Assessing the impact of hints in learning formal specification

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Learning Programming

- Programming tutoring systems have long employed automated hints \bullet
- \bullet

0 0 0						+	one_to_n - for-loop,range,accu	
0	Ask-Elle				X		Concepts: for-loop,range,accumulator,strings Given a number n, return a string that contain numbers from 1 to n. (So 5 results in "12345" Author: Kelly Rivers	
All Exercises	Description	8	He	lp		20	License: Creative Commons Attribution-Sha	
Asskell Asskell Asskell Asskell Asskell Sourcess Sourcess	Write a function that converts a list of bits to the corresponding is value: fromBin :: [Int] -> Int. For example: > fromBin [1,0,1,0,1,0] 42 > fromBin [1,0,1] 5	corresponding integer	Im	You can follow one of the following strategies plement fromBin using the fold Prelude function. Explanation Multiply n by two and add b.	rategles:		5.0	
				Hint Introduce the integer 2. More Help Tediate the second to be a	8		Error: Cannot test submission: no Test results Compiler errors Feedback	
	1 fromBin = ? where 3 op n b = ? * ? * ?			frombin = ? where op n b = 2 * 7 * 7	_	•	TEST FEEDBACK: 1.0/4.0 Failed assertion: given input (5), expected ou Failed assertion: given input (1), expected ou Failed assertion: given input (10), expected o Test passed on input (0), expected output "	
E range E removeat E repli E rotate	12 13 14 15 16 17						HINT: At line 3, column 22 change n to (n + '~right v If you need more help, ask for feedback again	

Ask-Elle, Haskell



Many user studies on learning impact, conclusions depend on language or type of hints





iSnap, Snap!

Learning Specification

- Platforms for learning to write formal specifications still incipient
- Being backed by solvers, counter-examples \bullet are the natural kind of feedback
- No studies on whether they (or other hints) have a positive impact on learning





Alloy4Fun, Alloy

• Consider the domain model:



• Fix the following incorrect specification for:

Every image is posted by one user

Fix the following incorrect specification: all p : Photo | lone posts.p

No additional feedback

• Consider the domain model:



• Fix the following incorrect specification for:

Every image is posted by one user

The example below is allowed by the following incorrect specification but should be forbidden: all p : Photo | lone posts.p



Counter-example



• Consider the domain model:



• Fix the following incorrect specification for:

Every image is posted by one user

Change the highlighted operator in the following incorrect specification: all p : Photo | lone posts.p

Highlight location

• Consider the domain model:



• Fix the following incorrect specification for:

Every image is posted by one user

The following specification incorrectly states that every photo is posted by at most one user: all p : Photo | lone posts.p

Error description

Research Questions

- What is the impact of different kinds of hints when learning formal specification on:
 - Immediate performance
 - Longterm performance
 - Emotional response

User Study Design

- 1st session to learn with hints \bullet
 - 4 hint groups ullet
 - Curated hints, hardcoded but automatizable
- 2nd to assess retention
 - No hints ullet
- 12 tasks lacksquare
 - Only basic set and relational operators \bullet
 - Cover different kinds of mistakes
- Measured emotional response



User Study Application

- 85 undergraduates majoring in CSE
- 3rd year, typical CSE background
 - Discrete math, logic, algorithmics (pre-/ post-conditions), minimal UML+OCL
 - No background on Alloy
- All resources and collected data available for replication

zenodo.org/records/10579475



1 Sig User {
2 follows : set User,
3 sees : set Photo,
4 posts : set Photo,
5 }
6
7 sig Influencer extends User {}
8
9 sig Photo {
10 date : one Day
11 }
12 sig Ad extends Photo {}
13
14 sig Day {}
15
16 /** Every image is posted by one user. **/
17 pred spec {
18 all p : Photo | lone posts.p
19 }





Change the highlighted operator in the following incorrect specification: all p : Photo | lone posts.p









Instrumentation in Alloy4Fun

Data Analysis

- Immediate performance:
 - Only error locations had significant positive impact
- Learning retention:
 - No significant difference between provided hints
- Emotional response:
 - When learning, error locations best response, error descriptions worst response
 - In future tasks, no significant difference between groups

• With error locations students acquire the same knowledge more efficiently, no indication of brute force

"the system's provided help that greatly assisted in quickly completing the tasks"

"the tips were essential to solve the problem, and without them, the solution would have been quite complicated"

Open-ended feedback

- With error locations students acquire the same knowledge more efficiently, no indication of brute force
- Counter-examples and error descriptions possibly cause cognitive overload and ignored, maybe not suitable for novices

"the system's provided help that greatly assisted in quickly completing the tasks"

"the tips were essential to solve the problem, and without them, the solution would have been quite complicated"

"needs to be more explicit"

"information is not specific enough"

"At first, I didn't find it very clear, but over time, with practice, I understood it better"

Open-ended feedback

- With error locations students acquire the same knowledge more efficiently, no indication of brute force
- Counter-examples and error descriptions possibly cause cognitive overload and ignored, maybe not suitable for novices
- Despite varied emotional response to hints when learning, no lasting impact, even considering withdrawal

"the system's provided help that greatly assisted in quickly completing the tasks"

"the tips were essential to solve the problem, and without them, the solution would have been quite complicated"

"needs to be more explicit"

"information is not specific enough"

"At first, I didn't find it very clear, but over time, with practice, I understood it better"

"I feel that this week I learned more than last week, which makes me feel less frustrated"

Open-ended feedback

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