A review of the dissertation:

# Effects of Intelligent Tutoring Systems in Basic Algebra Courses on Subsequent Mathematics Lecture Courses

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## Revisions:

**2016_02_28** Use term COURSE DELIVERY instead of IMPLEMENTATION as the fifth module of theoretical framework for intelligent and adaptive tutoring systems.

## Intelligent and adaptive tutoring systems:

- adapt the learning environment to each student
- guide the student individually through the content
- offer typical advantages of online education such as continuous availability and instant feedback

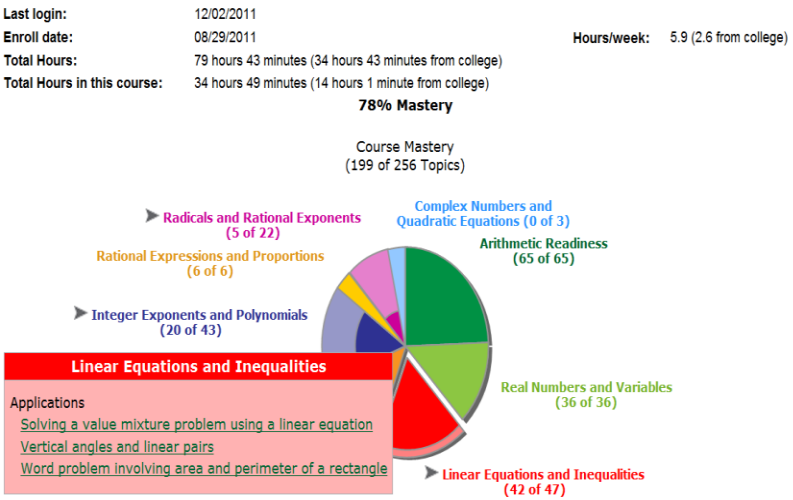
The theoretical framework of intelligent and adaptive tutoring systems consists of up to four modules: **CONTENT, LEARNER, PEDAGOGY**, and **INTERFACE**.

This study proposes the addition of **COURSE DELIVERY module** (formerly called implementation). COURSE DELIVERY includes: a) delivery type (lecture, online, emporium,…), b) course requirements, c) course organization, d) placement test, e) administrative rules, and f) any other external factors that affect how students perceive the course.

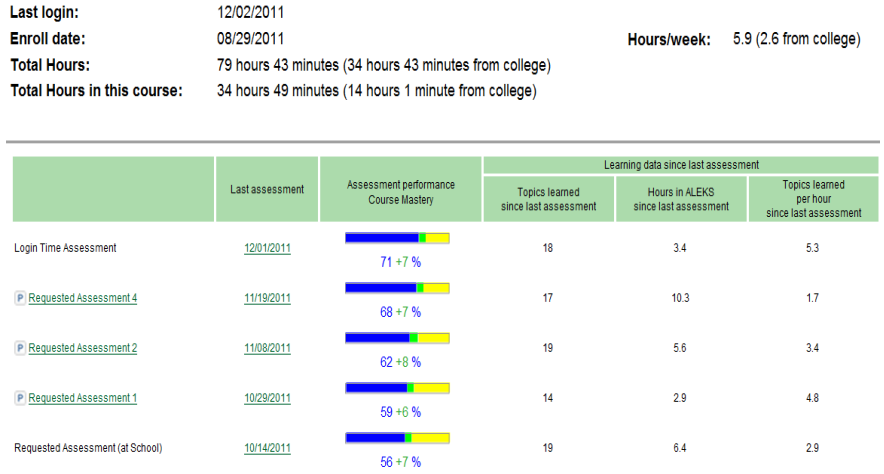
Intelligent tutor investigated in this study was **ALEKS** and it was implemented in **emporium style** in **remedial** Basic Algebra college courses.

# ALEKS Interface and Emporium Organization

## Student's "Pie"




## "Progress Report"




## ALEKS course setup and organization:

- online book, practice problems, assessments and progress reports
- students could work on problems from different categories in any order
- there were no lectures but instructors were available to answer students' questions - this type of course delivery is called **emporium**

## The purpose of this study:

- Investigate effects of intelligent tutor ALEKS implemented in remedial mathematics courses (Basic Algebra I to IV) on subsequent lecture mathematics courses.
- Review the features of intelligent tutor ALEKS from the perspective of intelligent tutors in general.

