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The Influence of Learning Characteristics on Evaluation of Audience Response Technology

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ABSTRACT

AUDIENCE RESPONSE TECHNOLOGY (ART) has been widely adopted on college campuses, and prior research indicates that, on average, it receives positive evaluations from students. However, research has not yet examined how characteristics of students as learners influence their responses to ART. The current study examined aptitude for learning, objective learning (i.e., class performance), subjective learning (i.e., self-perceived learning), and conceptualizations of the learning process as influences on students' evaluation of ART. Students who had used ART over the course of a semester in one of three large lecture classes (N = 703) completed surveys assessing their learning characteristics, perceptions of ART influence on their attendance, motivation, and learning, liking for ART, and evaluations of the course and instructor. Controlling for course and instructor evaluations, aptitude and objective learning were weakly but negatively associated with evaluations of ART and subjective learning was positively associated with evaluations of ART. Further, different conceptualizations of learning have distinctive associations with ART evaluations. Discussion focuses on the implications of these findings for instructors' use of ART. (*Keywords: audience response technology, clickers, teaching, learning*)

INTRODUCTION

IN THE PAST FEW YEARS, audience response technology (ART) has been widely adopted on college campuses and is becoming especially popular among instructors of large lecture classes (*Purdue's system-wide technology helps students click in to academics*, 2004). Current ART packages with coordinated hardware and software allow instructors to ask varied types of questions, obtain immediate responses from students via their response devices ("clickers" or "remote controls"), and display the pattern of answers in a tabular or graphic format that preserves individual anonymity. Virtually any class size can be accommodated.

A growing body of research provides evidence that students view ART as a positive influence on classroom engagement (e.g., increasing attention, interest, or involvement; Rice & Bunz, 2006; Fitch, 2004; Latessa & Mouw, 2005; Nicol & Boyle, 2003) and learning (e.g., comprehending or remembering course material; Blackman, Dooley, Kuchinski, & Chapman, 2002; Guthrie & Carlin, 2004; Latessa & Mouw, 2005). Global assessments of the technology, such as liking, effectiveness, or desire to continue use also tend to be positive (Blackman et al.; Fitch; Nicol & Boyle; Stuart, Brown, & Draper, 2004). Clearly, this research suggests the utility of ART as an instructional tool. However, these studies have focused on describing the *average* student response to the technology, giving little attention to factors that predict variation in these evaluations. With increasing ART use, it is important to examine factors that influence how students respond to the technology.

Although there are many factors that may predict variation in evaluations of ART, we focused the current study on characteristics of students as learners: aptitude for learning, objective learning (i.e., class performance), subjective learning (i.e., self-perceived), and conceptualizations of the learning process. Theoretically, students' learning characteristics have good potential for predicting how they respond to instructional efforts; learning characteristics are also relevant to virtually any type of student population or class. Pragmatically, knowing whether learning characteristics affect student reactions to ART may assist instructors in tailoring the way they present and utilize the technology. Two prior studies have shown that student traits can affect ART evaluation in potentially important ways. Jackson and Trees (2007) found that students who were younger (freshmen and sophomores) or who had less experience with lecture classes perceived greater learning as a consequence of ART technology. More recently, Rice and Bunz (2006) found that ART was perceived as more fun and easier to use by graduate students who viewed themselves as more competent at computer-mediated communication. However, no prior studies have focused on the influence of students' learning characteristics. In the following sections, we discuss these learning characteristics as potential influences on ART evaluation and propose the study's hypotheses and research questions.

ART TECHNOLOGY AND STUDENTS' LEARNING CHARACTERISTICS

APTITUDE

COLLEGE INSTRUCTORS are often challenged by the range of student aptitude they encounter, perhaps especially in large introductory classes. Teaching strategies that may work for lower aptitude students can be less beneficial to higher aptitude students or vice-versa. Consequently, it is important to consider whether students of differing aptitude respond differently to the use of ART. However, predicting the direction of influence is difficult. Higher aptitude students may have a stronger appreciation for the feedback they receive via ART or be more comfortable with technology; yet lower aptitude students may respond more favorably if they believe that ART improves their chances of succeeding in the class. Because prior research on ART has not addressed this issue, we asked the following research question:

RQ1: Does student aptitude for learning influence evaluations of ART?

