

Creativity and Feedback

Designing Systems to Support Student Learning and Improve Instruction

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Abstract

This chapter provides a historical perspective on the concept of creativity and its relationship to the development of education theory during the first half of the twentieth century. In the early twentieth century, creativity had a very specific meaning, which expanded in the mid- to late twentieth century into a more general, and in our view less useful, meaning. These two perspectives are linked to two conflicting educational theories, represented by Edward Lee Thorndike and John Dewey. Dewey described learning as a natural part of being an inquiring human being in a social and physical world, whereas Thorndike’s view was more reductionist, based on stimulus–response connections. The Thorndike’s theory gained prominence and still dominates today, over the Deweyan theory, due in part to the ease with which it can be experimentally tested.

Ideas are developed into a two-part manifesto to inform teaching practice and the development of education technology. The first part delineates the conditions for creative feedback in social learning and encapsulates a Deweyan educational approach. The second part describes the characteristics of education technology that can be used to experiment with creative feedback and social learning, and establishes how we can begin to validate experimentally the Deweyan theory of education.

Interactive task learning considers the challenge of interactively training bots to carry out a task. This chapter is most relevant to medium-term and future tasks for bots within a social context involving humans and bots, and may offer subjective or dynamic evaluation criteria. Bot instructors working with these types of tasks may benefit from considering the complexity and nuances of creative feedback.

History of Creativity and the Education Wars

Dewey introduced the concept of “creative intelligence” (Dewey et al. 1917) early in the twentieth century. His use of “creative” in this expression dates

back to discussions on the creative processes among a number of writers and artists at the end of the eighteenth century, especially William Wordsworth. Before then, in the eighteenth century, the word had been defined in terms of its product, be it great art or science (Engell 1981). However, Wordsworth referred to the experience as a special kind of activity, one that is unusually focused, mindful and purposeful, and often results in the production of significant art, poetry music, and science. Such creation was seen as analogous to natural growth, rather than as the result of a Godlike mental act. As experience anchored in this notion of growth, it is logically independent of any concrete product, as was apparent in Ralph Waldo Emerson's use of "creative reading" (Emerson 1837/1962) and Matthew Arnold's reference to "creative criticism" (Arnold 1914). This tradition culminated in the work of Dewey and other pragmatists. For them, experience was a flow rather than a succession of moments, as was expressed in William James's "stream of consciousness" and in Dewey's famous reflex arc paper (Dewey 1896). Here, Dewey treated the stimulus and response of the traditional reflex as abstractions of ongoing activity, and meaningless as isolated units.

This rejection of atomism went with the questioning by Charles Sanders Peirce and James of a strictly deterministic view of the physical world. They proposed, instead, that chance variation may be an inherent property of the universe (Hacking 1983). This view was taken further by Alfred North Whitehead during the 1920s and presented in his process philosophy, which he worked out with formal precision in *Process and Reality* in 1929. Whitehead used the term creativity to refer to the principle of novelty in nature, which is ultimate in his system (Whitehead 1979:21). The adjective "creative" had come to refer to a process of growth and production, for which Whitehead introduced the noun "creativity."

After reading Whitehead's philosophy and writing his major book on creative activity, *Art and Experience* (Dewey 1934), Dewey began to use the word "creativity" during the 1940s. From the start of his career, Dewey insisted that human beings are essentially social and argued against the individualism inherent in much of psychology. Nevertheless, what is creative is always individual. It is a capacity to vary: this capacity is cultivated by good education and suppressed by education that consists strictly of "learning lessons" (Dewey, in Boydston 2008:5):

The emphasis James places upon the individual quality of human beings and all things is, of course, central in his pluralism. But the adjective "individual" is often converted into a noun, and then human beings and all objects and events are treated as if they were individual and nothing but individual. The result is that identification of human beings with something supposed to be completely isolated which is the curse of the so-called individualistic movement in economics, politics and psychology. I find the actual position of James to be well represented in a remark he quotes from a carpenter of his acquaintance: "There is very little difference between one man and another; but what there is, is very

important.” It is this element which is precious because it is that which nobody and nothing else can contribute, and which is the source of all creativity. Generic properties on the other hand are replaceable, and express the routines of nature.