## The goal was to:

- propose ways to improve ALEKS implementation in remedial courses
- propose ways to improve intelligent tutor ALEKS
- look for possible generalizations about intelligent tutors and their implementations

# The Implementation of ALEKS Described in this Study

- 2011/2012 - ALEKS in emporium style was implemented in Basic Algebra I to IV

- Fall 2012 - The first generation of ALEKS students reached lecture mathematics courses. They are included in the study.

Each lecture course included in the study had:

- former ALEKS students (ALEKS group)

- students that did not take ALEKS courses (non-ALEKS group)

# The Research Themes

- **students' performance** in subsequent lecture courses
  - research questions 1-3
- **students' rating and observations** about ALEKS learning experience
  – research questions 4-8
- **observations of instructors in lecture courses** about students' performance and behavior – research questions 9-11
- **review of ALEKS features and emporium implementation** based on the theoretical framework for intelligent and tutoring systems defined by Camstra (2008) and Vandewaetere, Desmet, and Clarebout (2011).

## Research Questions

1. **SCORES ON FINAL:** Is there a difference between ALEKS and non-ALEKS groups?
2. **SELF-REPORTED-PREPAREDNESS**: Is there a difference between ALEKS and non - ALEKS groups?
3. **SELF-REPORTED-PREPAREDNESS and SCORES ON FINAL**: Is there a correlation for ALEKS students? Is there a correlation for non-ALEKS students?
4. **RATE of ALEKS**: How do former ALEKS students rate their ALEKS learning experience?
5. **RATE of ALEKS and NUMBER OF COURSES TAKEN**: Is there a correlation?
6. Students: **EFFECTIVE**: What do students perceive as effective in ALEKS courses?
7. Students: **INEFFECTIVE**: What do students perceive as ineffective in ALEKS courses?
8. Students: **LEARNING HABITS**: How did ALEKS change students' learning and study habits?
9. Instructors: **DIFFERENCES IN KNOWLEDGE:** Between ALEKS and non-ALEKS students.
10. Instructors: **DIFFERENCES IN EXPECTATIONS:** Between ALEKS and non-ALEKS students.
11. Instructors: **COURSE ADJUSTMENTS**: Were some adjustments necessary in lecture courses because of the former ALEKS students? If so, what and how effective were they?

# Participants

**Students**: 130 students **from four mathematics lecture courses** that follow Basic Algebra courses delivered in ALEKS emporium.

- Median age = 22.98 years, *SD* = 7.393 years
- 29.2% males and 70.8% females

**Instructors**: The four instructors had 10-30 years of teaching experience. They taught these course many times including the previous year.

**Participants**

| Research question | # of participants | Type of participants |
|---|---|---|
| Question 1 | 114 | Students who completed the survey and also a final. |
| Question 2 | 130 | Students who completed the survey. |
| Question 3 | 114 | Students who completed the survey and also a final. |
| Questions 4 to 8 | 47 | Former ALEKS students who completed the survey. |
| Questions 9 to 11 | 4 | Instructors who taught lecture courses. |

# ALEKS and non-ALEKS Group Equivalency

Within each course ALEKS and non-ALEKS groups were compared on:

- gender
- age
- academic standing
- hours of study per week
- number of courses taken
- hours of work per week

No statistical differences have been found between the groups except in one course ("Mathematical Concepts I") on the "number of courses taken". In that case ALEKS students in ALEKS group took on average one course more than students in non-ALEKS group and this was statistically different.

# Instruments and Procedures

**Scores on the final examination:**

Same instructor created tests for both sections of each course.

Each test had a maximum of 100 points and required students to show work.

**Student survey:**

Demographic data and feedback on ALEKS.

The answers to open-ended questions about ALEKS were coded by two coders.

**Interviews with instructors**:

Two interviews: at the beginning and end of semester.