OBJECTIVE LEARNING

Students vary not only in aptitude but also in objective learning, or performance. To date, there have been no empirical examinations of how students' performance in a class influences their evaluation of ART in that class. One reasonable possibility is that higher-performing students will evaluate the technology more positively, viewing it as contributing to their greater success. However, it is also possible that higher-performing students are more likely to view the technology as unnecessary or even interfering with their performance. The lack of research evidence to guide a hypothesis led to the following research question:

RQ2: Does student objective learning influence evaluations of ART?

SUBJECTIVE LEARNING

In addition to aptitude and objective learning, students vary in their subjective perceptions of how much they have learned in any given course. Logically, students who think they have learned more from a course will probably be more positive toward specific components of a course, such as ART. Hence, we hypothesized:

H1: Students' subjective learning will be positively associated with their evaluations of ART.

CONCEPTUALIZATIONS OF LEARNING

Students' conceptualization of the learning process may also be a factor influencing how they respond to ART. Vermunt (1998; Vermunt & Vermetten, 2004) has identified five distinctive conceptualizations of learning in university student populations. These conceptualizations differ with respect to students' knowledge and beliefs about learning, learning objectives and activities, and the extent to which students or teachers are responsible for the learning process. Vermunt's typology distinguishes among the following conceptualizations: (a) *construction*, in which learning is viewed as constructing one's own knowledge and insights, (b) *intake*, in which learning is viewed as a process of memorizing and reproducing the information provided by teachers, (c) *utility*, in which learning is viewed as acquiring knowledge to be used through concrete application (with responsibility for learning shared between teacher and students), (d) *teacher stimulation*, in which learning takes place through teachers' motivation and guidance of students' activities, and (e) *cooperation*, in which learning is a process that occurs via interaction and shared effort with other students.

These conceptualizations of learning could influence how students respond to ART, perhaps especially because the conceptualizations differ with regard to students' responsibility for learning. Proponents of ART have emphasized its capacity to engage students and facilitate interaction (Fitch, 2004; Wit, 2003). Obviously, the extent to which this capacity is realized depends on how instructors actually use the technology; for example, some instructors use it solely for quizzes that students answer individually at the beginning or end of a class, whereas others use the technology to facilitate peer instruction throughout class. Still, many (if not all) uses of ART are likely to be more engaging and interactive than the traditional lecture. Thus, student evaluations of ART may be positively associated with their conceptualizations of learning as *construction* or *cooperation*. It is especially important to determine how ART is viewed by students with a stronger conceptualization of learning as *construction*, as this conceptualization is associated with higher academic performance (Vermunt & Vermetten, 2004). Of course, as with many pedagogical techniques, ART is not wholly student-driven. Instructors write (or obtain), deliver, and comment on the answers to questions; the questions themselves are forced-choice or numeric, and answers are typically "right" or "wrong" as determined by the instructor (with the obvious exception of opinion surveys). Prior research indicates that students often perceive ART questions as providing them with information about what the teacher wants them to know (Fitch; Wit); instructors likely increase this perception if they choose the same or similar questions for exams and tell students about the similarity. Thus, ART may appeal to students with a stronger conceptualization of learning as *teacher stimulation* or *intake*. Accordingly, we asked the following research question:

> RQ3: How are learning conceptualizations associated with evaluations of ART?

DIMENSIONS OF ART EVALUATION

ART CAN BE, AND HAS BEEN, EVALUATED on a number of dimensions. These include the perceived impact of the technology on aspects of classroom engagement (e.g., attendance, attention), learning processes and outcomes (e.g., motivation, learning), as well as global evaluations, such as liking or desire for future use (e.g., Blackman et al., 2002; Fitch, 2004; Stuart et al., 2004). For the current study, we chose to focus on how student perceptions of ART influenced attendance, motivation to learn, and learning, as well as their liking for the technology. These dimensions of evaluation represent some of the range of prior evaluation and are clearly important outcomes to be considered with respect to ART use.

