantaneous feedback (Arteaga and Vinken, 2013; Cole and Spence, 2012; HELM, 2015; Rossiter et al., 2004). Nevertheless it is interesting to note that based on viewing several years of student feedback questionnaires, many students who have a number of such quizzes on a particular module often do not equate this with having received feedback on their work!

In summary this brief introduction has reviewed some of the literature on feedback and made some key points. Although students and in particular graduating students often perceive feedback as major weakness of their student experience, in fact this perception is more likely underpinned by a lack of recognition and engagement with the feedback that was available, notwithstanding that at times some staff do a poor job of facilitating effective feedback. This paper will use some insights from control engineering and in particular the topic of feedback control loops to give a different insight to this issue and thus demonstrate the criticality of focussing on student perceptions and an understanding of the feedback learning process and how staff can facilitate this.

2. LINKING LEARNING PROCESSES TO FEEDBACK CONTROL DIAGRAMS

In order to make clear links with control feedback diagrams, this section will use a simplified version of the learning process as this leads to many useful insights without claiming that the analogy should be taken to excess.

2.1 Block diagram representation of learning

This paper will approximate learning by a simple iteration between:

- Students reflect on the target learning and their current knowledge/information available.
- Students use their understanding to attempt problems and produce an output (could be a homework, coursework, formative study, etc.).
- Students receive some comment on their output (for example this could be right/wrong or more detailed textual analysis). This is new information which can be used in reflection.

This iteration is represented in figure 1 and ideally is an ongoing or continuous process. Using this form of block diagram representation shows clear analogies with feedback control systems such as that represented in figure 2 where in this case:

- Students reflection is represented by a block diagram $K(s)$ where the input information is the target learning outcomes (represented by $R(s)$) and a comparison with any 'feedback' they have received on their work (the signal $H(s)Y(s)$).
- Students attempt problems and produce an output is represented by system $G(s)$ and output $Y(s)$.
- Students receive comment on their work; this is represented by sensor $H(s)$ scaling the student output $Y(s)$.

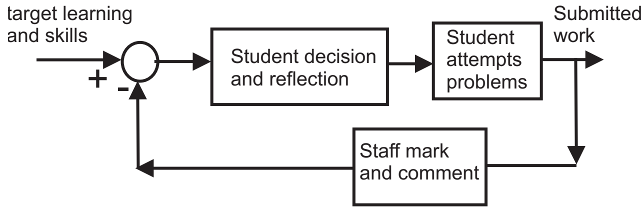

Fig. 1. Simple representation of a feedback learning process with iteration between staff comment, student reflection and student trying problems.

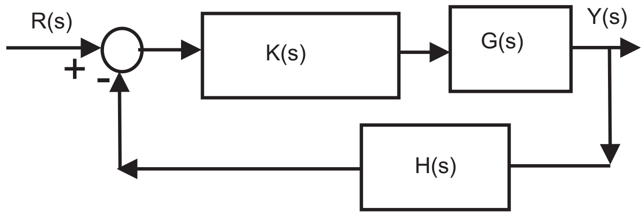

Fig. 2. Equivalent block diagram representation of a feedback learning process with between staff comment $H(s)$, student reflection $K(s)$ and student trying problems $G(s)$.

The main conjecture of this paper is that we can use the analogy of figures (1,2) to gain insights into the learning process and in particular the role or significance of the different components $K(s), G(s), H(s)$, that is the role of student reflection $K(s)$, students attempting problems $G(s)$ and receiving comments on their attempts $H(s)$.

2.2 What makes a feedback loop?

Before we proceed to analyse the analogy above more carefully, it is first worth while rebuffing a common myth about feedback and make a clear statement.

FEEDBACK IS NOT WHAT STAFF DO, IT IS WHAT STUDENTS DO!

The key point is that while staff provide the feedback path, that is measurement or information based on student output, this does not become feedback until it is collected and reflected upon by the student.