The instructors reviewed and confirmed interview notes.

# Results

1. **SCORES ON FINAL**: Is there a difference between ALEKS and non-ALEKS groups?

   *Scores on final were not statistically different between ALEKS and non-ALEKS groups in each course.*

2. **SELF-REPORTED-PREPAREDNESS:** Is there a difference between ALEKS and non -ALEKS groups?

   *ALEKS and non-ALEKS groups were not statistically different on self-reported-preparedness.*

   *ALEKS group average = 3.77*

   *non-ALEKS group average = 3.83*

3. **SELF-REPORTED-PREPAREDNESS and SCORES ON FINAL:** Is there a correlation for ALEKS students? Is there a correlation for non-ALEKS students?

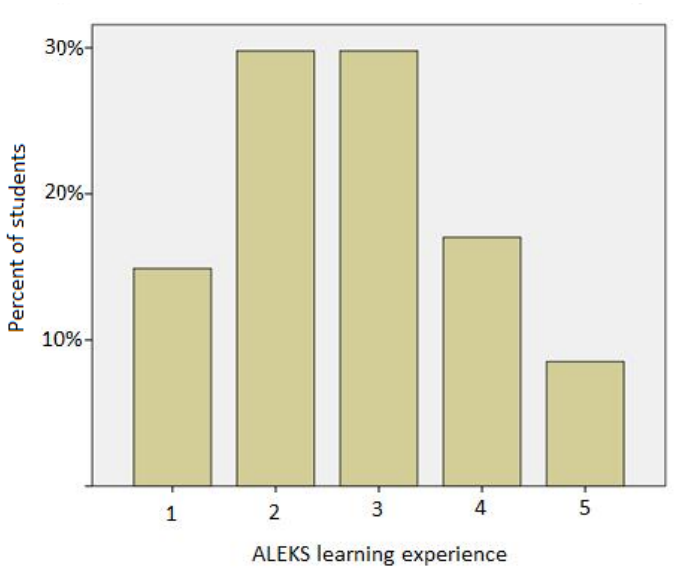
   *The correlation between self-reported-preparedness and scores on final did not exist except in ALEKS group in one course.*

# Results

4. **RATE of ALEKS :** How do former ALEKS students rate their ALEKS learning experience?

   **Mean=2.74** on the scale 1 to 5

   (self-reported-preparedness = 3.77 )




   Gender or age did not affect how students rated ALEKS (no correlation was found).

5. **RATE of ALEKS and NUMBER OF COURSES TAKEN: Is there a correlation**?

   Number of ALEKS courses taken did not affect how students rated ALEKS.

# Results

6. **EFFECTIVE:** What do students perceive as effective in ALEKS courses?

| Theme | % of students | Rate of ALEKS |
|---|---|---|
| Learning at one's own pace | 36% | 3.26 |
| Explanations in ALEKS are good | 32% | 3.33 |
| "Nothing is good" | 23% | 1.55 |