One challenge inherent in assessing student response to instructional technology used in the context of a course is that evaluations of any specific instructional strategy can be strongly influenced by perceptions of the course as a whole or of the instructor. Because we wanted to focus as closely as possible on students' evaluations of ART, we chose to obtain and then control for course and instructor evaluations in the course of our analyses. Including these variables also allowed us to test the following hypothesis:

> H3: Course and instructor evaluations will be positively associated with evaluations of ART.

METHOD

PARTICIPANTS

PARTICIPANTS were students at a large midwestern university who used an ART system (the Classroom Performance System from eInstruction) in one of three large lecture classes during Spring 2005. The response pads for this ART system did not have an LCD screen to display answers but were otherwise similar to current technology. The classes were all introductory, survey courses: Communication 102 (COM 102), *Introduction to Communication Theory*, Forestry and Natural Resources 103 (FNR 103), *Introduction to Environmental Conservation*, and Organizational Leadership and Supervision 274 (OLS 274), *Applied Leadership: Functions, Structures, and Operations of Organizations.*

There was no attempt to standardize, manipulate, or systematically measure how the course instructors used CPS in their classes, but there were points of considerable similarity. All three instructors were using CPS for the second or third time, so they were comfortable with the technology. Further, all three instructors typically used ART for comprehension questions, often based on the immediately preceding lecture material but also on material from assigned readings or from prior classes. They also used ART to provide review prior to quizzes or exams. In all three classes, students typically answered three-to-five questions per class period and did so largely independently (i.e., the classes did not employ peer instruction techniques). In addition, students were awarded course credit regardless of whether the answer was correct. Thus, course credit for CPS amounted to a grade for attendance.

Not surprisingly, there were also some differences in ART use across the classes. The COM 102 and FNR 103 instructors varied the placement of the ART questions within their lectures, whereas the OLS 274 instructor was more systematic, asking one or two questions at the beginning, middle, and end of each lecture. The FNR 103 instructor made use of some opinion questions (i.e., surveying students' attitudes on a topic relevant to the lecture); the other instructors did not. The amount of course credit awarded for ART use was 10% in OLS 274, 6.6% in FNR 103, and 5% in COM 102.

According to data provided by the registrar, a total of 1,192 students were enrolled in these three courses at the end of the semester. Seven hundred-thirteen students actually participated in the study. (This level of participation probably reflects the relatively small quantity of course credit awarded for completing the survey.) Data from 10 participants was subsequently eliminated, because the course reported by the student did not match the course reported by the registrar; this may have resulted from dual enrollments. This left an analyzable sample of 703 participants or 58.9% of the total enrollment of 1,192. COM 102 students comprised 20.5% of the sample (N = 144), FNR students comprised 39.3% of the sample (N = 276), and OLS 274 comprised 40.3% of the sample (N = 283). In COM 102, 65.8% of students participated in the study (144 of 219); these percentages were 64.9% in FNR 103 (276 of 425 students) and 51.6% in OLS 274 (283 of 548 students).

Demographics. Of the 703 participants, 353 were male and 350 were female. There were 34.4% freshmen (N = 242), 31.3% sophomores (N = 220), 20.8% juniors (N = 146), 13.4% seniors (N = 94), and one graduate student (N = 1). The mean age was 20.16 (SD = 1.87). The participants were European-American/White (83.4%), African-American/Black (4.4%), Asian/Pacific Islander (4.4%), Chicano/Latino/Hispanic (3.0%), Native American (0.3%), and Other ethnicity (4.6%). Participants were pursuing majors in many of the university's 11 colleges and schools. Thirty-two percent were students in Liberal Arts, 18.3% were in Consumer and Family Science, 22.6% were in Technology, 12.7% were in Agriculture, and 8.1% were in Management. The remaining 7.2% were in Education, Health Sciences, Engineering, Science, or Interdisciplinary and Graduate Studies.

