Raybourn, E.M. (2011). Incorporating reflection into learner and instructor models for adaptive and predictive computer-based tutoring. In A. Bruzzone, W. Buck, and J. Sololowski (Eds). Proceedings of DHSS: The International Defense and Homeland Security Simulation Workshop, DIPTEM Universita di Genova, 117-22.

INCORPORATING REFLECTION INTO LEARNER AND INSTRUCTOR MODELS FOR ADAPTIVE AND PREDICTIVE COMPUTER-BASED TUTORING

ADAPTIVE AND PREDICTIVE COMPUTER-BASED TUTORING TRACK

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ABSTRACT
In the present paper the act of learner reflection during training with an adaptive or predictive computer-based tutor is considered a learner-system interaction. Incorporating reflection and real-time evaluation of peer performance into adaptive and predictive computer-based tutoring can support the development of automated adaptation. Allowing learners to refine and inform student models from reflective practice with independent open learner models may improve overall accuracy and relevancy. Given the emphasis on self-directed peer learning with adaptive technology, learner and instructor modeling research continue to be critical research areas for education and training technology.

Keywords: adaptive, predictive tutoring, games, learner model, Reflective Observer/Evaluator, instructor model, reflection

1. INTRODUCTION

Transforming education in the United States is a White House priority and a national security challenge. Homeland Security, Defense, and other Government agencies recognize the need to boost learner performance. According to Secretary of Education, Arne Duncan (2010), the staggering numbers of students that either fail to graduate or drop out of high school altogether is "economically unsustainable and morally unacceptable." Many educators attribute a one-size-fits-all approach to contributing to the failings of the education system (U.S. Department of Education, 2010). Without a strong foundation in education the United States will be unable to meet global challenges alongside other nations.

In response to the inadequacies of a one-size-fits-all approach, a National Science Foundation (NSF) study identified grand challenges for education technology such as personalization, assessment, and supporting social learning among several others (Woolf et al., 2010). In the cases of personalization and assessment the NSF study indicated that computational technologies might one day match the ability of a human tutor to understand individual learner's strengths and weaknesses and remove perceived boundaries between learning and assessment. Social learning could one day ensure continuous inputs from team members when the learner needs feedback the most. Additionally, the Army Learning Concept (ALC) 2015 envisions a future for education that leverages peer-based and self-directed learning. According to ALC 2015 "the future learning model must offer opportunities for Soldiers to provide input into the learning system throughout their career" as well as account for Soldiers' prior knowledge and experiences (ALC 2015, pages 6-7).

In each of these cases, real-time reflection plays a vital role. As we reflect we hone in on our strengths and weaknesses. Constructive criticism blurs the boundaries between learning and assessment, and each day we receive continuous inputs from our instructors and peers as we interact with them. Reflection is a dynamic activity. The challenge for adaptive and predictive computer-based tutoring is to take lessons learned from real-life reflection and incorporate them. However in order to do this, challenges in authoring, instructional strategy selection, and learner modeling for predictive and adaptive systems will need to be addressed to achieve desired outcomes from education technology (Sottilare, et al., 2011).

Adaptive tutoring has been defined as "the ability of an intelligent computer-based system to adjust to needs of the learner" (Sottilare et al., 2011). According to Sottilare and others, "adjustments to learner needs may be based on learner performance, behavioral and physiological sensor data, demographic data, personality profiles, mood surveys, and learner-system interaction" (2011, page 1). These systems often utilize what is known as a *student model* for purposes of description or prediction (Woolf, 2009). These student models are usually local to the application—that is, they are often treated as a component of a computer-based tutor, and not as an open, negotiated representation of learning. Adaptive and predictive computer-based tutors are typically standalone systems for individual users although research goals exist to extend these systems for eventual use with teams and groups (Sottilare, 2010).

The present paper proposes that incorporating aspects of social learning theory such as reflection and real-time observation and evaluation may support the automation of adaptive student models and instructional strategy selection. Student models can be static and simplistic, therefore quickly becoming inadequate as the complexity of ill-defined, cross-domain problems increase (Woolf, 2009). However learners who are given opportunities to refine their student models by reflecting on their own performance before and after training as well as reflecting on others' performance during training by performing real-time, peer evaluations may contribute information to learner models otherwise difficult to come by.