Consider figure 3, in this case, it is irrelevant how high quality the comment and measurement provided by staff on student work because the student is not making use of this comment to correct and update future attempts. Consequently, feedback does not exist even though the information to facilitate feedback does! This information cannot become feedback until the student does something with it! Indeed, such an observation underpins the literature which uses the terminology feedforward (Benjamin, 2012) to suggest that feedback information needs to be able to influence future student submissions; in fact this

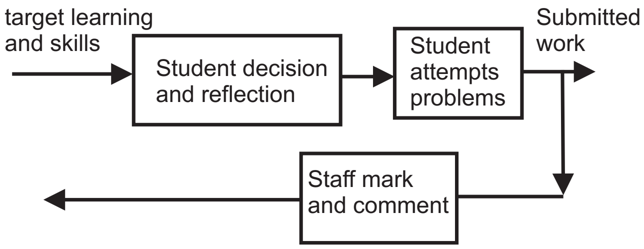

Fig. 3. Equivalent block diagram representation of a feedback learning process where student makes no use of comments provided by staff on their work.

terminology is being abused in the literature in that the continuous iteration of figures (1,2) is a better representation of what is actually occurring. Feedforward is something which lies outside of the feedback loop (see figure 4) and technically this terminology links better to lecture material, comments on earlier assessments and the like, that is useful information students are provided in advance of any new assessment. Feedforward is not discussed here.

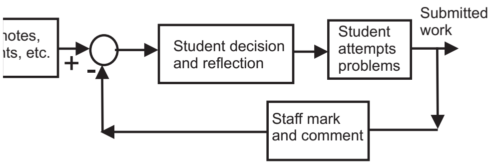

Fig. 4. Equivalent block diagram representation of a learning process with explicit inclusion of feed forward.

Practitioners in control engineering will realise that feedback actually means that output measurements (or observations) are used to influence the system input and without this direct influence of a system output on the system input, feedback does not exist. Of course it is implicit in this analogy that this iterative learning loop exists, which means that students must have opportunities to practice problem solving, receive comment on their attempts and then try again! Indeed this could be used as an argument to recommend a need for far more formative assessment than summative assessment.

Remark 1. One obvious weakness of the typical end of semester examinations is that they are, in effect, like figure 3. You could argue that students get a mark but otherwise the comment on their efforts is non-existent and cannot be used effectively to improve their understanding and learning or indeed to influence how they tackle future assessment. That is not to say that end of semester examinations do not have a role, but students must have access to feedback learning processes, that is formative assessment, in order to prepare.

2.3 Summary

It is not enough for academic members of staff to provide detailed comments and marking of student work. This only becomes feedback when the student actively engages in those measurements and moreover, uses these to change their future actions. Many students claim a lack of feedback during their studies whereas staff can provide evidence that ample measurement has been provided. An obvious conclusion is that the students are not using the information provided appropriately and therefore the feedback loop is not being closed due to student inactivity, perhaps caused by a lack of clear guidance from staff.

3. USING FEEDBACK LOOPS TO UNDERSTAND THE EFFICACY OF DIFFERENT LEARNING COMPONENTS

This section will focus on the block diagram of figure 2 and make analogies between different choices of the components $K(s), H(s)$ and the efficacy of student reflection/staff comments. The main point is to give insight into how both student ineffectiveness and staff ineffectiveness can affect learning and thus give a systematic mechanism for improvement. The reader is reminded that an underlying message in this paper is that the over-emphasis on staff writing detailed comments on students' work to improve student perceptions of feedback is misplaced and this will be demonstrated clearly.

The section focuses on two aspects:

(1) What is the impact of poor student reflection and decision making which is represented by the block $K(s)$.
(2) What is the impact of poor quality measurement information (e.g. staff not providing adequate detail or timeliness in their marking); this is represented by block $H(s)$.

Feedforward in the classical control sense is not discussed here for brevity.