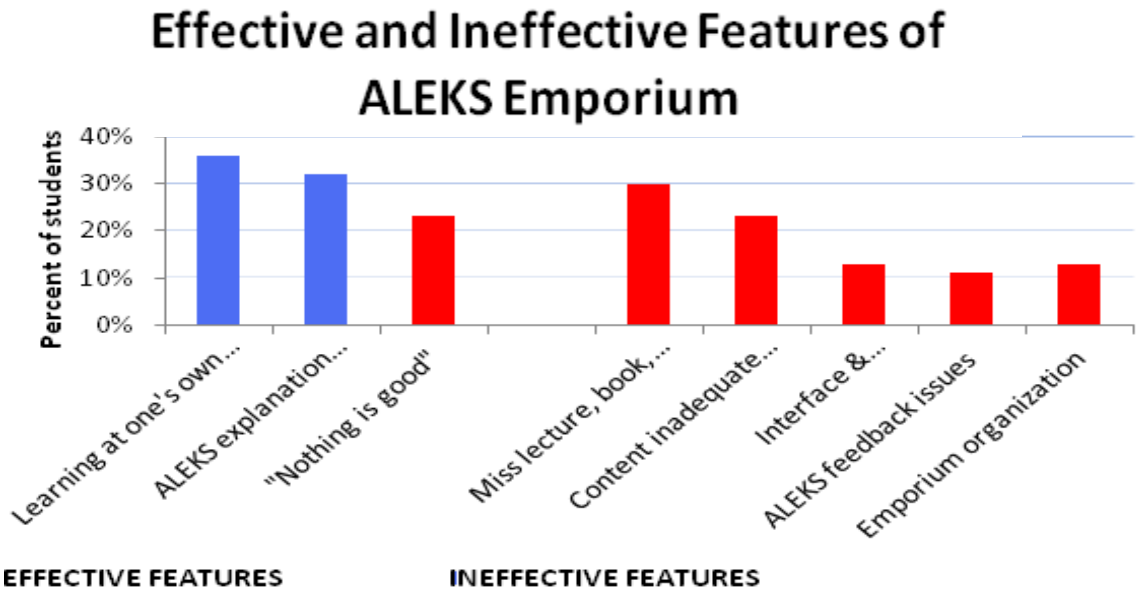
*7.* **INEFFECTIVE:** What do students perceive as ineffective in ALEKS courses?

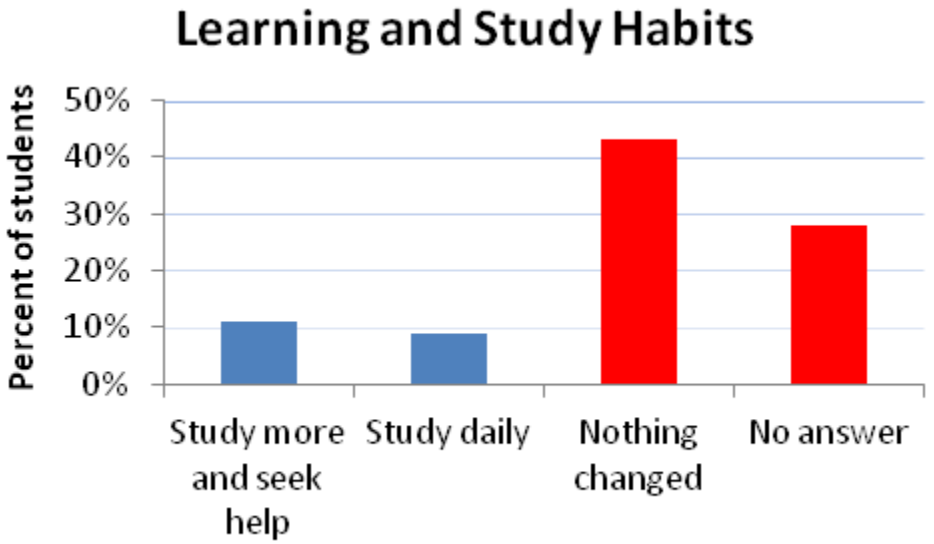
| Theme | % of students | Rate of ALEKS |
|---|---|---|
| Miss lecture, book, and student-teacher relationship | 30% | 2.14 |
| ALEKS content is inadequate, confusing | 23% | 2.91 |
| ALEKS interface and organization is confusing | 13% | 2.67 |
| ALEKS feedback issues | 11% | 2.60 |
| ALEKS emporium organization at school | 13% | 3.50 |

# Results

8. **LEARNING HABITS:** How did ALEKS change student's learning and study habits?

| Theme | % of students | Rate of ALEKS |
|---|---|---|
| Study more and seek help more | 11% | 2.40 |
| Study daily and more organized | 9% | 2.50 |
| Nothing changed | 43% | 3.15 |
| No answer | 28% | 2.31 |


Effective and Ineffective Features of ALEKS Emporium
Percent of students
40%
30%
20%
10%
0%
Learning at one's own...
ALEKS explanation...
"Nothing is good"
Miss lecture, book,...
Content inadequate...
Interface &...
ALEKS feedback issues
Emporium organization
EFFECTIVE FEATURES
INEFFECTIVE FEATURES


Learning and Study Habits
Percent of students
50%
40%
30%
20%
10%
0%
Study more and seek help
Study daily
Nothing changed
No answer

## Results: Instructors' Observations

9. **DIFFERENCES IN KNOWLEDGE:** Between ALEKS and non-ALEKS students.
   - The instructors **did not differentiate** between ALEKS and non-ALEKS students.
   - One instructor observed that students overall appeared somewhat better prepared.
   - One instructor observed that students have problems with signed numbers and fractions and that that represents major hurdle in the lecture course.

