THE NEW "ARMS RACE" IN EDUCATIONAL TECHNOLOGY: COMPUTERIZED PERSONALIZED ASSIGNMENTS VS. HIGH-TECH CHEATING

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I. INTRODUCTION

For at least thirty years there has been the hope and belief that computers may be able to aid and eventually possibly replace humans in the process of teaching other humans.[1] And before the invention of the computer, similar claims were made for other technologies (the printing press, the radio, the television, the video recorder/player, ...) too. Where the computer may be qualitatively different from these other technologies of information transfer is the ability to produce customized feedback. In particular, since the invention of the World Wide Web a little more than a decade ago, the process of networking of computers has amplified this possibility. It has, unfortunately, also amplified the possibility of sophisticated methods of cheating by web-savvy students.

Over the last few years the extensive use of interactive Java applets has been tried in the classroom [2,3], and computers have been used as tutors. Most successful is perhaps the use of the computer as a homework system, where the computer provides individualized and personalized problem sets and enables the student to input solution attempts with immediate feedback and customized help.[5-9] At their best, these homework systems can entice the student to spend more time on task, create a more active learner, and make learning problem solving skills more enjoyable. Perhaps most important: computer-based individualized systems prevent the students from mindless copying of their friends' homework assignments.

Realizing that the creation of sophisticated computerized homework assignments is extremely time-intensive, we have put a very substantial effort into the creation of large databases of homework problems and other multimedia resources on the internet, the **L**earning **O**nline **N**etwork with **C**omputer **A**ssisted **P**ersonalized **A**pproach (LONCAPA) project. These databases enable faculty at universities, community colleges, and K-12 schools to take advantage of the work of their colleagues in creating online resources, a process which we have named **m**ultimedia **c**ollaborative **c**ontent **c**reation (mc^3).[9,10]

However, the same computers that can be used by faculty to create richer and more individualized learning environments can also be used by students in ever more sophisticated schemes to short-circuit the system, in other words to cheat on their assignments. While the Internet is now a global research library of previously unknown power, it also enables enterprising would-be cheaters to cut and paste material for easy and relatively thought-free composition of essay assignments. This has forced faculty to resort to the creation of sophisticated search engines that check for hints of plagiarism -- an electronic "arms race" of sorts.[11]

We have now encountered a new level of sophistication in this "arms race", a commercial web site constructed by students to defeat personalized computer homework assignments. Personalized homework assignments present the same text with different numbers to different students. This prevents the direct copying of the answers. The algorithm that determines if the given answer is correct is implemented in a server-side cgi-script and can thus not be discovered by a simple "View Page Source" command on the user's web browser. However, all student answers are computed from their input numbers via the same formula, derived from the relevant physics principles, in a given problem. Posting this formula constitutes reverse engineering of sorts and enables the kind of mindless plug-and-chug procedure that our homework systems were created to avoid.

II. STUDENT DATA

During the winter semester 1999, one of us (EK) taught an introductory calculus-based course in

engineering physics using our personalized homework system. The combined enrollment in all sections of this course was 458. An interesting component of this course for the purposes of this paper is that we created our own web-based threaded discussion forum and chat room. This forum was monitored by teaching assistants who helped the students with their problems, but were discouraged from simply giving the solution away. Of the 458 students in the class, 129 posted questions and contributions at least once. Based on this information, we created a variable labeled "Post-sanctioned" that indicates whether or not the student ever posted a question or contribution on this course sanctioned site. We also recorded how often students visited our site without posting, just "looking", during the semester. This distribution was highly skewed, with a mean of 33.01 and a standard deviation of 29.95, ranging from 0 to a maximum of 172. Taking the square root of the number of visits resulted in a much more manageable distribution with mean of 5.08, standard deviation of 2.68, and range between 0 and 13.11. We refer to this square rooted variable as "Look-sanctioned."

After the semester was completed (and all grades were assigned to the students), we researched how widespread the use of the above-mentioned third party cheating web site for the homework assignments had been. We wanted to know if use of the site had been beneficial or detrimental to student learning, and if we should take steps to shut down that site. To this end, WB, in his role as associate chair and undergraduate program director, sent an email to all students in the course. This email asked for the percentage of homework problems for which each student had used the site, with the promise that no repercussions would result from the answers. We explicitly stated that we would like the students to respond even if they had never used the site.

Approximately one third of the students in the class responded to the email and of these 133 gave a quantitative estimate of their use of the site. More specifically, students were asked to provide a number between 0 and 100 indicating the (approximate) percentage of their homework problems for which they used the third-party site. This percentage estimate is referred to as "Third-party percent". Of the responses containing numeric estimates, 122 were identified by name and student number so that their estimates could be linked with classroom performance.