3.1 Underlying models for the learning components

For simplicity learning or student acquisition of skills or understanding is represented by a transfer function

$$G(s) = \frac{0.6}{s+1} \quad (1)$$

using a time scale of weeks. An output of 1 represents full understanding. This system has a steady-state of 0.6, that is with just lecture input and no feedback one expects learning to converge to 60% of full requirements. Consequently, full learning requires more than just lecture input - it needs the student to be proactive and provide a stronger or more informed input which comes about using the reflection implicit in $K(s)$.

A fully conscientious student is represented by a well tuned PI compensator

$$K(s) = K_p + \frac{K_I}{s} = \frac{s+1}{0.6s} \quad \rightarrow \quad \frac{GK}{1+GK} = \frac{1}{s+1} \quad (2)$$

that is a closed-loop with a time constant of one week; students will converge to almost full understanding over about 3 weeks with perfect staff support. A fuller discussion of tuning follows in a page, in the interim: :

- The proportional term K_p represents students having an instantaneous reaction to new information/targets but no reflection and thus while some learning occurs, it is imperfect. If the proportional is too large, students over-react to new information and thus their understanding is expected to be oscillatory/chaotic. If the proportional is too small, they under-react and this represents disengagement and lack of attention.

- The integral component K_I represents the ongoing reflection process and thus while learning is slow to progress, it can converge to full understanding. A larger integral terms represents more active reflection and engagement and a smaller integral means the student is slow to do this or simply not putting enough time into it.

Staff activity is represented by the sensor term $H(s)$. A value of 1 indicates immediate and comprehensive comments on student work. The introduction of lag components and/or delays represents staff needing time to provide comment to students. However, in order for the analogy to work, readers should note that, for this section (a more involved paradigm comes later) incomplete staff feedback is represented by steady-state gains in $H(s)$ of over one, this because this indicates an over-emphasis on just some aspects of the student submission and thus implicitly, some parts have been ignored.

3.2 The impact of poor measurement

For now, this section will assume that all students are perfect and conscientious (using the compensator of (2)), thus engage fully and quickly with an input from staff. This assumption is made to highlight the impact of different levels of *support* or marking quality provided on formative work. Student learning or understanding is represented by the line graphs in figure 5; remember that full understanding is represented by a value of 1.

- With perfect and immediate measurement ($H(s) = 1 = H1$), learning is relatively rapid and converges to full understanding.
- With fast but incomplete measurement ($H(s) = 1.2 = H2$, $H(s) = 2 = H3$), students learn rapidly but do not converge to full understanding.
- Where the staff measurement is gradual (a bit like a drip feed) but complete, this is represented by $H(s) = 1/(s+1) = H4$. Here, students converge to a full understanding but may do so quite slowly compared to $H1$ and with unpredictable transients in their understanding in the interim.
- Where measurement is both gradual (drip feed) and incomplete ($H(s) = 1.5/(s+1) = H5$), student learning is both unpredictable and unlikely to converge to a full understanding.
- Where measurement is delayed for nearly 2 weeks (a common scenario in Universities is to require feedback to students within 2 weeks) but complete, this can be represented by $H(s) = e^{-2s} = H6$. Again, the delay has caused unpredictable impacts on student learning which here does not converge in reasonable time and this form of measurement has been of little help.

In summary, the example in this section has demonstrated that the use of a feedback loop with a sensor has many of the characteristics required to capture the learning process and in particular, to show the dependence of student learning upon the quality and timeliness of marking/comments. This section has shown that ideal student's learning is severely impacted by both the quality and timeliness of comment on their work and thus reinforces the benefits of students receiving regular, quick and complete comment on their work.

