QuizBot: A Dialogue-based Adaptive Learning System for Factual Knowledge

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Factual knowledge sometimes needs to be learned outside of a classroom setting
However, current electronic tools (flashcards) are passive and boring
We want to provide better automated ways to help students learn factual knowledge.
Chatbots are a promising solution for casual learning

- NLP grading algorithms are becoming sophisticated
- Having people interact can promote stronger learning than recall alone (Chi & Wylie 2014)
- Conversational UIs might be more interactive and engaging than flashcards
Chatbots are mostly used as formal study tools

- Auto Tutor for computer literacy and physics (Graesser et al. 2004)
- Ms. Lindquist for high school algebra (Heffernan & Koedinger 2002)
- Piagetbot for college psychology (Heller & Procter 2007)

![Interface of AutoTutor](image-url)
System Design and Implementation
QuizBot: conversational fact tutor
Key components of QuizBot

- Interactive chat interface
- Animated avatar with positive feedback
- NLP targeted feedback for typed answers (Arora et al. 2017)
- Ability to ask for hints/explanations
- Adaptive question sequencing algorithm (Lindsey & Mozer 2016)
- A mix of typing and button-based interactions
QuizBot teaches vocabulary, science, and safety
Evaluated QuizBot against a custom flashcard app
Key components of the flashcard app

- Tap-to-flip interface inspired by Quizlet
- Ability to toggle hints/explanations
- Same adaptive question sequencing algorithm
- Same factual question pool
User Study
Research questions

• How engaging is QuizBot to learners in comparison to flashcards?
• How effective is QuizBot with helping learners per number of practice items compared with flashcards?
• Given voluntary usage, which system is more effective?
Study procedure

- The question pool of each app contained 48 questions, 16 for each subject
- Pre-test contained 96 multiple-choice questions from two question pools
- Users used both apps for 5 days under study specifications
- Post-tests only contained questions answered incorrectly in the pre-test. A fill-in-the-blank post-test was followed by a multiple-choice post-test
Study procedure

- **Recall accuracy:**
  \[ \text{percentage of questions correctly answered on the fill-in-the-blank post-test} \]

- **Recognition accuracy:**
  \[ \text{percentage of questions correctly answered on the multiple choice post-test} \]
Two within-subject studies

Study 1
Fix number of questions practiced
Effectiveness

Study 2
Use both apps voluntarily
Engagement
Study 1: fix number of questions practiced

- **40** university students and alumni from **11** different universities
- Users were required to practice **20** questions within each app in the **first four** days, and **16** questions in the **fifth** day
- Every question was practiced by every user exactly **twice**
- Each app sequenced **48** questions using the **same** algorithm
QuizBot more effective when usage was fixed

Given a fixed number of items practiced, with QuizBot people

- **recalled** over 20% more correct answers
- **recognized** over 20% more correct answers

The bottom and top of the box are the 25th and 75th percentile.
QuizBot learning improvement persisted over time

Recognition accuracy of study 1 users over time

Error bars represent +/- 1 standard error
Study 2: use both apps voluntarily

• 36 university students and alumni from 8 different universities
• Users were asked to use both apps for 5 days of their own volition
QuizBot more engaging

People spent 2.6x more time with QuizBot than with the flashcard app of their own volition.

The bottom and top of the box are the 25th and 75th percentile.
QuizBot more effective when usage was voluntary

Given voluntary usage time, with Quizbot people

- **recalled** over 12% more correct answers
- **recognized** a similar amount of correct answers

The bottom and top of the box are the 25th and 75th percentile
Participants self-reported QuizBot to be more engaging & more effective.

Fun and effective results are statistically significant in both studies.
Participants prefer QuizBot for casual learning

Study 1: User Preference

From left to right: which app users like better (Like) / prefer to use for casual learning (Casual) / for short-answer exams (SA) / for multiple-choice exams (MC)

Study 2: User Preference

From left to right: which app users like better (Like) / prefer to use for casual learning (Casual) / for short-answer exams (SA) / for multiple-choice exams (MC)
Positive qualitative responses

• On communication and interactivity
  “I could actually answer and type it out rather than just looking at flashcards.”

• On engagement and feedback
  “QuizBot was more interactive and engaging. The feedback (positive or negative) was also motivating.”
Positive qualitative responses

• On conversations
  “The penguin had a lot of personality, and I enjoyed trying to trick the chatbot.”

• On context of use
  “It is something that I would definitely use if available and can easily be used during a bus ride etc.”
Suggestions for improvement

• On speed

“I can go over questions and answers very fast. Sometimes I have to wait for QuizBot to respond.”
Directions for Future Work
QuizBot is inefficient compared to flashcards

- Support speech in addition to keyboard based conversations (Ruan et al. 2018)
- Consider a flashcard system where learners have to type in the answer
Understand long term usage behaviors and attitudes

Average usage time of study 2 users from day 1 to day 5

Error bars represent +/- 1 standard error
Parse and understand user input better

- Randomly selected 11,000 (out of 43,956) consecutive conversational logs
  - contained 1052 questions and 144 questions were answered via typing
  - 139 questions were correctly graded by our algorithm (96.5% accuracy)
    - 1 was because the system could not handle a typo
    - 3 were because our algorithm penalized short answers and users tended to type terse answers
    - 1 was because the system was not perfect at understanding phrases
- Leverage richer natural-language input from learners to provide feedback of a higher granularity (Kolchinski et al. 2018)
Conclusion

• Designed and built the first chat-based learning system for factual knowledge memorization outside of classroom settings
• Evaluated its effectiveness and engagement through rigorous comparison studies with a traditional learning tool
• Offered design suggestions for building improved future educational chatbot systems
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Educational chatbots are beneficial, particularly for learning outside of traditional settings

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