The potential opportunities to incorporate learner reflection that occurs before, during, and after training into adaptive and predictive computer-based tutoring systems are explored in the present paper. Two examples of making use of learners' reflection in adaptive systems are discussed: 1) reflection on peer performance occurring during adaptive or game-based training and 2) reflection on one's own performance before or after training via an independent open model such as an e-portfolio. The following section describes a role designed for real-time reflection in multi-player or team-based adaptive training and games.

2. INCORPORATING REAL-TIME REFLECTION INTO PREDICTIVE TUTORS

2.1. Reflection in Military Training

Reflection is a large part of all military training whether live or virtual. However, in most military training reflection largely occurs as a byproduct of face-to-face interactions with others, during group debriefings, or when lessons learned are taken from the classroom into the field. Military field training is often considered to be the most rigorous training experience available as it usually consists of mentally, emotionally, and physically challenging live exercises. These live exercises are role-play scenarios that can last up to two weeks and may involve a cast of approximately 1,600 role-players who collectively provide learners with experiences that rival a real-life situation (Tressler, 2007). Following the exercise, the learners and instructors discuss and debrief individual and/or team performance, and the consequences of actions taken in the scenario (Gredler, 1992). Military debriefings and hot washes are generally large or small group discussions in which performance is analyzed for what went wrong, what went right, and what could have been improved. It is common practice for sense-making to occur in a debriefing outside of the exercise context after one's performance has concluded. The challenge for the military is to engender real-time habits of reflection so that learners can debrief their own actions in situ, while they still have an opportunity to influence outcomes (Raybourn, 2007).

2.2. Player Role for Real-time Reflection

Very few computer games are designed to specifically engender habits of reflection even though this ability is a key metacognitive skill for successful learning. General perceptions of what constitutes computer game interaction or what behaviors constitute a "player" tend to closely align with trends in the entertainment industry even though opportunities exist for serious games and adaptive training to conceptualize both game play and "player" roles completely differently. According to Salen and Zimmerman (2004), rules as we know them in games can be broken and are sometimes transformed through the experience of social interaction. A unique opportunity therefore exists for serious games and military training systems to support real-time reflection and evaluation in-game with novel roles and new approaches to multi-player interaction.

As noted in the previous section, the opportunity to reflect on game-based training experiences or performance largely occurs after learning exercises have concluded, and outside of the exercise. Likewise in multi-player military training games the challenge of designing compelling learning opportunities that replicate live exercises is also usually met by separating action from reflection.

In the sections below we address the following questions: What are the implications of real-time reflection for team training? What are the affordances of using real-time reflections on peer performance for fine-tuning computer-based predictive tutoring models utilizing machine learning techniques?

2.3. Reflective Observer/Evaluator Role

A player role for real-time reflection based on the United States Government-owned Real-time In-Game Assessment, Evaluation and Feedback system was invented for a military training game developed for the U.S. Army Special Forces (Raybourn, 2007, 2009a). The design of the Reflective Observer/Evaluator role for multi-player games was inspired by the Special Forces' desire to hone intercultural competence and adaptive thinking through the practice of real-time reflection on actions taken, and the practice of providing constructive peer performance feedback. Operating competently in intercultural settings constitutes an ill-defined domain for predictive computer-based tutors and requires that the learner develop the ability to be aware of oneself and others, reflect on salient experiences, evaluate or assess situations, and act purposefully on those evaluations.

Early instantiations of the Real-time In-Game Assessment, Evaluation and Feedback system involved the instructor in-the-loop (Raybourn, 2009a,b) while a subsequent instantiation was developed for teams to work in pairs (Raybourn, et al., 2011). For example, in one of the scenarios for the Special Forces game a team conducts an area assessment of a local leader's courtyard. As the Detachment Commander communicates with the local leader, the instructor notices a behavior that she would like Reflective Observer/Evaluators to score. The instructor chooses the topic for evaluation (e.g. ethics) from a drop down menu on the instructor interface and instantly the request for evaluation appears in the Reflective Observer/Evaluators' interfaces. They enter a numerical evaluation and write comments in the text box as desired. The Detachment Commander is simultaneously evaluated by any number of Reflective Observer/Evaluators (e.g. 20 or more) on behaviors such as whether he exhibited cultural awareness, used appropriate nonverbal gestures, effectively built rapport, used clear communication, etc. The role-play scenario does not stop while Reflective Observer/Evaluators score their peer's performance. They can also enter annotations in the interface text field. Their feedback is quantitative and qualitative, logged by the game, and time-stamped. The evaluations across all Reflective Observer/Evaluators are aggregated and statistical analyses performed on their performance evaluations. The Reflective Observer/Evaluator interface has a scale bar in the lower left-hand corner that allows Reflective Observer/Evaluators to tap the space bar to raise or lower the bar to indicate team performance. Reflective Observer/Evaluators are able to evaluate both individual and team performance without becoming overwhelmed. Team and individual assessments can be displayed either in real-time or during group debriefings.