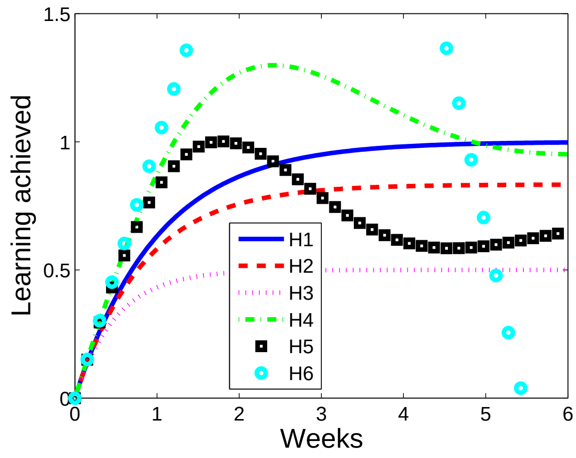

Fig. 5. Representation of the impact of quality and timeliness of feedback information on student learning.

3.3 Impact of student engagement on the efficacy of feedback

As mentioned earlier, information from staff only becomes feedback once students receive it and do something with it; this action is represented by the compensator $K(s)$. Of course students can use this information in a number of ways and these examples indicate some of the possibilities. Here the analogies are between a proportional response which is rapid learning and benefit from feedback and an integral term which is linked to ongoing student reflection and correction. Without a rapid engagement, the student learning will be slow. Without adequate reflection, student learning will not converge to the correct understanding.

In this section, it is assumed that the measurement or feedback path is perfect and hence $H(s) = 1$. The following choices represent different types of student engagement.

- A choice of $K(s) = K1 = (1+s)/(0.6s)$ is assumed to be ideal with a good balance between immediate response and careful reflection (that is the proportional and integral components) so that learning converges fully in about 3 weeks.
- A choice of $K(s) = K2 = 0.5K1$ indicates a student who is a little more passive or inactive, so although they do respond to feedback on their work, their response is relatively small and their reflection processes are slow. Unsurprisingly therefore, convergence to full understanding is relatively slow.
- The choices of $K(s) = K3 = 1/0.6, K(s) = K4 = 1$ represent students who have an immediate response to any feedback information, but no ongoing reflection. As a consequence, although some relatively rapid learning takes place in transients, there is no convergence to full understanding.
- The choices of $K(s) = K5 = 1/(0.6s)$ represents a student who has no immediate reaction but does undertake reflection. Consequently, learning is slow in transients, but they eventually master the material.
- The choice of $K(s) = e^{-3s}K_1$ represents a student who puts all the feedback information to one side until a revision period (here the delay is taken as only

3 weeks). Clearly the learning is slow to being and chaotic thereafter.

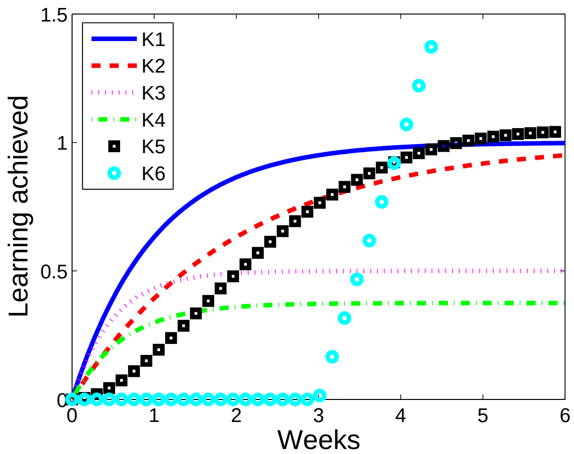

Fig. 6. Representation of the impact of student engagement with feedback information on learning efficacy.

3.4 Discussion

It is clear that the quality of staff information which is what has classically been interpreted as feedback has a significant impact on performance, that is student learning and any absences of core data or delays affects learning detrimentally. However, it is also clear, that even with perfect feedback information, student learning is significantly effected by student activity and engagement, that is, the extent to which they make use of the feedback provided. There is no benefit from 'marking' information if students do not turn this into useful feedback by appropriate reflection and action and thus ultimately it is students actions which create feedback and determine the quality and quantity of feedback.

4. CRITICAL ROLE OF STUDENT ACTIVITY IN BOTH CREATING FEEDBACK AND REFLECTION

The preliminary conclusions indicate that there is a roughly equal role between staff and students in promoting effective learning, in that students need good measurement (or marking) and also good control. However, this section takes the argument one step further to show that, in many cases, poor measurement is not in fact due to poor behaviour by staff but more often is due to poor behaviour by the student.