Prior ART use. Participants were asked about prior use of ART systems in college courses or in primary or secondary schooling. The majority (91.5%) had never used any ART system in college or during their primary or secondary education (98.7%).

PROCEDURE

During the last week of the semester, students in the three courses were directed by their instructors to a Web site from which they could access and complete the study survey online. The link to the Web site was made available via secured "courseware" (WebCT) to reduce the likelihood of anyone outside the relevant classes gaining access to the Web site or participating in the study. Instructional technology staff administered the Web site and provided instructors with a record of student participation so credit could be awarded. They also added data obtained from the registrar (see Measures) and removed all identifying information before releasing the data to the authors for analysis.

MEASURES

Aptitude and Objective Learning. Students' aptitude for learning was assessed with their composite SAT scores, and their objective learning was assessed with the final grade awarded in the course; both types of data were obtained from the registrar. SAT scores were available for 571 of the 703 participants. The mean was 1060 (SD = 131.03), with a possible range from 200 to 1600, and an actual range of 660 to 1460. Letter grades were available for 702 of the 703 participants; one student received a "P" (passing) grade. On a 4.0 scale (0 = F), the average grade was 3.02 (SD = .96).

Subjective Learning. Students' subjective learning was assessed with three items created by the authors. These items were "How much do you think you have learned about the concepts and principles taught in this course?," "How well do you think you have comprehended the content of this course?," and "How well do you think you would do if you were given an exam today to measure your retention of the content of this course thus far in the semester?" The inter-item reliability for these three items was excellent (α = .92), so the index of subjective learning was created from the mean of the items.

Conceptualizations of Learning. Students' conceptualizations of learning were measured using the 5-item scales for each conceptualization taken from the Inventory of Learning Styles (ILS) developed by Vermunt (1994; 1998). The items, used with permission, included:

> The things I learn have to be useful for solving practical problems (*utility*).
> I like to be given precise instructions as to how to go about solving a task or doing an assignment (*intake*).
> When I prepare myself for an exam, I prefer to do so together with other students (*cooperation*).
> To me, learning means trying to approach a problem from many different angles, including aspects that were previously unknown to me (*construction*).
> The teacher should encourage me to combine the separate components of a course into a whole (*teacher stimulation*).

The inter-item reliability (Cronbach's α) as .70 for *construction*, .78 for *utility*, .75 for *intake*, and .80 for *cooperation*. One item was eliminated from the scale for teacher stimulation because doing so improved reliability from .70 to .75.

Evaluations of ART. Student evaluation of ART's influence on attendance, motivation, and learning, as well as liking for the technology, were assessed using three-item scales developed by the authors (MacGeorge et al., in press). The items for attendance were:

> Because CPS is used, I attend class more regularly than I would otherwise.
> Using CPS increases my likelihood of attending class.
> CPS motivates me to attend class.

The items for motivation were:

> CPS boosts my enthusiasm for studying the material we learn in this course.
> Using CPS makes me more motivated to learn in this course.
> If we didn't use CPS, I would be less interested in the topics we cover in this course.

The items for learning were:

> My knowledge of course material is improved by using CPS.
> I understand more in this class because we use CPS.
> CPS helps me learn course material better.

The items for liking were:

I do not like using CPS (reverse).
I enjoy using the CPS technology.
I have had a good experience with CPS.

Inter-item reliabilities were acceptable, ranging from 0.80 for liking to 0.81 for motivation, 0.85 for learning, and 0.87 for attendance; so indices for these dimensions of evaluation were created from the means of the items.

COURSE AND INSTRUCTOR EVALUATIONS

The items used to assess participants' evaluations of their courses and instructors were the same as those typically used for global evaluation of courses and instructors at the university. The item for course evaluation began with the prompt "Overall, I would rate this course as . . . ." and students selected from five responses (ranging from 1 = *very poor* to 5 = *excellent*). The item for instructor evaluation had the same response set but began with the prompt "Overall, I would rate this instructor as . . . ." (Actual course and instructor evaluations for each of the three classes were conducted separately from this study and were not connected in any way.)