# Results: Instructors' Observations

10. **DIFFERENCES IN EXPECTATIONS:** Between ALEKS and non-ALEKS students.

- One instructor observed a positive change in students' readiness to use calculators, in their persistence and confidence but suggested longer observations.
- One instructor observed that the exposure to ALEKS emporium courses was certainly helpful to the lecture course that also had online component.

11. **COURSE ADJUSTMENTS:** Were some adjustments necessary in lecture courses because of the former ALEKS students? If so, what and how effective were they?

No adjustments have been done in any of the courses.

**ALEKS-like tool would be helpful in any course for the drill-and-practice.**

# Limitations:

- The number of lecture courses that had two sections taught by the same instructor was limited.
- Sample size within courses was small.
- Students' population at regional campus may differ from students' population on the main campus or other universities related to demographics and therefore to their readiness to learn online.
- Surveys rely on the accuracy of students' self-reported information.
- Qualitative research is susceptible to the interpretation.

# Discussion

**Positive findings :**

- No statistical difference between ALEKS and non-ALEKS students on scores on final which, reinforced by instructors observation of no-difference between ALEKS and non-ALEKS students, could be considered as positive.
- Self-reported-preparedness for lecture courses was 3.77.

**The results that could be better:**

- Almost one-fourth of students said that "nothing is good" in ALEKS courses.
- The rate of ALEKS learning experience was 2.74.
- Greater number of ALEKS courses taken did not improve students' rating.
- The instructors viewed ALEKS more as a drill-and-practice tool than the environment where students can effectively learn new material.

# Discussion

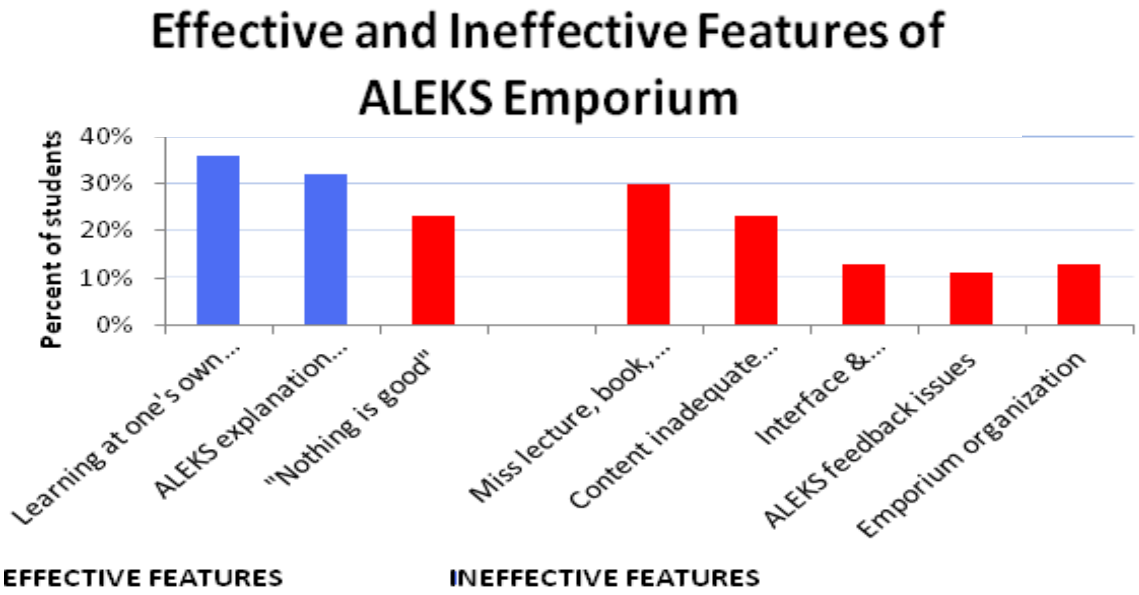
**No adjustment to the new learning environment:**

Although the learning environment changed, not many students adjusted their study and learning habits.