Creativity in the Mid- to Late Twentieth Century

After Whitehead, “creativity” became popular in the United States and flourished during the 1940s as part of the jargon associated with advertising, where it reached a state of Pollyannaish vagueness (Osborn 1948), much loved and beyond criticism, far from the precision of Whitehead. From there it was seized upon by Joy Paul Guilford, one of the leading lights of mental measurement, who invented a new entity in the brain or mind he called “creativity.” This was a measurable power which he defined as the “the generation of novel and valuable ideas.” This power was subjected to all the rigors of psychological measurement, but the word’s imprecision remained. As Liam Hudson (1966:100) stated a few years later:

This odd word [Creativity]...applies to all those qualities of which psychologists approve. And like so many other virtues...it is as difficult to disapprove of as to say what it means. As a topic for research creativity is a bandwagon on which all of us sufficiently hale and healthy have leapt athletically aboard.

Nothing much has changed. Creativity can be a behavioral process (Simonton 2003) as well as a trait or product, sometimes both at the same time (Eysenck 1995:231):

There are two major definitions of creativity, and these are quite different in many ways. “Trait creativity” is conceived as a latent trait underlying creative behavior...“Achievement creativity” is defined in terms of novel and socially useful/acceptable products.

The situation remained so bad that Mark Runco, the most prolific of academic experts on creativity, confessed in his recent textbook *Creativity* (Runco 2007) that he had considered giving up the word altogether. Then he read Bill Bryson’s *Short History of Nearly Everything*, which told him how much ambiguity exists across all sciences, so why not in the science of creativity? Less cavalier about this, George Mandler (1995) suggested that the word should be treated as an umbrella term or chapter heading that gathers together several disparate topics giving different meanings to the word. The implication is that creativity is not a useful scientific concept at all, any more than the word “cricket” is a good cricketer, or Physics is a useful concept within Physics.

The transition of the word creativity, from a well-defined to a less well-defined status, is unusual in science. The French historian and philosopher of science, Gaston Bachelard, pointed out that the start of a science is often marked by a change from an imprecise but poetic common language for dealing with an aspect of the world, to a system of concepts with exact meanings (Tiles 1984). But in the case of “creativity” exactly the opposite has happened. The

meanings offered by Whitehead and Dewey have been replaced (after Guilford made a “science” of creativity) by a prolonged semantic inflation, as the word has gained yearly in popularity since 1950. Our use of creative in “creative feedback” below returns to Dewey and Whitehead. If that means turning back the clock, then so be it. If we are right, the future of scientific creativity lies in its past.

Dewey and Thorndike on Education

Having explored creativity and creative intelligence, we shall now return to the past and recount a story about the development of education practice and pedagogy in the early twentieth century. The chief protagonists are John Dewey and Edward Lee Thorndike, whose views on feedback and education reflect quite different views on the nature of life, and what it is to be human. Both were egregious figures. Dewey was a pragmatist through and through, and managed to be America’s greatest philosopher, most notorious educationalist, and most neglected psychologist. Dewey did not like measuring people, whereas Thorndike, Guilford’s mentor in the science of mental measurement, followed Descartes in believing that the world is there to be measured. Thorndike pioneered experimental studies of reward and punishment in education, and recognized that social control follows from scientific measurement. He was an enthusiastic supporter and contributor to eugenics, the attempt to breed better human beings. He also, as we shall see, carried out one of psychology’s most famous experiments in 1898: cats in a puzzle box.

Thorndike’s “Ideas”

The way of thinking behind Thorndike’s experiments is based on the stimulus–response (S–R) model, which treats organisms as independent individuals that can be studied outside of their customary environments, similar to laboratory “preparations” in physiology. In the simplest form of the model, S–R connections in the brain are strengthened when followed by reward, weakened when followed by punishment. These connections are mediated by ideas in the brain, which were treated as “atoms of the mind,” and Thorndike speculated that “the vague gross feelings of the animal sort might turn into the well-defined particular ideas of the human sort, by the aid of a multitude of delicate associations” (Thorndike 1901:63). This is Thorndike’s connectionism, and it has provided the main framework guiding studies of learning throughout the twentieth century. The Thorndikean icon to match Dewey’s reflex arc paper (Dewey 1896) is Thorndike’s puzzle box experiment, in which cats confined in a strange box learned to escape by pressing a lever. He claimed that the gradualness of their learning showed that they learned through trial and error rather than reason, with the correct response being rewarded and strengthened (Thorndike 1898).