RESULTS

TO ISOLATE THE INDEPENDENT INFLUENCES of the predictor variables, we conducted a series of hierarchical regression analyses, one for each of the four dependent variables. In each analysis, we controlled for the demographic variables of gender, year in school, and course (all dummy coded) by entering them collectively at the first step, followed by instructor evaluation and course evaluation at the second step. Because the demographic variables of ethnicity and prior use of ART were so homogeneous in this sample, we did not control for these variables. We then entered aptitude at the third step, objective and subjective learning at the fourth step, and the conceptions of learning variables at the fifth step. This order of entry for the learning characteristics was chosen to reflect the logical and chronological priority of aptitude. (Aptitude is typically viewed as a factor that influences subsequent learning outcomes, and the SAT scores were obtained considerably prior to the other variables in this study.) The order of entry was also influenced by the desire to determine whether conceptualizations of learning influence evaluations of ART above and beyond any associations with other learning characteristics (or demographics). For descriptive completeness, bivariate correlations among the continuous predictor and dependent variables are reported in Table 1.

Table 1.
Bivariate Correlations

	1	2	3	4	5	6	7	8	9	10
1. Course Evaluation	1.00									
2. Instructor Evaluation	.69***	1.00								
3. Aptitude	.03	.06	1.00							
4. Objective Learning	.13***	.19***	.34***	1.00						
5. Subjective Learning	.62***	.63***	.15**	.33***	1.00					
6. Intake	.16***	.22***	-.04	.00	.15***	1.00				
7. Teacher Stimulation	.20***	.32***	.03	.02	.27***	.62***	1.00			
8. Cooperation	.10**	.09*	-.11*	-.15***	.02	.24***	.32***	1.00		
9. Construction	.25***	.28***	-.02	-.02	.28***	.43***	.67***	.35***	1.00	
10. Utility	.16***	.26***	.03	.04	.26***	.66***	.74***	.22***	.57***	1.00

Note. N=703, except for correlations involving Aptitude where N=571. p<.05* p<.01*** p<.001 (Bonferroni correction = .05/45 =.001)

For the dependent variable of liking, the predictor variables of gender, course, course evaluation, and instructor evaluation had significant independent effects. Follow-up tests showed that women believed ART had a stronger positive influence on their attendance (M = 3.41) than did men (M = 3.33) and that students in FNR 103 perceived ART as having a stronger positive influence on their attendance (M = 3.64) than did students in OLS 274 (M = 3.34), which was in turn stronger than that for students in COM 102 (M = 2.90). For the dependent variable of motivation, course, course evaluation, aptitude, subjective learning, *utility*, *cooperation*, and *construction* had significant effects. A follow-up test indicated that students in FNR 103 perceived ART as having a stronger positive influence on their motivation (M = 3.19) than did students in OLS 274 (M = 3.01) or COM 102 (M = 2.92); the latter means were not significantly different. For the dependent variable of learning, course, course evaluation, aptitude, subjective learning, cooperation, and construction had significant independent effects. A follow-up test indicated that students in OLS 274 perceived ART as having a weaker influence on their learning (M = 3.05) than did students in COM 102 (M = 3.33) or FNR 103 (M = 3.40); the latter means were not significantly different. For the dependent variable of liking, gender, course, course evaluation, instructor evaluation had significant independent effects. Follow-up tests indicated that women (M = 3.47) liked ART more than men (M = 3.24) and that students in OLS 274 liked ART less (M = 3.15) than did students in FNR 103 (M = 3.48) or COM 102 (M = 3.51); the latter two means were not significantly different. Complete statistics for each regression analysis are reported in Table 2 on page 38.

DISCUSSION

THE CENTRAL PURPOSE of the present study was to examine how students' learning characteristics—aptitude, performance (objective learning), subjective learning, and conceptions of learning—affect evaluations of ART on several important dimensions. The results indicate that these learning characteristics do influence how student respond to ART, to varied degrees, and with potentially important implications. In the following sections, we discuss the findings, consider the limitations of the study, and make recommendations for future research and application.

