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Chapter 4

FEEDBACK VIA EDUCATIONAL TECHNOLOGY

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ABSTRACT

Effective feedback is critical to successful learning environments. Though many of the principles that make feedback effective in face-to-face settings also apply to educational technology, there are some special characteristics of feedback via educational technology to consider. This chapter discusses the conditions in which feedback via educational technology is most and least effective for improving learning outcomes. The discussion includes characteristics of three aspects of the instructional system that improve or hinder learning outcomes: feedback, learners, and tasks. The challenges of implementing feedback via technology are also considered. The chapter concludes with limitations of the current research and recommendations for future research.

Keywords: feedback, educational technology, learning science

INTRODUCTION

Feedback is an effective tool to bridge the gap between a learner's current understanding and a given learning goal. Feedback via educational technology aims to provide more of this valuable resource without increasing the workload of instructors, but it has limitations. This chapter will examine the conditions in which feedback via educational technology is most and least effective for improving learning outcomes. The examination considers characteristics of the feedback, learners, and tasks that contribute to learning outcomes. Characteristics of feedback include the type of feedback, granularity, and the social presence involved. Learner characteristics include the learner's ability and their prior knowledge relevant to the task.

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Characteristics of the task include the type of learning outcomes desired as well the complexity of the task. The chapter concludes with challenges associated with providing educational technology feedback and recommended future research.

For the purposes of this chapter, feedback is defined as external information provided to increase learning (e.g., McLaughlin 2006; Salmoni, Schmidt and Walter 1984; Shute 2008). Feedback can come in many forms, such as the indication of an answer being marked correct or incorrect, providing the correct answer, hints, worked examples, or explanations. Feedback from educational technology typically refers to programmed instruction from a computer-based environment. Feedback from a human tutor who is using computer-based technology as the medium to provide feedback, such as with email or chat-based feedback, is not included in this definition. For the purposes of this chapter, feedback from educational technology encompasses programs that choose feedback from prepared options in response to a learner's actions, as opposed to simply being a delivery mechanism for a human tutor. Intelligent tutoring systems are also outside the scope of this chapter. An intelligent tutoring system (ITS) is a computer system that uses a model of the learner to construct feedback; therefore the mechanism used to provide feedback is qualitatively different than those described in this chapter. Although many of the same guidelines discussed below apply to ITS design, those interested in how to design an ITS should consult the ITS literature, such as the recent review by Kulik and Fletcher (2015).

There are many types of learning environments that could benefit from using feedback through educational technology. For example, a human instructor might have a class of anywhere from 20 to 200+ students. Using technology to provide feedback to these students could save time for all users; the instructor does not need to spend hours creating personalized feedback for each individual when feedback via technology can be provided without a long delay. While large classes could potentially receive the most benefit from feedback via educational technology due to scalability, smaller classes and one-on-one tutoring might also benefit depending on the relationship of the benefits and cost to create the computer-based system.

Challenges in Online Environments

Many feedback concepts can be applied in online environments the same way that they are applied in traditional classrooms, particularly those concepts related directly to pedagogy. However, online environments also present some unique challenges. For example, in a 2006 survey, online learners reported that they still preferred print materials "for reasons of portability, dependability, flexibility, and ergonomics" (Spencer 2006, p. 33). This preference is even more noticeable in situations that require thorough reading (Chen and Catrambone 2015; Jamali, Nicholas and Rowlands 2009). Some of the challenges can directly affect the way feedback should be implemented.

