Reflections on a reflection paper: "The computer as a tool for learning through reflection"

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Abstract
Collins & Brown's "the computer as a tool for learning through reflection" provides a valuable resource on how computer support should be utilized to encourage reflection, and thus improve learning. They presented clear and easy to follow guidelines which were exemplified in three learning scenarios: problem solving, reading, and writing. More than two decades have passed since the publication of this paper, yet computer support for reflection is still far behind the original vision. Interaction designers for computer supported learning applications would do well to revisit this seminal work and reflect on its implications for their own designs.

Keywords
Reflection, learning, collaborative learning, feedback, computer support.

ACM Classification Keywords
H.4.0 nformation systems applications: General.

General Terms
Reflection, learning, collaborative learning, feedback.

Introduction

Twenty three years ago, when the use of computers in education was still in its early stages, Collins & Brown [2] recognized and described the potential of digital technologies for supporting learning in general, and reflection in particular. They considered the computer to be "a powerful, motivating, and as yet untapped tool for focusing the students' attention directly on their own thought process and learning through reflection". In their paper "The computer as a tool for learning through reflection", Collins & Brown tried to draw the attention of educators and computer scientists to both the importance of reflection for learning and the valuable role that well-developed computer applications can play in supporting reflection.

An important point raised by Collins & Brown was that students' problem solving process, struggling, false starts and restarts, and partial successes should be made explicit. Learning benefits from problem solving can be maximized when students are encouraged to step back and reflect on their problem solving process and how this process can be improved in the future. Without this, students are more likely to struggle at the same points in a problem, repeat the same mistakes, or follow the same imperfect procedure.

While there is a consensus amongst pedagogy researchers as to the importance of reflection to learning, current practice in interaction design with respect to making students aware of the value of reflection through explicit *design-for-reflection* in educational software still leaves much to be desired. On the part of the teachers, a limited enthusiasm for teaching students about reflection and its importance can be attributed both to the high levels of motivation required to engage in reflection, and to the fact that the use of paper and pencil as the medium for problem solving does not readily lend itself to such activity [2]. Influenced by the same realization regarding students' motivation, educational software developers continuously fail to recognize the potential of the technology to overcome these motivation and medium barriers.

Why this paper

I have chosen to revisit the message of Collins & Brown's original paper, and document the paper's profound impact on my own PhD research [5] on the use of tabletop technology to support collaborative learning. Supporting metacognitive skills was one of my main goals, yet this was not reflected well in the application design. While evaluating a second iteration of the collaborative learning tool I was developing using tabletop technology [4,5], and while working on minor improvements on the design based on the observations, I first read Collins & Brown's paper on reflection. Their account, and vision, was the source of one of the "aha moments" that led to a significant conceptual leap in my doctoral research (and probably my future research). It provided the general guidelines for the design enhancements needed for the third iteration of the collaborative learning tool which, by now, were no longer minor.

Highlights of the paper

The paper focuses on the ability to use computers to capture the steps that novices or experts go through in carrying out a complex task, and how such a log should be used by learners trying to improve their performance. In order to be useful, such logs must be properly abstracted and structured so as to bring focus

on critical moments in the process and so that they can be played back or reviewed as quickly and effectively as possible. For Collins & Brown, reflection is important because it allows for

1. comparing between how novices and experts carry out a process;
2. representing the process spatially (reification) and in more than one representational form, and thus enables students to see separate aspects of the process together, or view the same process from different perspectives;
3. deriving abstractions from the process by comparing multiple performances simultaneously; and
4. Constructing abstractions in forms that are critical to the development of good metacognitive skills.

They posited four types of post activity reflection:

1. *Imitation*: the teacher imitates what the student did highlighting correct and incorrect things and critical moments.
2. *Replay*: a conventional video playback of the process. With the help of the teacher, critical moments and correct and incorrect things can be highlighted and compared to the performance of experts.
3. *Abstracted replay*: recording of only critical aspects of the process, possibly from different perspectives, to provide an abstracted playback that helps in keeping the students' focus on the important aspects of the process.
4. *Spatial reification*: a static visualization of the process that displays time spatially allowing the identification of critical aspects and moments of the process quickly.

Collins & Brown emphasized the benefits gained from providing different ways of looking at the same problem (i.e., playback, abstracted playback, or spatial reification).

Another interesting (and radical) issue raised was whether to design educational software in a way that allows students to flounder in the process or not. While some have argued that computer support should be used to prevent floundering, Collins & Brown suggested that except when teaching students basic domain skills (for which floundering is undesirable), computer supported education application designs should give enough space for students to try different approaches, even if they are incorrect, thereby allowing students to gain insights into what strategies lead to successful outcomes and (importantly) which do not. The paper concludes with a number of helpful examples on how reflection can be provided in different domains such as problem solving, writing, and reading.

Putting the paper into practice

Guided by these ideas, my approach was to add a dedicated reflection stage to the collaborative learning tool I was developing [4,5]. The application logged only the results of each action in order to allow for a quick abstracted replay of the interaction. It also identified critical moments in the process (i.e. when the application recognizes that students required support in order to proceed). Finally, a simple static visualization showed screen captures at the beginning of the process and at the end of each distinctive stage in the process, along with a progress bar that clearly marks the length

of each stage and the critical moments in the process. This reflection stage, which was designed to last only for a few minutes to maintain students' interest, was to be supervised by a teacher. It allows two forms of presentation: an abstracted replay, and spatial reification. Observations of repeated trials with the same group of students using the application showed notable improvement in the students' problem solving strategy, with the discussions undertaken in the reflection stage playing a major role in such improvements.

Complementary work

While the work of Collins & Brown focused on reflection provided at the end of a process, Nunes et al. [3] emphasized the importance of providing reflective feedback during a problem solving activity. They recommended dividing such processes into stages in order to allow for the provision of such feedback at stage boundaries so as not to interrupt the students in the process. On the other hand, Baker and Lund [1] highlighted the inherent reflection support found in collaborative interactions. Peer collaboration, in addition to maintaining students' motivation, encourages verbal communication, externalization of ideas (explaining and justifying opinions and reasoning), negotiation, and asking questions of each other. Such activities prompt reflection, metacognition, and self-regulation, with peers normally playing the role of the feedback agent.

My realization of the importance of supporting reflection in application design (as stated by Collins & Brown) lead me to investigate such other approaches to supporting reflection as in [1] & [3]. In addition to the separate reflection stage that I have added at the end of the learning activity, the application's support for reflection was also improved by inducing moments of reflection at stage boundaries in the process, and by focusing on the role of the cognitive tools provided in the application (to make the students' thinking visible on the table, i.e. externalization) in increasing the probability of useful reflective discussions between the students.

For an application to fully support reflection, it must provide post-activity and inter-activity reflection, and in cases where collaboration is involved, the application should also be designed to increase the space for peer discussions that further prompt for reflection [6].

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