Table 2.
Regression Analyses

Entry	Predictor Variables	Dependent Variables			
		Attendance	Motivation	Learning	Liking
1st Step	Demographics	R^2_{change} = .092	R^2_{change} = .024	R^2_{change} = .03	R^2_{change} = .05
	df = 6, 563	F = 9.52***	F = 2.33*	F = 2.97**	F = 4.84***
	Gender	_ = .12**	_ = -.01	_ = .02	_ = .09*
	Course—Dummy Variable 1	_ = -.32***	_ = -.04	_ = .02	_ = .01
	Course—Dummy Variable 2	_ =-.12*	_ = -.11*	_ = -.15**	_ = -.15**
	Year—Dummy Variable 1	_ = .06	_ = .09	_ = .00	_ = .01
	Year—Dummy Variable 2	_ = .08	_ = .06	_ = .02	_ = .02
	Year—Dummy Variable 3	_ = .00	_ = -.02	_ = -.04	_ = -.07
2nd Step	Evaluations	R^2_{change} = .071	R^2_{change} = .086	R^2_{change} = .16	R^2_{change} = .12
	df = 2, 561	F = 23.86***	F = 27.12***	F = 56.99***	F = 39.33***
	Course Evaluation	_ = .13*	_ = .28***	_ = .37***	_ = .18***
	Instructor Evaluation	_ = .19***	_ = .04	_ = .09	_ = .22***
3rd Step	Aptitude	R^2_{change} = .001	R^2_{change} = .015	R^2_{change} = .006	R^2_{change} = .00
	df = 1, 560	F = .49_ =	F = 9.89**	F = 3.89*	F = .35_ =
		-.03	_ = -.13**	_ = -.08*	-.04
4th Step	Learning	R^2_{change} = .015	R^2_{change} = .015	R^2_{change} = .02	R^2_{change} = .01
	df = 2, 558	F = 5.10**	F = 4.84**	F = 6.82***	F = 2.51
	Objective Learning	_ = -.10*	_ = -.06	_ = -.05	_ = .05
	Subjective Learning	_ = .15**	_ = .17**	_ = .20***	_ = .10
5th Step	Conceptualizations of Learning	R^2_{change} = .082	R^2_{change} = .14	R^2_{change} = .08	R^2_{change} = .04
	df = 5, 553	F = 12.35***	F = 21.06***	F = 12.70***	F = 6.29***
	Utility	_ =-.01	_ = -.15*	_ = -.01	_ = .00
	Intake	_ =.12*	_ = .03	_ = .04	_ = .08
	Cooperation	_ =.12**	_ = .31***	_ = .15***	_ = .03
	Construction	_ =.06	_ = .17***	_ = .12*	_ = .04
	Teacher Stimulation	_ = .12+	_ = .04	_ = .09	_ = .13+
Total Model		R^2 = .261	R^2 = .278	R^2 = .299	R^2 = .219
		F = 12.14***	F = 13.31***	F = 14.77***	F = 9.70***

+p<.07* p<.05** p<.01***p<.001

CONTROL VARIABLES: DEMOGRAPHICS, COURSE EVALUATION, AND INSTRUCTOR EVALUATION

Gender influenced evaluations of impact on attendance and liking. In both cases, women's evaluations were more positive. These findings may reflect women's liking for—and educational benefit from—active learning, interaction between instructor and student, and frequent feedback (Lorenzo, Crouch, & Mazur, 2006). Upper and lower classmen did not differ on any evaluations of ART, contrary to one prior study in which lower classmen thought the technology was more beneficial to learning than did upper classmen (Jackson et al., 2004). The most consistent demographic influence was course: There were differences in evaluation between two or more courses for all of the dimensions. Unfortunately, these can only be interpreted *post hoc*. The FNR 103 instructor was especially successful at using ART to influence students' attendance and motivation to learn. This may reflect the instructor's considerable experience in the classroom and with that particular class; he was the most senior of the three instructors and was teaching FNR 103 for the 11th time that semester (as opposed to the 1st and 6th time for COM 102 and OLS 274, respectively). However, it may also reflect other factors, such as specific strategies for using ART or discussions of its use with students. This is an important limitation not only of the current study but of prior studies as well. Future research should examine how instructors' actually use ART and begin linking these instructional choices to student perceptions and outcomes.