One challenge to consider is cognitive load, the mental burden being placed on a learner's working memory. Although learners are generally becoming more comfortable using technology to supplement or even facilitate learning, there is evidence to suggest that learners are more mentally taxed when using screens to learn as opposed to more traditional materials such as paper. According to one study, people reading on screens achieved comprehension levels no higher than those reading on paper, but endured significantly higher amounts of workload to achieve that comprehension (Noyes, Garland and Robbins 2004). Wastlund et al. (2005) made similar discoveries in their study, noting that readers of screens reported higher tiredness and stress levels than paper readers doing the same activities. With respect to feedback, these findings are important because the increased workloads inherent with screens (and by extension, technology-driven learning) should be considered in conjunction with any feedback system, particularly forms of feedback that improve learning at the cost of higher workload. Of course, higher workload for learners is not inherently counter-productive, especially on relatively easy tasks or for learners of relatively high aptitude, but the fact remains that screens should be considered differently from paper in terms of workload. Some of the workload inherent to screens, such as that induced by scrolling, can likely be considered extraneous load because the workload is solely a function of the presentation manner and does not contribute to understanding the material (Chandler and Sweller 1991). Not only does higher workload leave fewer mental resources for learners to process relevant information, it also increases the susceptibility of learners to the hard-easy effect, or the tendency for learners to be overconfident when studying difficult materials (e.g., Lichtenstein, Fischhoff and Phillips 1982). The hard-easy effect is thought to occur because working relatively hard to understand materials evokes stronger feelings of accomplishment, leading to feelings of superior understanding (e.g., Lichtenstein et al. 1982). As long as screens are inherent to educational technologies and are more difficult ergonomically than paper materials, this overconfidence could be present in students learning in venues such as online courses. In at least one study, *predictions* of comprehension test performances were significantly higher for participants reading from screens than their counterparts on paper (even though *actual* comprehension differences were not statistically significant), suggesting that study medium can indeed be a vehicle for the hard-easy effect (Ackerman and Goldsmith 2011). Therefore, when considering feedback strategies in educational technologies, especially those related to learner self-assessment, it should be noted that those using screens might be less able to accurately evaluate their own progress.

CHARACTERISTICS OF FEEDBACK THAT AFFECT EFFICACY

Type of Feedback

Feedback can be classified into the following three categories: knowledge of results (KR), knowledge of correct response (KCR) and elaborated feedback (Shute, 2008). KR indicates only the correctness of the answer, such as text that states “right” or “wrong” appearing after a student has submitted an answer. The purpose of KR is to reinforce correct recall, but is not very effective because the learner is not provided any information on how to improve (Van der Kleij, Feskens and Eggen 2015). Providing only KR has been shown to be an inferior method of feedback compared to KCR or elaborated feedback (Jaehnig and Miller 2007). KCR provides more information than KR by giving the learner the correct answer, but is not necessarily more effective than KR (Van der Kleij et al. 2015). Elaborated feedback includes many forms of feedback including hints, explanations, strategy information, worked examples, and additional study material (Shute 2008; Van der Kleij et al. 2015). Most studies using elaborated feedback incorporate KR or KCR with additional feedback such as those previously mentioned. Therefore, elaborated feedback blurs the line between instruction and feedback because the feedback often becomes new instruction (Hattie and Timperley 2007; Kulhavy 1977). Elaborated feedback is generally much more effective than KR or KCR, especially for higher learning outcomes as opposed to lower order learning outcomes as discussed later in the chapter (Van der Kleij et al. 2015). However, elaborated feedback often requires more time and labor from the developer, which can make it less appealing than KR or KCR (Jaehnig and Miller 2007).

Granularity of Feedback

Granularity of feedback refers to the scale at which feedback is given. Granularity can be classified by the following feedback types listed in increasing specificity: Answer-based, step-based, substep-based, and human (VanLehn 2011). Answer-based feedback is characterized by giving students feedback on their answers, whereas step-based feedback allows the student to enter steps necessary to solve the problem. Answer-based feedback provides feedback on only the final solution whereas step-based feedback allows each step to be marked as correct or incorrect. Substep-based feedback provides scaffolding and feedback at an even finer level than step-based feedback. Substep-based feedback is often used to guide inferences needed to complete a given step. For example, a student who is trying to solve a word-based problem converting pints to gallons might press the hint button. The tutor might first ask the student, "Are you familiar with the imperial system?" This is not a step per say, but prerequisite information for completing the next step. Feedback from a human can have a smaller grain size than substep-based feedback because the scale of the feedback is not constrained to a tutoring system with predetermined settings.