In emporium courses the students should:

- Use all online resources and actively **search for generalizations and deeper meaning** otherwise mathematics is very hard. Generalizations are typically offered and emphasized in lecture courses. In the emporium classes the instructor can help only during, in most cases short, student-instructor interaction.

- Ask for help when they needed it.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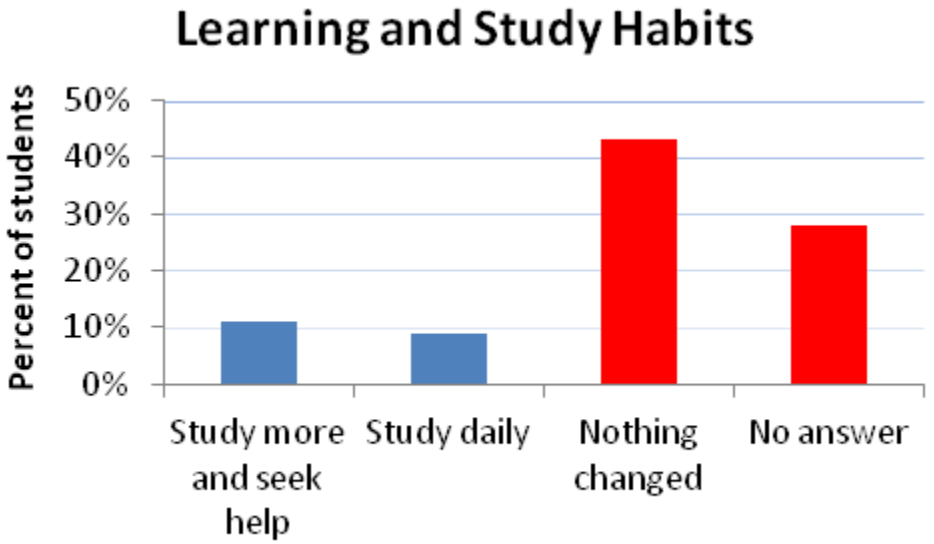
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# Discussion

Student comments will be considered through the intelligent tutor framework that consist of: **CONTENT(Expert), LEARNER, PEDAGOGY and INTERFACE modules**.

**COURSE DELIVERY module** was added to the framework to cover course type, course requirements and organizations, placement test, administrative rules, and any other external factors that affect how students perceive the course.

| ALEKS emporium features brought up by students | Proposed actions | Map to framework features |
|---|---|---|
| Missed lecture, book, and student-teacher relationship. | • Add assessments that will require instructor's feedback.<br>• Provide printed book. | Meaningful student-teacher relationship. |
| ALEKS content has inadequate/incomplete explanations and is confusing. | Add assessments that will require reading the book. | The book and practice problems are fully integrated. |
| ALEKS interface and organization is confusing and difficult. | Replace student's "pie" with a bar graph (the "pie" did not sufficiently convey the structured nature of the content). | The learner is guided through the structured material in a structured manner. |

| ALEKS emporium features brought up by students | Proposed actions | Map to framework features |
|---|---|---|
| ALEKS feedback: not explaining student's mistakes, no hints and tips | Add assignments that will include hints and tips or interpret student mistakes. | Feedback using hints and tips, or based on the analysis of student mistakes. |
| ALEKS organization: not forgiving for typos, not able to revisit problems on test. | • Allow students to revisit problems on tests and to review graded assignments.<br>• Recognize typos. | Interface technical issues.<br>The recognition of student typos. |
| EMPORIUM – too many students per instructor, to many hours in ALEKS required, only final score determines the grade. | Emporium organizational changes. | Implementation - consider student feedback for possible course organizational changes. |