Because only a subset of the students in the class responded to our email, we first tested whether there were any systematic differences between responders and non-responders in terms of general academic ability and class performance. Although there were small differences between responders and non-responders on the ACT composite, the ACT math, overall GPA, and score on the final exam for the course, such that responders tended to have slightly higher scores, no statistically significant differences emerged. Given these results, it seems reasonable to assume that the students who responded to our email comprise a representative sample of the overall student population in this course.

Thus we have data concerning use of the sanctioned discussion forum, data concerning use of the third party site, and data concerning success in the course. Success in the course is measured by students exam scores, their total homework score, and their improvement in the Force Concept Inventory (FCC) score [12], administered at the beginning and end of the semester.

Table I contains the correlation coefficients between measures of success in the course, percent use of the third party site, and posting/looking at the course sanctioned site. Consider first the results for the third-party site. Students who used this site more often (according to their own self report) tended to perform more poorly on exams, quizzes, and the final. In other words: the more students relied on the easy plug-and-chug answers on that web site, the worse they ended up performing on the exams. Several students echoed exactly this sentiment in their email comments to us, too. In addition, relative to those who used the site less, those who used it more did not perform better on the homework.

It is possible that students who may be destined to perform relatively poorly tend to seek more help wherever it can be found. Thus, there may be a built-in negative relationship with help-seeking behavior and success. However, the second and third columns in Table I clearly contradict this line of reasoning. There we

see a small *positive* correlation between use of our web site and the exam scores. This shows that helping the students find their own solutions to problems has a positive effect on the learning outcome, whereas simply giving away the solutions has strongly negative consequences.

Table 1: Correlation coefficients (and p-values) between the course-work scores and student use of different web sites. The column named 3rd Party Percent refers to percent use of a web site that simply gave away the solution. The other two columns refer to the use of our own course-sanctioned web site with threaded discussion forum, which did not give away the solution. but attempted to guide the students to find their own solution.

3rd Party Percent	Post-sanctioned	Look-sanctioned	
Homework	0.041 (0.655)	0.118 (0.016)	-0.109 (0.026)
Final Exam	-0.348 (0.001)	0.147 (0.003)	0.129 (0.008)
Midterm Exams	-0.352 (0.001)	0.166 (0.001)	0.160(0.001)
Quizzes	-0.302 (0.001)	0.098 (0.044)	0.069 (0.157)
FCI Improvement	-0.151 (0.162)	0.121 (0.034)	0.152 (0.008)

Because we had access to a measure of the students' general academic performance level (ACT composite), we were able to assess whether students who were poorer academically also tended to use the help sites more. The correlation between general academic ability and use of the third party site was $r = -0.284$, $N = 111$, $p = .002$. The corresponding correlation with Posting on the sanctioned site was $r = .142$, $N = 383$, $p = .005$, and the correlation with Looking was $r = .130$, $N = 383$, $p = .011$. Therefore there is evidence that students who used the third party site more frequently tended to be poorer students and students who used the course site tended (albeit weakly) to be better students. Such a pattern suggests that the results in Table 1 may simply reflect varying levels of academic ability rather than a problem with the web sites.

To examine this issue, partial correlation coefficients between site use and success were computed, partialling out the composite ACT score. The partial correlations are presented in Table 2 and are highly similar to those in Table 1. So even after accounting for varying levels of academic ability (and for the fact that people who were stronger academically tended to use the third-party site less), there is still a negative impact of the site on performance. In addition, there is still a tendency for students who used the course-sanctioned site to do better even after accounting for academic ability, but the relationships are quite weak.

Table 2: Partial Correlation coefficients (and p-values) between the course-work scores and student use of different web sites., partialling out ACT composite scores.

	3rd Party Percent	Post-sanctioned	Look-sanctioned
Homework	.024(804)	.121(018)	-.115(024)
Final Exam	-.327(001)	.126(014)	.098(056)
Midterm Exams	-.314(001)	.116(023)	.111(030)
Quizzes	-.247(.009)	.045(.376)	.023(.654)
FCI Improvement	-.149(.192)	.081(.172)	.115(053)

III. CONCLUSIONS

Perhaps the most important question that these results generate is whether or not an "arms race" is really necessary at all. The results suggest that high-tech cheating is associated with lower levels of

performance across all levels of academic ability. If students are provided with this information (i.e., they are told that use of high-tech cheating has been shown to lower overall course performance), they should be able to decide for themselves whether or not to do their own work.

These results also offer a measure of "peace-of-mind" for instructors who may be concerned that students are artificially inflating their grades by high-tech cheating. Sophisticated design of personalized assignments can make such cheating more time consuming than doing the work properly. We are making progress in designing such questions, albeit at a significant cost in time and effort.[13] However, with inventive students, new methods that allow a large fraction of the students to circumvent doing the assigned work will continue to be developed. It may be, however, that competing with these inventive students, while it provides an intellectual challenge for instructors, may be of limited use.

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