For this scenario, we introduce a more involved figure 7 which shows that learning activity and appropriate measurement information can come from numerous sources. The figure shows a few typical learning outcomes as an illustration and the key point is that the required activity and measurements are different, but taken together add up to the whole learning outcomes for a module/topic.

Next, it is useful to analyse the measurement data, or if you prefer feedback paths, in a little more detail.

(1) A classic path is that students submit hard copy and staff mark this. Typically this is slow and thus has

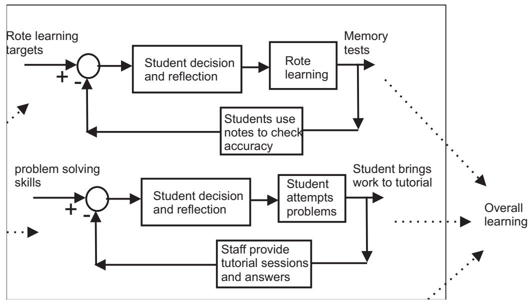

Fig. 7. Representation of different typical learning outcomes and feedback mechanisms within a single module or topic.

the weakness of slow measurement as indicated in the previous section. Should be avoided where faster measurement is possible.

(2) Students can get almost instantaneous measurement/feedback by asking questions in lectures. Critically however, this requires students to be proactive and of course will cover only a limited range of learning outcomes.

(3) Students can get feedback by bringing their work and questions to drop in tutorials. Again, the key point here is that students need to be proactive in seeking out this feedback, both by doing tutorial work in a timely fashion (without which there is no output on which to ask questions) and attending to make use of the support available. Although there is some lag in this feedback mechanism, it is high quality and individualised otherwise.

(4) Many staff provide weekly home works and quizzes with answers which students can attempt to test their ability to do basic problem solving. Students only get feedback if they produce the output, that is by trying the problems - the feedback is already in place in the notes/quizzes ready to be used and thus is instantaneous!

(5) Students reflecting on lectures and handouts and comparing new insights with previous understanding and concepts. Such learning is often supported by discussion, with peers and staff, and thus staff need to provide mechanisms for students to engage with this. Where such engagement opportunities are provided in lectures and tutorials, students need to be active participants to get any benefit.

(6) The simplest feedback students can get is by memorising key knowledge and testing themselves. There is a need for staff here to ensure the key knowledge is supplied clearly. Again, measurement here is almost instantaneous, but students have to take responsibility to taking the measurement.

(7) Many software tools enable students to self test their own learning by acting as benchmark answers for many typical questions, but this is only effective if students make use of those tools.

Readers will notice that for many of the feedback mechanisms above, staff ensure the mechanism exists, but it is the student who is active in closing the loop, both by collecting or creating the feedback and by reflecting on their efforts and the feedback available. The direct staff role in creating feedback information is limited to a small range of the overall learning outcomes and consequently, a student complaining of too little feedback has often not been effective in utilising what is available to them!

5. CONCLUSION

The work in the literature and in particular reactions by Universities to NSS, has encouraged a mis-alignment of priorities where all too much focus has been on the staff role in feedback mechanisms. However, the simple analysis in this paper demonstrates that the staff role in providing feedback is relatively minor, although important. Staff set up mechanisms where students can obtain feedback, but students must be active in using those mechanisms or the feedback will either fail to materialise (e.g. open-loop learning as in figure 3) or be ineffective (poor measurement and/or poor control). Consequently, the real need within Universities is to help students understand their pivotal role in feedback mechanisms and to recognise, generate and use effectively the numerous forms of helpful measurement information available to them.

A second and key contribution of this paper is to demonstrate how a simplistic analysis of classical control feedback loops gives a good representation of learning processes with students and thus provides useful insight into how staff can create effective learning environments and, for example, it emphasises clearly the negative impact of any delays or imprecision in the marking process.

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