Unsurprisingly, both course and instructor evaluations were positively associated with ART evaluations at the bivariate level. However, in the regression analyses, only course evaluation was a consistent influence; shared variance with course evaluation resulted in significant effects of instructor evaluation only for attendance and liking. In all likelihood, much of the shared variance between course, instructor, and ART evaluations results from a type of "halo" effect in which ART was perceived more positively, because the entire class experience was perceived more positively. However, it is also possible that students who perceived ART more positively in turn evaluated the course more positively. Future research should examine more directly whether the use of ART affects course evaluations.

APTITUDE

Despite being the first learning characteristic entered in the regression analysis (and thereby able to "capture" any variance shared with other learning characteristics), aptitude was a relatively weak influence on ART evaluation, significant only for motivation and learning, and limited to less than 2% of the variance. The limited influence of aptitude suggests that the technology has relatively wide appeal and that instructors need not be overly concerned about the response from any aptitude "strata" of their classes. However, the direction of influence is also interesting: Students with *lower* SAT scores saw ART as a greater positive influence on their motivation and learning in the course. Future research should examine whether this perception is accurate: Do lower aptitude students actually benefit more from the use of ART technology? In addition, instructors should probably consider whether their ART use can be made more beneficial to higher aptitude students. For example, are at least some of the questions being used sufficiently challenging to stimulate students at high levels of aptitude?

OBJECTIVE AND SUBJECTIVE LEARNING

Like aptitude, objective learning (performance as measured by final course grade) proved to be a weak negative influence on ART evaluation (less than 2% variance explained). Interestingly, this did not occur because of shared variance with aptitude or subjective learning. In fact, the bivariate correlations between objective learning and the ART evaluations are all nonsignificant, so that objective learning had a significant influence on attendance only with the other two variables controlled. Thus, although students in the current study completed the survey in the final week of the semester (when their likely course grades should have been much in mind), final grades did not have much influence on how they evaluated ART. Like the findings for aptitude, this suggests that instructors need not be overly concerned about whether ART is disproportionately well-received by students who are more or less successful in their courses.

In contrast to objective learning, subjective learning (self-perceived learning) was a relatively strong, positive influence on all dimensions of ART evaluation. This is relatively unsurprising in that students who think they have learned more in a course tend to view many of their instructors' pedagogical choices (technological or otherwise) as having benefited them. However, it is worth noting that this consistent, significant effect was not dependent on aptitude or final grade. Further, it is possible that the directionality extends in the opposite direction: from ART to perceived learning. This would suggest, for example, that when ART has a beneficial influence on attendance and motivation, it produces greater learning. An important direction for future research is to examine relationships between these variables using methods that will help to clarify cause and effect.

CONCEPTUALIZATIONS OF LEARNING

The most consistent, sizeable associations between ART evaluations and conceptualizations of learning involved the conceptualizations that placed primary responsibility for learning on the student rather than the teacher. The conceptualizations of learning as *cooperation* (learning through interaction with other students) was positively associated with higher evaluations on attendance, motivation, and learning, and the conceptualization of *construction* (learning as a personal, creative process) was positively associated with motivation and learning. Although the data in the present study cannot address this question directly, it is possible that students who hold these conceptualizations respond positively, because aspects of ART use correspond to these views of learning. For example, students who conceptualize learning as *construction* may value the opportunity for self-testing, and students who conceptualize learning as *cooperation* may enjoy the sense of camaraderie as classmates all try to answer the questions. It is also important to note that the associations between *construction*, *cooperation*, and ART evaluations might well be stronger in classes that utilize the technology in the context of peer instruction or other techniques that demand even more student involvement and interaction.