It is important to note, however, that the cats were in an environment that was frightening and alien to them, nothing like their usual settings where they could follow their interests and curiosity. There was none of the familiar feedback on which the security of their ordinary living depended. In a similar, but less drastic way, the human environment for laboratory experiments, to say nothing of examinations and tests of IQ or creativity, is often unfamiliar to the subject or student. Success in tests depends, in part, on the compliance by the person being tested, a willingness to sit down for a long period of time and answer questions that are at best tedious and often seen as ridiculous. They are tests of compliance as well as intelligence. Unlike ambitious Western students, cats are not compliant: they hate being forced into cages, and Thorndike was mistaken to ignore compliance and treat his experiments as pure tests of reason. Later work on animal intelligence has gone well beyond Thorndike (Seligman and Hager 1972) to take into account the animal's normal setting, as well as the pervasive feedback underlying the active life of animals, both of which were largely ignored by Thorndike and laboratory psychology, more generally.

The Thorndike tradition has dominated education for over 100 years. Its basic assumption is that learning takes place in the head, through ideas, connected together as a result of reward and punishment. Apart from their role in connectivity, Thorndike's ideas are largely passive (Thorndike 1913).

Dewey's "Ideas"

Dewey (1916:16) also used the concept of idea but for him, ideas were dynamic:

Ideas...are anticipations of possible solutions. They are anticipations of some continuity or connection of an activity and a consequence which has not as yet shown itself. They are therefore tested by the operation of acting upon them. They are to guide and organize further observations, recollections, and experiments. They are intermediate in learning not final.

Ideas for Dewey, therefore, are not self-sufficient atoms to be combined together to form knowledge, nor are they the same as intentionality (already familiar by 1916 through the work of Brentano and Husserl), defined as "the power of minds to be about, to represent, or to stand for, things, properties and states of affairs" (Jacob 2003). For Dewey, ideas point to things outside themselves, like intentions, but also to the actor or thinker herself, and to potential actions upon the environment. The relationship is mutual or threefold, like teaching itself, which he believed should be based on inquiry and discovery rather than "lessons" and adds (Dewey 1916:160):

This does not mean the teacher is to stand off and look on; the alternative to furnishing ready-made subject matter and listening to the accuracy with which it is reproduced is not quiescence, but participation, sharing, in an activity. In such shared activity the teacher is a learner, and the learner is, without knowing it, a teacher.

This mutualist or triadic relationship is characteristic of the anti-dualist philosophy of pragmatism, and it is present throughout the work of Dewey and his predecessors; for instance, in Peirce's concept of a sign (Peirce 1902/1935), what James views as "pure experience" (James 1975), or more recently James Gibson's affordance which "points two ways, to the environment and to the observer" (Gibson and Walker 1984). It is also present in Russian "activity theory," as in Lev Vygotsky's concept of "word meaning" (Vygotsky 1967).

The Outcome of the Battle

Thorndike's S-R model was elaborated by Clark Hull into the mechanisms of behavior theory, in which stimuli were worked upon by internal processes and transformed into responses (Cordeschi 2002). Hull recognized that his terms would be improved with a more sophisticated language, and in this way anticipated the replacement of his S-R model by the input-output models of information processing. Like Thorndike's connectionism, both models focus on internal mechanisms in an isolated organism. In that form, the same opposition between Thorndike and Dewey has continued, with Dewey joined by the Russian activity theorists, starting with Vygotsky. As (Aukrus 2007:47) stated in a recent commentary that introduced computer-supported collaborative learning (CSCL):

Broadly speaking, there are two main traditions within the learning sciences: cognitive psychology and the situated/sociocultural perspective. The former is based on an information processing perspective...and the latter on American pragmatism...and Soviet psychology....In CSCL studies, methods and techniques from both traditions are used and sometimes blended (e.g., interaction analysis). However, within each tradition there are unique interpretation of key concepts, methods and empirical design...