VanLehn (2011) found that decreasing the granularity of the feedback from answer-based to step-based increased the effectiveness of the feedback. However, further decreasing the granularity did not lead to further increases in effectiveness. In other words, step-based, substep-based, and human feedback produce roughly the same results. This effect has been found in various educational domains such as medicine (Evens and Michael 2006) and physics (Reif and Scott 1999), and has shown to hold true regardless of the learner's prior knowledge (VanLehn et al. 2007).

Social Factors in Feedback

The source of feedback has also been shown to affect a learner's performance. Social facilitation describes the phenomenon in which people behave differently when they are alone compared to when they are in groups. Social facilitation has two parts: the presence of others causes people to A) perform easy or well-known tasks better than when they are alone, and B) perform difficult or novel tasks more poorly. Virtual humans can be used to deliver feedback, and have been shown to cause the same social facilitation as actual humans (Park and Catrambone 2007). A virtual human's voice or face has been shown to independently cause social facilitation, but syncing the voice with the facial appearance, with or without conveyed emotion, evokes an even stronger response (Park and Catrambone 2007).

When designing an instructional system, consideration should be given to how learner behavior changes depending on the presence of a virtual human. Learning and performance might suffer if the virtual human is present during a difficult or novel task, but will likely improve during a practiced or easy task (Park and Catrambone 2007). Developers might want to avoid the use of a virtual human in the beginning stages of learning to avoid the negative effects of social facilitation. After the learner has acquired some familiarity with the task, using both verbal and nonverbal forms of communication can make animated pedagogical agents more effective (Atkinson 2002).

Successful human tutors utilize motivational and affective features that are often lacking in computer-based tutoring systems (Atkinson 2002). However, animated pedagogical agents can mimic human-to-human interaction and employ nonverbal communication like gaze and gesture (Johnson, Rickel and Lester 2000). Animated pedagogical agents are autonomous characters with lifelike emotional responses that can make use of information-filled, non-verbal cues that normally occur in face-to-face interactions but are less invasive than verbal feedback (Johnson, et al. 2000). For instance, an approving nod, a head shake to indicate disapproval, a puzzled expression to indicate the learner made an error, or even a smile when a task is completed can provide feedback unobtrusively while allowing the student to continue working or thinking about the task at hand. The less obtrusive facial expressions and other nonverbal feedback might often be preferable to more disruptive verbal feedback (Johnson et al. 2000). Other forms of body language can have a strong influence on the learner and could be used to show a learner that they are about to commit an error (Johnson et al. 2000). Nonverbal feedback can also be used to direct the learner’s attention to important details. Gaze and gestures as opposed to arrows or colored highlighting can be used to guide attention to a specific area. Animated pedagogical agents can demonstrate how to carry out a task which can be sometimes be more helpful than a block of text describing the procedure (Johnson et al. 2000).

When a student is struggling and needs large amounts of feedback, a demonstration of the task might then be more beneficial than a text-based explanation. An agent has the advantage of being able to direct the learner’s attention while demonstrating an activity, or to point out important features of a video or animation. The agent is able to mimic the important aspects of the social interaction that an animation alone would not accomplish.

Another advantage of using a virtual human is that students learn better from conversational instructions than didactic instructions, such as a passage in a textbook (Moreno, Mayer and Lester 2000).

Moreno et al. (2000) found that learners performed better on transfer problems and also reported higher levels of motivation and interest when an animated pedagogical agent was present. Both the agent’s voice (i.e., modality effect) and the personalized conversation style (i.e., dialogue effect) contributed to these results, although the image of the agent did not have an effect.

Key Points

- Elaborated feedback is generally the most effective type of feedback, but requires more resources to develop than KR or KCR. If resources are limited, KCR is recommended over KR.