This approach to learning places real-time reflection directly in the training event, and gives Reflective Observer/Evaluators the ability to assess other players' performance and comment on events as they unfold. Following the game session, learners' roles can be switched and game play repeatability is preserved.

2.4. Reflective Observer/Evaluator Role for Learner Skill Development and Automated Knowledge Capture for Model Refinement

Learners in the Reflective Observer/Evaluator role observe, reflect, and evaluate the performance of another learner in real-time during role-play. The rationale for introducing the Reflective Observer/Evaluator role is fourfold. As described below the first two reasons primarily benefit the learner, while the latter two benefit the learner-system interaction with the express purpose of enhancing predictive capability and refining machine learning algorithms. In essence, the Reflective Observer/Evaluator role serves to train learners as well as train the system's predictive capability.

First, real-time reflection and assessment are introduced into training without having to stop or pause action. Several theories of reflection or reflective practice have been advanced (Kolb, 1984; Schön, 1983; Gibbs, 1988; Atkins & Murphy, 1994). Each includes reflecting, thinking, feeling, evaluating, and acting as key components. Reflection in the Reflective Observer/Evaluator role for games or adaptive training systems is treated the same way one would expect to exercise this skill in real-life.

Second, the introduction of this role allows different people to hone different cognitive processes at the same time, together. This also may increase content reuse and game play repeatability. By playing roles that allow learners to act (conventional player roles) and observe, reflect, & act (Reflective Observer/Evaluator role) different cognitive tasks are executed. Experiential Learning Theory's combined modes for grasping experience (watching or doing) via reflective observation and active experimentation and transforming experience (thinking or feeling) via abstract conceptualization and concrete experience provided a solid framework for the development of the Reflective Observer/Evaluator role (Kolb, 1984). For example more concrete, active experimentation (e.g. negotiating from a different cultural point of view) takes place with role-play itself, while abstract conceptualization and reflection is fostered by the Reflective Observer/Evaluator role (e.g. pause, observe the negotiation performance in light of the cultural context, critically evaluate best practices, and communicate feedback).

Third, large numbers of learners can participate as Reflective Observer/Evaluators in small group scenarios simultaneously. It therefore becomes possible to train an entire class on an intimate, small group exercise. It is also possible to obtain an aggregate evaluation of performance across a large number of participants to include experts, peers, and instructors. Reflective Observer/Evaluators may be anonymous and their feedback may assist the intelligent system in learning when, how, and why system feedback is appropriate.

Fourth, learners in the Reflective Observer/Evaluator role provide continuous inputs of subjective, value judgments and constructive feedback on performance that can be captured by the system. This may further refine computational models of human performance. For example, adaptive and intelligent tutoring systems often utilize a student model to "provide knowledge that is used to determine the conditions for adjusting feedback" for purposes of description or prediction (Woolf, 2009; p. 49). These systems often rely on discrete performance on well-defined problems, generalizations of expertise, and in worst cases, stereotypes of learners. The limitations of student models unfortunately contribute to computer-based games, simulations, tutors, and adaptive systems that are limited in perception and adaptability. The

Reflective Observer/Evaluator role can assist with system capture of naturalistic data to include perceptions on whether, or to what degree, human performance is perceived by others to be good, effective, valuable, etc. Instead of refining a learner model based solely on inputs from the learner, now multiplayer inputs on how the human performance is perceived by others can be captured and incorporated into models that aim to predict learner or system performance, and select instructional strategies. This topic is explored more deeply in the subsequent section on reflection before and after training with independent, open, and negotiated models for adaptive systems and computer-based predictive tutors.