Knowledge Objects

What are the essential characteristics that distinguish a Thorndikean from a Deweyan approach to learning and teaching? In Thorndike's S-R models, the focus is on setting up the connection, and this piecemeal approach is suggested by a list of twenty-five principles of learning presented by Arthur Graesser (2009) in the inaugural editorial for the *Journal of Educational Psychology*. Even when social and cultural context is taken into account, the unit of analysis is always the item to be learned. In Dewey's learning, by contrast, the main goal is further inquiry, and therefore further learning. As one of the founders of CSCL, Carl Bereiter's concept of "knowledge objects" allows for a more Deweyan principle (Bereiter 2002). For Bereiter, a knowledge object is a concept that becomes real for a student who develops a passion for it, whether it is evolution, existentialism, artificial intelligence,

Charles Dickens, or numbers. It is a love object which (ideally) will effortlessly organize, guide, and motivate the social and individual activity which drives further inquiry.

In education, victory has gone to Thorndike: "One cannot understand the history of education in the United States during the twentieth century unless one realizes that Edward L. Thorndike won and John Dewey lost" (Lagemann 1989:185). Thorndike won for at least two reasons. First, experimental studies on feedback are much easier to set up if the independent variable is simply reward or punishment, or information, rather than if it pervades the social situation. Second, teachers are usually obliged to follow a curriculum which allows little room for free inquiry; this forces them back into the default approach with which they are familiar, involving the I-R-E sequence of interaction (initiate-response-evaluation).

Below, we shall revisit the challenges of experimentally investigating Deweyan education theory. This will then lead us to suggest a solution.

A Manifesto

Creative Feedback for Social Learning

Dewey's 1948 definition of creativity was given in the foreword to a book on what we would now call art therapy (Schaefer-Simmern 1961:ix-x). There he describes individuality as the "creative factor in life's experience." It is "the life factor that varies from the previously given order, and that in varying transforms in some measure that from which it departs, even in the very act of receiving and using it . This creativity is the meaning of artistic activity (Schaefer-Simmern 1961:ix). Illustrating this, the first chapter described how a severely withdrawn woman, with an IQ of 49, slowly emerged from her withdrawal through kindness and patience and the opportunity to use paper and colored crayons. At first, following the work of others, she gradually developed her own style. "This creativity is the meaning of artistic activity." She achieved it with the encouragement and creative feedback of others. What was involved in this process? Creative feedback is part of the flow of creative activity, or creative learning, but to some extent a teacher can intervene, in a way that will encourage creative activity through (creative) feedback. We can see this in the work of the nineteenth-century writer Matthew Arnold, as well as the twentieth-century founder of modern counseling, Carl Rogers.

Arnold had an important influence on Dewey. As a young man he was a prolific poet, until he ran out of steam and became one of the great critics of his time, providing feedback to other writers. His experience of joyful creative activity was similar in his work as a poet and critic, and he outlined the conditions under which this (creative criticism or feedback) could be possible (Arnold 1914:35-36):

To have the sense of creative activity is the great happiness and the great proof of being alive, and it is not denied to criticism to have it; but then criticism must be sincere, simple, flexible, ardent, ever widening its knowledge. Then it may have, in no contemptible measure, a joyful sense of creative activity....And at some epochs no other creation is possible.

Rogers acknowledged the influence of Dewey, especially through the teaching of William Heard Kilpatrick (Dewey's pupil and later close colleague). Rogers's views on creative activity and traditional education were similar to those of Dewey (Rogers 1954:250):

In education we tend to turn out conformists, stereotypes, individuals whose education is "completed" rather than freely creative and original thinkers.... My definition...of the creative process is that it is the emergence in action of a novel relational product, growing out of the uniqueness of the individual on the one hand, and the materials, events, people, or circumstances of his life on the other.

Rogers was the founder of modern counseling and his career, as he saw it, was to help people change from being conformists, imprisoned by the demands of themselves and others, to finding the uniqueness in themselves, which he referred to as "self-actualization." This change was brought about by setting up a therapeutic relationship in which feedback from the counselor enabled the client to let go of self-demands. For this to take place, his famous core conditions were empathy, acceptance or unconditional positive regard, and congruence. Empathy is to reflect the other's point of view, rather than imposing your own; unconditional positive regard is to always accept the other as a worthwhile human being; and congruence is to be honest, not to say what you do not feel. To these core conditions we would add "interest"; that is, the deep interest of both student and teacher in the student's project.