| Framework models | Features of ALEKS emporium brought up by the students and some of the more important supported features brought up by the researcher | |
|---|---|---|
| Content/Expert module | Supported | Content is of high quality and well organized. |
| | Supported | Capable of guiding a student based on students' current knowledge. |
| | | |
| Learner module | Supported | Learner knowledge and past performance are tracked in the model. |
| | | |
| Rules/Engine (Instructional or pedagogical module) | **Partial** | **The book and practice problems are fully integrated.** |
| | Not Supported | The learner is guided through the structured material in a structured manner. |
| | Supported | Instant feedback is available as step-by-step solutions on practice and summative feedback on assessments. |
| | Not Supported | Feedback using hints and tips, or based on the analysis of student mistakes. |
| | **Partial** | **The recognition of student typos.** |
| | Supported | The support of online communication and data sharing. |
| | | |
| Interface module | Supported | Supports learning at one's own pace. |
| | **Partial** | **Interface technical issues (examples: revisit problems on tests, review graded assignments).** |
| | | |
| Course Delivery module | **Partial** | **Meaningful student-teacher relationship.Consider student feedback for possible course organization changes (number of students per instructor, base final grade on multiple evaluations, consider other course requirements).** |

# Discussion: Study and Learning Habits

**The majority of students did not report change in study and learning habits.**

Teaching students how to study online can be addressed:

- in ALEKS through the assignments such as making notes or concept maps after reading some course material

- through  the lecture or hybrid course organization of ALEKS courses

Systematic instructional design may be used to map ALEKS features to instructional strategies and uncover potential problems ahead of the implementation.

# Future Research

## Evaluate Proposed Changes in ALEKS Emporium

- Add assignments that require instructors' feedback to strengthen student-teacher relationship.
- Conduct a longitudinal study on trends in students' use of online resources and satisfaction with courses.
- Investigate the effect of ALEKS emporium on students' beliefs about the benefits of repeated practice.
- Compare the results of this study with the results of similar studies related to intelligent tutors. Generalizations could help future development of intelligent tutors.

# Future Research

## Evaluate Proposed Changes in ALEKS Design

- Add problems that require reading the book and measure the use of online book and effect on final grade.
- Change the "pie" with the bar-graph and evaluate if this reduces the amount of student switching between problem categories and improves exam scores.
- Provide a closely integrated printed book and/or videos and evaluate the effect on final scores.
- Explain grading policies within "Progress Reports" so that students can review them as they view test results.

# Future Research

## Evaluate Proposed Changes in Course Organization

- Ensure that students pass the mastery test on the category level before they move to the new category (reduce the effect of the "pie").

- Re-introduce lectures or hybrid courses to support students that prefer lectures and also with the goal to teach students how to study online.

Proposed changes need to be evaluated through the systematic instructional design along with all other course features and then most promising ones should be tested.

Large implementations may benefit from the cooperation and expertise of several departments.

# Conclusions

- Intelligent tutors have great potential and ALEKS emporium produced satisfactory results in student achievement.
- Following changes may improve student satisfaction and learning:
  - the design should reflect the pedagogy (the "pie" implies no structure)
  - close integration of all course resources
  - provide variety of assignments and feedback
  - make student-teacher relationship more meaningful
  - teach students how to learn online
- Continuous evaluation of intelligent tutor implementations is justified and needed.
- Large implementations may require the expertise of different departments.
- Framework of adaptive software should include the implementation model.

# Conclusions Grouped by Goals of the Study

- propose ways to improve the existing ALEKS implementation:
  - integrate all course resources closely
  - provide greater variety of assignments and feedback
  - increase the role of instructors
  - teach students how to learn online
- propose ways to improve intelligent tutor ALEKS **and** look for possible generalizations about intelligent tutors:
  - the design should reflect the pedagogy (the "pie" implies no structure)
  - integrate all course resources closely
  - provide a variety of assignments and feedback
  - add implementation model to the framework of adaptive software
  - (**make student-teacher relationship more meaningful**)
  - (**teach students how to learn online**)

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