The two conceptualizations of learning that most emphasized the teacher's role were not strongly or consistently related to evaluations of ART. *Intake*, in which learning is conceived as memorization and reproduction of material provided by the teacher, was positively associated only with the perception that ART encouraged attendance. *Teacher stimulation*, in which learning is viewed as something that should be motivated and guided by the teacher, was only marginally (positively) associated with attendance and liking for ART. These associations were weak despite the fact that all three instructors used ART questions similar to those they used for their exams, noted this similarity to students, and used ART in review sessions for exams. Thus, the current findings suggest that instructors need not be concerned that ART appeals only (or even primarily) to students with a more passive view of learning.

Utility, in which learning is driven by practical application, had one negative association, with the perception that ART increased learning. This finding suggests that instructors could improve educational outcomes for at least some students by creating questions that appear as "practical" as possible. Future research should examine how and why ART appeals to students with different conceptualizations of learning, with a focus on improving benefit across these conceptualizations. For now, since instructors often try to encourage students to take greater "ownership" of the learning process and since *construction* is associated with better learning outcomes (Vermunt & Vermetten, 2004), it is valuable to note that ART appeals to students who have this orientation already.

LIMITATIONS

Several limitations of the current study have already been noted, including the cross-sectional and self-report data that limits conclusions about the direction of causality. Our sample should be noted as both strength and limitation. Much prior ART evaluation has been conducted with "atypical" students and classes and small sample sizes (for a review, see MacGeorge et al., in press). Hence, our relatively large sample of undergraduates who used ART in introductory, large lecture courses supports the potential generalizability of the findings. However, because we recruited from social science and life science classes, there were relatively few physical science or engineering majors in our study. In addition, because our sample consisted of university students with relatively high average aptitude for learning, the sample may not do a good job of representing how learning characteristics might affect responses to ART in other student populations. Thus, the findings of the current study should be tested with other samples.

Perhaps more important than the limitation of our sample is the lack of detailed data on how the three instructors used ART in their classes. The regression analyses controlled for course at the first step; thus, significant relationships between the evaluations and the predictor variables are independent of variance explained by course. However, it remains possible that some relationships between variables might be stronger or weaker if examined in the context of courses where ART was used in ways not represented in the current study (e.g., peer instruction). Overall, with increasing evidence that ART has positive value for a wide range of students, it is important that research move in the direction of evaluating how instructors use the technology. For example, how do instructors' choices about number, type, or placement of questions, follow-up to student answers, encouragement (or discouragement) of interaction between students, and other aspects of ART use affect students?

Finally, the current study did not include objective measures of ART influence on students' learning process and outcomes; only a small number of such studies have been conducted to date (Blackman et al., 2002; Poulis, Massen, Robens, & Gilbert, 1998; Schackow, Chavez, Loya, & Friedman, 2004). Clearly, student perceptions such as those measured in the present study are an important component of evaluating the technology. However, there remains a difference between showing that students *believe* they know more as a consequence of using a technology and demonstrating that they actually *do* know more. Further, things that students like about a technology may fail to benefit them or even be detrimental to learning (Mayer & Moreno, 2002). To address these issues with regard to ART, experimental or quasi-experimental research needs to be undertaken.

CONCLUSIONS

LIMITATIONS NOTWITHSTANDING, we believe the current study supports the following conclusions with pragmatic implications. First, students of varied aptitude and performance have relatively similar responses to ART. There is a slight tendency for students with higher aptitude and performance to be "less impressed" with the technology. Instructors might attempt to overcome this tendency by creating more challenging questions or by explicitly discussing possible benefits of ART for high-achieving students. Second, although the direction of causality is unclear, there are solid associations between perceived learning in the course, course evaluations, and perceived benefits derived from ART. Thus, instructor efforts to improve students' experience using ART may have positive outcomes for both student and instructor. Third, the appeal of ART is not limited to students who adopt a passive, "memorize and regurgitate," approach to learning. Instead, the technology appears to have the greatest appeal for students who want their learning to be active and interactive.

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