The Nine Elements of Creative Feedback

Elaborating on the views of Arnold and Rogers, and many other writers who followed or anticipated Dewey, we have developed the following principles of creative feedback leading to a manifesto of creative feedback for social learning (d'Inverno and Still 2014), which defines nine characteristics of creative feedback as it applies in a social learning context. We believe that giving feedback to others is a profoundly creative and difficult act—one with many dimensions along which a range of useful skills must be developed. If we consider education as a process wherein people learn to provide effective feedback, we find that the following aspects of that feedback neatly encapsulate the goals of a Deweyan educational approach.

All of these criteria build on the precondition that the tutor or student who is giving the feedback has a genuine curiosity and interest in the student to whom the feedback is being given.

1. *Creative feedback is a social process.* It comes from one social human agent (the tutor or peer learner) who has perceived the feedback object (such as a performance, a proof, an essay or an artwork) to another social human agent (the learner and originator of the feedback object). Note this definition does not preclude students giving creative feedback on their own work which can often provide great insight as long as a sufficient distance can be taken.
2. *Creative feedback is mindful.* This incorporates at least two aspects: (a) that the person giving the Creative Feedback is aware of the cultural and individual context of the receiver (such as an understanding of the individual's artistic or scientific goals/methods/audiences, etc.) and (b) that individuals are aware of any personal judgments that are being made and can articulate these if required.
3. *Creative feedback involves community awareness.* If creative feedback occurs in a community of learners (rather than one-on-one), then it should embody community awareness of the creative feedback that has previously occurred as well as the part it plays in a complex and developing system. Giving and receiving creative feedback should be embraced equally for the community to sustain itself. It would be difficult, of course, for communities to thrive if everyone wanted to give more creative feedback than they wanted to receive. Creative feedback creates a self-sustaining, self-organizing system where flexibility and robustness need to be balanced. While each learner may have more or less knowledge about what is required to maintain such a system, it is clear that it can only exist if individuals in the learning environment actively encourage engagement in creative feedback.
4. *Creative feedback is clear.* The language used must be unambiguous and the terms used must be mutually understood. There is no attempt to hide meaning behind technical or ambiguous words and sentences.
5. *Creative feedback is democratic.* Being a tutor or student bestows no special right to giving or receiving creative feedback. One might hope that tutors have more experience and skills in giving, but this is not a prerequisite.
6. *Creative feedback is challenging.* Underpinning any creative partnership is the notion of the challenge that each brings to the other. Creative feedback that provides the right level of challenge is arguably the most sought after feedback. To do so involves "skill in means": a Buddhist concept which holds that feedback should be geared to the level and character of the student, and is always open to the student's needs. The idea of programs and feedback challenging students is a critical part of the design and delivery of any course.
7. *Creative feedback incorporates generosity of spirit and compassion.* It is an act of giving and enabling; that is, the giving of guidelines (not rules) for future exploration and awareness.

8. *Creative feedback allows further discussion and explanation.* This is what makes it a social process between equals, allowing for more detailed and nuanced exchanges, making sure nothing is ever closed off.
9. *Creative feedback is comparative rather than absolute.* No absolute judgment about a feedback object can be made. Comparisons (explicit or implicit) of the feedback object to other existing objects are a mindful tactic involving skill in means. For instance, creative feedback to a jazz piano student from a tutor may simply be to say how close the student's playing is to another well-known jazz pianist, or that the student may wish to listen closer to certain aspects of that person's approach.

The very best tutors are able to give feedback that encompasses many of these qualities. The ability to demonstrate to students just how engaged a tutor is with the students and their work is, we believe, critical to keeping students engaged. This coincides with the first of the “big four factors,” described by VanLehn (this volume), that impact human learning (i.e., *engagement*). Moreover, creative feedback requires tutors to be sensitive to the student and provide feedback that is *appropriate for the students' position along the learning curve* (VanLehn's second major factor). Furthermore, through creative feedback, students learn how others experience their work, and this provides students with greater abilities to evaluate their own work. This view coincides with VanLehn's fourth factor: *feedback*.

Application and Critique

To demonstrate how one might critique any education technology, including intelligent tutoring systems and robotic tutors, using the manifestos, we present a case study below: the MusicCircle. Thereafter we discuss how the manifesto for creative feedback applies to interactive task learning (ITL).