- Step-based feedback is generally more effective than feedback at a smaller (sub-step based) or larger level (answer-based).
- Due to the social facilitation effect, virtual humans are not recommended to be used when learning a difficult or novel task as they will likely impair performance. In contrast, including a virtual human in the later stages of learning will likely improve performance.

LEARNER CHARACTERISTICS THAT AFFECT EFFICACY

Ability

As with many interventions in the education realm, the characteristics of learners are a key factor to consider when implementing a feedback system. Perhaps the most important individual difference factor is the general aptitude and/or intelligence of the learner. For example, poorer learners (i.e., those with relatively low scores on tests of retention and transfer) are less likely to be able to assess their own understanding, and in fact often overestimate how well they understand material after receiving feedback, while learners of higher aptitude often respond to feedback by asking for further clarifications and/or analysis of what they did incorrectly in the first place (Chi et al. 1989). Chi et al. (1989) noted that low-ability students tend to use feedback as a crutch, rather than using it to help them go through the more arduous process of self-evaluation. Therefore, it appears that feedback can sometimes be useful, but other times provide a false sense of understanding that could undermine its effectiveness. This phenomenon is especially troubling when considering the fact that learners often subjectively prefer learning mechanisms that improve short-term performance but are not necessarily the best for them in terms of long-term learning (e.g., Baddeley and Longman 1978). Feedback that improves retrieval strength, which merely reflects current activation and is often dependent on context cues, often improves short-term performance, but does little for long-term learning (Bjork and Bjork 1992). Learners of lower aptitude might be particularly susceptible to preferring those methods because of their relative inability to assess their own learning. If the goal of feedback is to produce learning that is relatively permanent and transferable, then one possible method is to provide feedback in a way that emphasizes connections between new material and a learner's existing knowledge, a key to building the storage strength that is indicative of enduring learning (Bjork and Bjork 1992). Many "minimal guidance" instructional methods (in which learners solve problems without receiving much or any instruction) rely on learners' use of pre-existing and long-term knowledge to solve problems; therefore, feedback provided in "minimal guidance" environments would be more likely to integrate with a learner's long-term knowledge than when provided in other environments.

The aptitude of a given learner is also important in determining how he or she will respond to a prescribed degree of structure in the feedback system. In general, higher degrees of structure (e.g., "knowledge of correct response" methods) favor learners of lower ability, while lower degrees of structure (e.g., "answer until correct" methods) favor learners of higher ability (e.g., Sullivan and Skanes 1971). High-ability learners tend to prefer the freedom to develop their own methods and to personalize content, so they learn relatively poorly in highly-structured environments; low-ability leaners are more likely to need help developing strategies and also tend to learn using rote memorization, so highly-structured environments are favorable to them (Gray 1982; Snow 1982). Therefore, when creating feedback systems for those of lower aptitude, a predictable rhythm (e.g., after every X minutes, after every N completed steps) and format to the feedback (e.g., KR, KCR, elaborated feedback) is relatively important so that the learners know what to expect. With someone of higher aptitude, the structure of the feedback is less important; the content itself is more important because the learner will generally be able to figure out a way to incorporate the information in a way that he or she understands. If measuring a learner's general intelligence is difficult, a highly-related measure to use in its place might be working memory capacity (Conway, Kane and Engle 2003), the amount of information a learner can hold for use in ongoing cognitive processes. Working memory capacity is useful because it is a relatively easy characteristic to measure that is also fairly enduring (Conway et al. 2003).

Prior Knowledge

A learner's prior interactions with related materials also affects feedback effectiveness: Those with less existing knowledge tend to require more elaboration (such as the hints or worked examples used in elaborated feedback) when provided feedback, but unfortunately also generally lack the knowledge structures to process those elaborations (Sweller 1988), while those with more pre-existing knowledge tend to require less elaboration on feedback. Therefore, more feedback is not necessarily the answer for novice learners at any given time during a task; helping them build accurate mental models before providing elaborated feedback is likely important.