3. INCORPORATING REFLECTION FROM INDEPENDENT OPEN LEARNER MODELS INTO PREDICTIVE TUTORS

3.1. E-portfolios for Naturalistic Knowledge Capture

The rationale presented above serves to illuminate the different ways reflection can inform learner and instructor models in adaptive and predictive computer-based tutoring systems. The present section describes how independent open learner models can be used in military training to automatically populate student models for intelligent tutoring systems and adaptive training environments.

Platforms for aggregating and managing personal data residing on different desktop applications and internet services are an active area of computer science research (Kay & Kummerfeld, 2010). These prototypes aggregate pervasive computing sensors, online portals, and direct user input about personal health data. This approach characterizes a more naturalistic capture of social learning via *cognition in the wild.* Cognition in the wild refers to human cognition as it naturally occurs and adapts in the everyday world—situated in culturally constituted human activity (Hutchinson, 1995; Holland et al., 2000). Learner models can be informed by data capture via sensors that are typical in our learning environment such as desktop search aides, mobile devices, biometric sensors, social media, and the integration of these sensors into learning applications, as well as integration with e-portfolios.

E-portfolios (a.k.a. electronic or digital portfolios) are independent open learner models that are an education technology of interest in that they can provide opportunities for learner self-reflection before and after training with adaptive and predictive tutoring systems. An independent open learner model is an open learner model that is used independently of or external to a system (Bull, 2010). Open learner models are defined as student models that are accessible to the learner being modeled and possibly to teachers, peers, or others who may be able to enhance the model (Bull & Kay, 2007).

E-portfolios are under review by the International Standards Organization (ISO). E-portfolios enable learners to populate quantitative records, monitor, share skills, educational goals, competencies, outcomes, and achievements. E-portfolios are learner-managed and can aid decision-making as well as provide personal reflections beyond the abilities of most assessment systems typical of performance-based simulations/training environments and Learning Management Systems (LMSs) representative of formal learning and training. An example e-portfolio would have a variety of data fields for learner-generated quantitative and qualitative entries, as well as hooks to data sources for tracking formal and informal learning experiences (e.g. social media, Google Mail, Withings body scale and blood pressure monitors, etc.).

E-portfolios offer opportunities to infer learner attributes through data mining and statistical analyses. These data can set the initial challenge level in intelligent tutoring systems or adaptive systems avoiding the cold start problem where the system initially knows nothing about the user (Durlach, personal communication June 13, 2010; Bull & Kay, 2007) or where learner stereotypes are used (Woolf, 2009). E-portfolio components may also be used to enhance adaptation. Durlach and Ray (in press) distinguish between local and model-based adaptation. Local adaption involves providing feedback in adaptive and predictive computer-based tutors without taking explicit learner information into account whereas model-based adaptation takes the student model information into account to influence the sequence of instruction.

E-portfolio data in the form of peer or instructor evaluations may also serve to inform Negotiated Learner Models. Negotiated models may be preferred in instances when learners want the system to initiate interaction and negotiation. If the learner and the system have differing beliefs about knowledge representation, the negotiation process is initiated. Negotiated models can result in more accurate learner models and boost learner reflection. Incorporating the reflections (and perceptions) of others' performance into negotiated learner-model interaction could have implications for refinement of performance measurement in ill-defined domains and automating shared mental models for teams.

4. CONCLUSIONS

Learner modeling, instructional strategy selection, and authoring research will benchmark how personalized education and training is delivered to meet international security challenges. The present paper discussed how a role for real-time reflection and evaluation in military training games can be incorporated into adaptive and predictive computer-based tutors. Incorporating learner-system interaction such as reflection and real-time evaluation of peer performance can support the development of automated adaptation. Allowing learners to refine and inform student models from reflective practice with independent open learner models may improve overall accuracy and relevancy. It is the position of the present paper that we have only scratched the surface regarding leveraging reflection in adaptive and predictive computer-based tutoring. Military game training need not follow general game play assumptions and rules but rather can set the bar for how critical learning and meaningful social interaction is achieved through adaptive systems. The challenge for international militaries is to engender real-time habits of reflection such that learners can debrief their own actions in situ, while they still have an opportunity to influence outcomes.

ACKNOWLEDGEMENTS

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DEAC04-94AL85000.

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