MusicCircle: An Online Music Learning Support Tool

Built at Goldsmiths during the FP7 Project PRAISE,¹ MusicCircle is a web-based social network that encourages members to share their creative works and receive feedback from others. This novel peer-to-peer learning approach views “learning to give and receive feedback” as integral to getting better. Users can upload, share, and annotate time-based media in several ways: by uploading a file to the browser, using a smart phone app which also allows recording, or recording directly into the browser. An application programming interface (API) allows software agents access to the full set of uploading, sharing, and annotation features.

¹ The Social Enterprise Museifi was set up to make MusicCircle available. For details on MusicCircle and Museifi, see museifi.com.

A screenshot of the browser-based user interface is shown in Figure 14.1. A key feature of the user interface is the social timeline (Brenton et al. 2014), visible as a set of colored blocks below the audio waveform in the figure. These blocks represent sections of the recording that have been highlighted and annotated. Each person who has created an annotation has their own strip on the timeline. Each annotation becomes a discussion thread visible to everyone who can see the top level media item.

To evaluate how the MusicCircle system supports creative feedback manifesto, we enumerate the manifesto's key points and discuss how each point is addressed (or not) by the system. Where possible, we relate these points to VanLehn's discussion (this volume). We present this evaluation as an example of how the creative feedback manifesto can be used in practice to analyze a real system and hold that this approach can also be used to evaluate an ITL system.

1. *Creative feedback is a social process.* This is a core feature of MusicCircle. Feedback is visible to all and can be garnered from all members of a community. This type of interactive behavior relates to the most challenging level of the ICAP framework (see VanLehn, this volume).



Figure 14.1 Screen shot of the MusicCircle system, showing an audio recording being annotated. At the top is the waveform, then below is the social timeline showing the annotations of various members of the community. This audio recording and the associated dataset is available at <http://zenodo.org/record/46232> (accessed Feb. 11, 2019).

2. *Creative feedback is mindful.* Mindfulness in an educational context includes awareness of your own learning as well as that of others (metacognition). Studies of MusicCircle have shown that through its use, students became more aware of their improvement and that other people learned and improved as well. The simple act of recording and reflecting on work in progress allowed this to happen. Mindfulness is social; thus it maps directly onto interactive behavior.
3. *Creative feedback in groups embodies community awareness.* The MusicCircle system includes a set of community guidelines which emphasize the need to be a positive member of the community by considering the feelings of others, for example.
4. *Creative feedback is clear.* Feedback given on MusicCircle consists of an annotation that is mapped to a very specific region of the recording. This encourages clarity in the feedback, and it focuses on the recording, not the person. As VanLehn (this volume) states: “human tutors love to give explanations, but many are not very good at it.” This emphasizes the challenge of giving clear feedback.
5. *Creative feedback is democratic.* All members of a MusicCircle community have equal rights to upload, share, and annotate. The user interface also displays everyone’s annotations simultaneously.
6. *Creative feedback is challenging.* Once an annotation has been placed, it becomes a discussion thread, and both the annotator and the receiver can discuss the annotation more deeply. Challenging comments are more likely to be received positively if they are tagged to a specific part of the media, not the person. In terms of learning curves, challenging feedback encourages students to operate in the sense-making phase: they are encouraged to gain a stronger understanding of the basic subject matter. The use of a discussion thread may be helpful as a detailed diagnostic assessment, which is a valuable instruction strategy seldom used by tutors (cf. VanLehn, this volume).
7. *Creative feedback incorporates generosity of spirit and compassion.* MusicCircle provides community guidelines related to these aspects, but does not explicitly encourage this kind of feedback.
8. *Creative feedback allows further discussion and explanation.* MusicCircle allows each annotation to become a discussion thread in and of itself. It is also possible to link comments to further media items, either on MusicCircle or other media-sharing platforms.
9. *Creative feedback is comparative rather than absolute.* MusicCircle allows linking to other media items in comments, for comparative or demonstrative purposes. One could extend this to allow multiple versions of the same media item (e.g., recordings of a band practicing a song) to be aligned, thus enhancing comparisons. The current version of MusicCircle does not yet permit aligned comparison. Comparative

instruction is a key technique in ITL, where the performance of the bot is compared to the desired performance.