Key Points

- Low-ability learners tend to have trouble self-assessing and therefore might not use feedback as effectively as it could be used
- Feedback that improves learning in the short term is not necessarily better for learners in the long term
- Learners of high ability do not require as much structure in the learning environment as those with lower ability
- Elaborated feedback might be helpful for those with less pre-existing knowledge, but only after helping those learners create accurate mental models first

Characteristics of Tasks That Affect Efficacy

Skill Types

The type of feedback that effectively improves learning outcomes depends on the desired learning outcomes. Some types of learning outcomes need only knowledge-of-correct-response (KCR) feedback while others benefit greatly from elaborated feedback. In their 4C/ID model of complex learning, van Merrienboer, Clark, and de Croock (2002) argued that students need more support while learning non-recurrent skills than recurrent skills. Recurrent skills are those that are applied to problems in the same way each time regardless of the context (van Merrienboer et al. 2002). The same procedure is used to solve multiple problems. For example, the conjugations for a verb do not change based on sentence context; they simply need to be practiced until they are memorized. Conversely, non-recurrent skills are applied in different ways, depending on the problem to be solved. Unlike recurrent skills, the same process cannot be used for each problem. Instead, the process must be adapted to the specific problem. These are the skills for which transfer of knowledge is valuable. For example, students can solve several types of problems using the equation $f = ma$, but the procedure for solving such problems varies depending on the givens. Sometimes students are given f and a and need to calculate m. Other times, students are given the information to calculate f and a and need to take extra steps before solving for m. Most systems that provide computer-based feedback can support development of non-recurrent skills, but many systems do not provide sufficient support for non-recurrent skill building.

Development of recurrent skills typically involves learning activities in which providing immediate and repetitive feedback is valuable to the learner. Jia, Chen, Ding, and Ruan (2012) argued that technology can better provide feedback that would be repetitive and time-consuming for an instructor to provide. For example, when students are practicing conjugating verbs in a language course, technology can provide immediate feedback to students as they work through an assignment, whereas an instructor would have to collect the assignment, grade each student's assignment, and provide delayed feedback. Immediate feedback from technology is better for the student's learning than delayed feedback from an instructor in cases like this (Jia et al. 2012). Furthermore, computer-based feedback does not burden the instructor, and immediate feedback typically leads to higher student satisfaction (Gikandi, Morrow and Davis 2011).

In their review of courses that were taught partially face-to-face and partially online, Margulieux, McCracken, and Catrambone (2015) found that half of the courses that used computer-based feedback improved learning outcomes while the other half had equivalent outcomes. The courses that improved outcomes asked students to practice recurrent skills using educational software, and the courses that had equivalent outcomes asked students to practice non-recurrent skills using technology. Though these studies did not provide much information about the software that they used, they likely provided knowledge of results (KR) or knowledge of correct response (KCR) feedback. Margulieux et al. (2015) concluded that the educational software typically used to supplement in-class instruction – those that provide KR or KCR feedback – provide enough support to improve development of recurrent skills but not non-recurrent skills.

In their review, Margulieux et al. (2015) found that computer-based feedback did support development of non-recurrent skills in a particular circumstance. If the software provided feedback on a non-recurrent learning activity that started in class and continued online, then the software aided learning. For example, if engineering students started working on a problem set in class, where the instructor was available to help students through impasses, and the students then continued the problem set later with KR or KCR computer-based feedback, they performed better in the course than if they did not receive feedback (computer-based or human). In contrast, if the instructor spent the class period lecturing and students completed the problem set entirely outside of class, then the students performed equally whether they received computer-based feedback or no feedback. Margulieux et al. (2015) concluded that development of non-recurrent skills requires more support than is typically provided through computer-based feedback from currently-employed software. However, if instructors support students' initial practice of non-recurrent skills, then computer-based feedback can sufficiently support students' later practice, even though it is less than that provided by instructors.

A recent meta-analysis of computer-based feedback argues that elaborated feedback is even more effective than KR or KCR feedback for improving low-order learning outcomes, such as recalling, recognizing, and understanding information, (Van der Kleij et al. 2015). In all cases, Van der Kleij et al. (2015) found that computer-based feedback improved learning for low-order outcomes, but the size of the effect varied depending on the type of feedback that was provided. For KR feedback, the effect was rather small (0.12) and Van der Kleij et al. argue that this number is too small and based on too small of a sample size to be reliable and, therefore, meaningful.

For more informative feedback, however, the effect sizes are much larger. For KCR feedback, the effect was 0.31. Van der Kleij et al. again acknowledge that this number is based on a small sample size, so it might not be reliable; however, the effect size is large enough in this case to suggest that there is a benefit of KCR feedback from technology on low-order learning outcomes. The most effective type of feedback was elaborated feedback with an effect size of 0.37, and this effect was based on a sufficient sample size. Though Van der Kleij et al. found large variation in what was included in elaborated feedback, their findings suggest that providing information about why an answer is correct or incorrect helps students to learn more from computer-based feedback.

Similar to low-order outcomes, more informative feedback improves learning for high-order outcomes. High-order outcomes are defined by Van der Kleij et al. (2015) as those that require knowledge to be applied to new situations, such as applying physics formulas to physics problems. When examining high-order learning outcomes in their meta-analysis, Van der Kleij et al. found that KR feedback from technology had no effect (-0.01) on outcomes. In contrast, they found that KCR feedback improved learning with an effect size of 0.38, but this effect was based on a small sample size and might not be reliable. Feedback with more information had a larger impact. Van der Kleij et al. found that elaborated feedback from technology had an effect size of 0.67, and the effect was even larger when the feedback included additional information about task, process, or regulation. Van der Kleij et al. defines task feedback as feedback that corrects error in task execution, process feedback as feedback that addresses the process used to complete the task, and regulation feedback as feedback that relates to learners' self-regulation of their learning.

In their meta-analysis, Van der Kleij et al. (2015) found that elaborated feedback produced a larger effect for high-order learning outcomes (0.67) than for low-order learning outcomes (0.37) which contradicts Margulieux et al.'s (2015) finding that computer-based feedback helped students to improve recurrent skills but not non-recurrent skills. Without comparing the exact uses of computer-based feedback in the studies included in both reviews, it is difficult to account for these differences. Because low-order outcomes are easier to develop than high-order outcomes, it is possible that the difference in effect sizes in Van der Kleij et al.'s meta-analysis is due to the difficult nature of learning high-order outcomes. Students completing learning activities for low-order outcomes might have had less variation among themselves and performed well overall, leaving little room for improvement from feedback. Students completing learning activities for high-order outcomes, however, might have needed the help that elaborated feedback provided.

Margulieux et al.'s (2015) review included learning environments with both online and in-person instruction, making unclear the amount of elaboration that students received from instructors compared to the amount from technology. Based on both of these reviews, we conclude that elaborated feedback improves learning for both types of learning outcomes and skills, but that it is particularly important for high-order outcomes and non-recurrent skills, especially if the elaboration includes information about the task, process, or regulation.

Complexity of Task

Like the level of learning outcomes, the complexity of learning activities affects the type of computer-based feedback that improves learning. Level of learning outcome and complexity of learning activity are usually related so that high-order outcomes are taught with more complex activities, but this is not always the case. For example, complex procedures can be taught through part-task training so that the student learns the procedure in parts before attempting to combine the parts. Because of discrepancies such as this, the effect of computer-based feedback on learning from simple and complex activities deserves separate consideration.

For purposes of this chapter, the main difference between simple and complex activities is the amount of cognitive resources required to complete them. Simple learning activities do not require nearly all of the learner's cognitive resources; therefore, feedback can provide extra information about the domain or task. For example, learning the chemical bonds within molecules is a relatively simple task. It requires the application of a few rules and the memorization of some exceptions, but it does not require a high cognitive load. In this case, feedback might provide information about what rules or exceptions are being applied. When computer-based feedback provides additional information like this during simple activities, learning improves (McLaughlin 2006). Furthermore, when completing simple activities, students have resources available to self-assess their learning. McLaughlin (2006) found that general feedback is more effective than specific feedback because general feedback allows students to practice self-assessing their progress whereas specific feedback tells students exactly what to fix.