Creative Feedback and Its Relationship to Interactive Task Learning

Creative feedback can happen reflexively, in which case there is one agent (A). It is also possible in a one-on-one meeting, in which case there are 2 agents, as well as in a community where there are 3 or more agents. In any learning scenario, there is at least one agent who receives feedback (the learner, L) and at least one agent who gives feedback (e.g., a tutor or peer in the learning group: the giver-of-feedback, G). In the case of reflexive feedback, $A1 = A2$ whereas in the other instances, $A1 \neq A2$. The effectors of agents, in our view of the world, include being able to make a work (e.g., a performance, a computer program, or a painting) and being able to provide either written (text) or spoken feedback. The sensors of all agents in our model include being able to sense/experience (a) the work, (b) the student who made the work, and (c) the community of other agents, if they are present.

As in the ITL framework presented by Mitchell et al. (this volume), agents have different abilities in terms of their experience of the subject, the experience they have developed in giving feedback, and their ability to empathize with the learner (their goals, their background, their culture, and so on.) This fits exactly with the model of communication that Mitchell et al. (this volume) describe, where aspects of the mental state of any agent can be observed: "To define a learning problem precisely, we say that an Agent A learns to improve its performance, P, at task, T, through experience, E." This provides a strong framework within which we can characterize creative feedback. The task (T) in ITL includes producing a software program, playing a musical instrument, or painting a picture in our world of creative feedback. Performance (P) of these activities is what the agent has to get better at through the experience (E), which is creative feedback. Experience can be in several forms:

- Submitting a program and getting feedback from a tutor or peer learner.
- Submitting a performance online (e.g., to Music Circle) and requesting feedback from the community to which it is posted.
- Presenting the software program as well as demonstrating its performance and getting feedback on all of this from a tutor and a peer learning group.
- Showing the painting and discussing aspects of it and the process of creating it, and then inviting feedback from a community of tutors and learners.

In all cases, the student wants to get better at programming, playing the piano, or making art by opening themselves up to receiving the creative feedback of others. The working definition of ITL, therefore, applies very precisely to creative feedback; it is an example of ITL. A student (A) improves its creative

practice (P) of making a work (T) by communicating to other agents and receiving the creative feedback from other agents who have considered aspects of A, P, and T.

Concluding Thoughts: Can Artificial Intelligence Systems Give Creative Feedback?

The systems described above were set up to support creative feedback and we were essentially agnostic about whether the agent giving feedback on a performance was human or machine. Many of the characteristics of creative feedback place the activity of generating it at the difficult end of the range of tutoring strategies discussed by VanLehn (this volume). For example, community-aware feedback is innately social, and therefore falls at the most highly engaged (i.e., *interactive*) end of student behavior in the ICAP framework (Chi and Wylie 2014a). This means that the task of providing creative feedback is challenging for human beings, and therefore it is interesting to consider how well automated agents might perform in this area.

In conjunction with an EU FP7 Project called PRAISE (Practice and Performance Analysis Inspiring Social Education), we have worked closely with some of the leading AI groups in Europe (e.g., Carles Sierra at IIIA in Barcelona, Francois Pachet who was then at Sony Computer Science Research Labs in Paris, and Luc Steels at VUB in Brussels) to look at the potential of automatic feedback. In this scenario, the automated agents needed to place comments on the audio recordings uploaded by music learners. This is consistent with the expanded view of ITL, in which agents or bots are the instructors, providing feedback on the tasks carried out by the humans. In this case the task is to play a piece of music. We could extend the scenario and say that the teaching bots were carrying out the task of giving creative feedback to music learners and that humans needed to teach these teaching bots, but we did not push the implementation that far.

The challenges with this work were the sensors and processing for the bot. The effectors of the bot allow it to retrieve the data it needed and to post the comment on the platform; this was quickly achieved through a web service API, which provided a programmatic interface to the platform. The sensors of a feedback bot allow it to listen to the audio uploaded by a musician, then to listen to a model recording uploaded by the tutor. The bot could also see the score for the piece of music, which was in a machine-readable format. If the bot were to follow the manifesto of creative feedback, it might consider previous recordings of the student, and possibly the other students who could see the comment, and even previously uploaded comments. Implementing the sensors and processing needed to do the basic audio listening, score reading, and commenting involved a signal processing task and a natural language generation task. Full creative feedback required natural language processing

and social network analysis, but we did not implement that. The signal processing extracted the notes and features of the performance and aligned the different performances with the score. The natural language system generated the feedback comments.