The optimal computer-based feedback for complex learning activities is different from the feedback for simple activities. Complex activities demand more of the learner's cognitive resources, and sometimes these activities require more resources than the learner can allocate. For example, if a learner were determining the chemical bonds in a molecule and how those chemical bonds will affect the molecule's interactions with other molecules of various types, then the learner will likely have a high cognitive load. These types of activities are draining on learners because they require a high amount of concentration and attention. Therefore, feedback for complex learning activities should focus on reducing the cognitive load on students (McLaughlin 2006). Feedback in these situations might help students direct their attention to the most important aspects of the problem or the aspect that needs to be considered next. For example, a good type of feedback to use for complex activities is plan-based feedback, which reiterates the goal of the problem and emphasizes information needed to correctly achieve the next step but does not give extra information (McLaughlin 2006). Extra information should be included in feedback only when the learner has enough resources to process that new information. Feedback on complex activities can also be used to reduce floundering. If a learner has reached an impasse or has taken an incorrect step, feedback can draw attention to information relevant to overcoming the impasse or correct missteps (McLaughlin 2006).

When considering the complexity of learning activities, an instructional designer should remember that computer-based learning activities tend to require a higher base level of cognitive resources than non-computer-based activities. Using computer-based systems places some cognitive load on learners, unless they are as familiar with the virtual learning environment as the non-virtual environment. This extra cognitive load will be required for using any tool with which the learner is not intuitively familiar. For example, the cognitive resources required to use a calculator is greater for an elementary school student than a college student. To design appropriate feedback, it is important to consider the cognitive resources required for all aspects of the learning activity.

Key Points

- Computer-based feedback can improve learning of recurrent skills by providing immediate feedback, which is as effective as instructor feedback but does not require instructor resources.
- Whether computer-based feedback improves learning of non-recurrent skills is less certain. Providing learners with elaborative feedback is more likely to support non-recurrent skill development.
- Feedback on simple learning activities is more effective when it includes additional information about the concept or skill being learned.
- Feedback on complex learning activities is more effective when it helps reduce learners' cognitive load, and it should not include additional information.

CONCLUSION

Technology-driven learning is on the rise, particularly for web classes. In 2011, almost one-third of American college students had taken at least one online course, and these numbers continue to increase (Online Learning Consortium 2012). Feedback is an effective way to help learners assess and improve their performance, and providing feedback through technology offers both benefits and challenges. Designers of instructional technology should consider both learner characteristics as well as characteristics of the task when deciding which type of feedback should be implemented.

Several areas still need additional research. The results discussed in this chapter are primarily from research with undergraduate students. The degree to which these results apply to other learners is not clear. Van der Kleij et al. (2015) found lower effect sizes for studies using younger students, but the low number of studies using primary or secondary education settings do not yet allow for sound comparisons.

The relationships between “feedback intervention, task, learning, context, [and] characteristics of the learner” also have not been thoroughly examined (Van der Kleij et al. 2015, p. 504). We already know that, for example, characteristics of the task or of the learner can change how effective a type of feedback will be. However, how the interactions between these variables affect the efficacy of feedback is yet to be determined.

McLaughlin (2006) recommends that feedback should be designed with the following two principles: 1) Feedback should teach the learner to ultimately provide their own feedback through internal self-assessment, and 2) feedback should be tailored to the learner’s capabilities and task requirements. As demonstrated by the rising popularity of online courses, a large part of the future of education will involve students learning without teachers present. Therefore, feedback via technology will continue to grow in importance, with the goal of enabling task performance without instilling dependency (McLaughlin 2006). To reach that goal, it is imperative that research in this area rise to meet the challenges ahead.

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