The bots were able to generate natural language feedback on specific regions of recordings, but only in quite constrained scenarios with carefully selected inputs and processing algorithms. The technology was not sufficient to operate independently on the live platform in a realistic scenario, due to the difficulty of automatically locating the correct inputs (audio, model, score), and yet not constraining the case study to an artificially simple scenario. In addition, even a simple scenario where students are expected to upload and tag the correct files was challenging to implement from a usability perspective. Further, providing comparative, natural language comments on deeper aspects of the performance, beyond playing the correct notes at the correct speed, was beyond the reach of the available signal processing, score comprehension, and natural language technology.

In summary, we were able to automatically generate natural language comments on musical performances and to place them at the appropriate position in the audio timeline. However, the scope of commenting was limited in terms of instrument types and performance aspects. The bots could not be considered to have generated creative feedback.

The results of our investigation of the capabilities of bots to generate creative feedback stand in stark contrast to recent press reports about the potential of robots to replace human tutors (Bodkin 2017). In this article, Sir Anthony Seldon, Vice-Chancellor of the University of Buckingham in the United Kingdom, is quoted as saying:

Everyone can have the very best teacher and it's completely personalized; the software you're working with will be with you throughout your education journey...

The article continues to report that

Experts predict that automated teaching of maths and science will form the vanguard of machine-led learning, but that sophisticated algorithms would soon be devised to teach the humanities.

For creative activity to take place, we need to remember that Dewey's approach needs a physical and social system. We certainly believe that feedback is a creative activity, hence our introduction of creative feedback.

We could imagine taking a Thorndike approach and a Dewey approach to the design of tutors. To bring out, in the simplest possible form, the difference between the mechanistic feedback of a Thorndike-influenced robot (Tbot), and the creative feedback of Dewey (Dbot), let us imagine contrasting robots: The Dbot tries to tap into the student's interests and draws on these to generate inquiry into the topic. Learning for a Dbot is directed toward future learning

and is usually initiated by the student. Learning, by contrast, for the Tbot is initiated by the teacher/tutor and is focused on a classroom task, with reward and punishment strengthening correct and weakening incorrect responses. These thoughts are illustrated in the following conversations:

- *Dialogue between a Tbot and a young student of elementary arithmetic*

Tbot: What is $2 + 4$?

Student: 8

Tbot: Wrong. You need to practice adding numbers up to 10. Let me give you a simpler example.

T-bot: What is $2 + 2$?

Student: 4

Tbot: So what is $2 + 2 + 2$

Student: 6

Tbot: Excellent.

Student: Oh I see, 6.

- *Dialogue between a Dbot and a student*

Dbot: How are your mice?

Student: Shows Dbot a picture on her iPhone

Dbot: So here they are peering out of their 2 cages.

Student: Yes, do you like them?

Dbot: Lovely, how many are there in each cage?

Student: 2 in that one, 4 in the other

Dbot: So how many altogether?

Student: 8

Dbot: Try counting them.

Student: Student counts the mice in their cages and responds: Oh, there are 6.

Dbot: So what's $2 + 4$

Student: Oh I see, 6.

We believe that a Tbot could probably work as a robot, is similar in structure to a standard teaching machine of 50 years ago (Lumsdaine and Glaser 1960). A Dbot would need a lot more information about the student, and would be unable to capture Dewey's crucial insight that good teaching and social interactions cannot be reduced to rules and mechanisms.

Once again we need to ensure that we understand the limitations of AI and Dewey helps us. Machines for imparting knowledge and machines that take a Tbot approach are all very well, but the best teachers—those who embody a Deweyan approach—will understand that teaching is a social process: one concerned not just with the acquisition of knowledge, but with teaching students by example how to think and how to discuss. It is a process where student and teacher are interested in each other, and where the dialogues are mindful, aware, and clear.

By setting out our criteria for creative feedback based on a Deweyan approach, it is clear that a machine cannot give creative feedback. It may be that the teaching program envisaged by Sir Anthony Selden will yield better exam results in a national curriculum, not just in maths and information technology, but in the humanities as well. This would be what Dewey referred to as “learning lessons,” which he distinguished from education. In education, according to our interpretation of Dewey, there is no sharp boundary between the discourse of students and teachers, students among themselves, and students in the world outside school: the knowledge objects absorbed at school permeate the whole of life. This process depends on creative feedback throughout, and would be a move toward a realization of Dewey’s belief that “education...is a process of living and not a preparation for future living” (Dewey 1897).

