Assessing the impact of hints in learning formal specification

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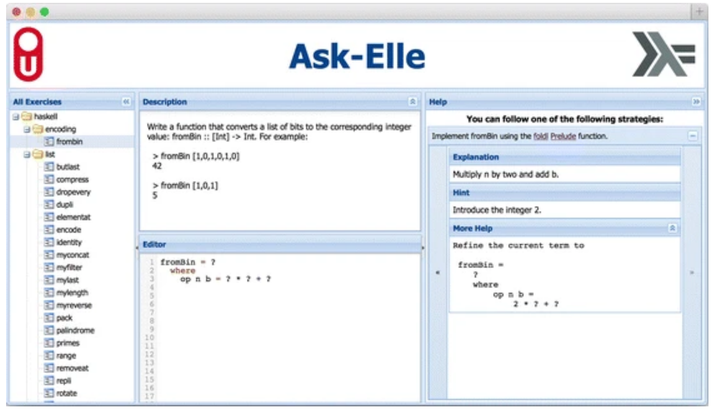
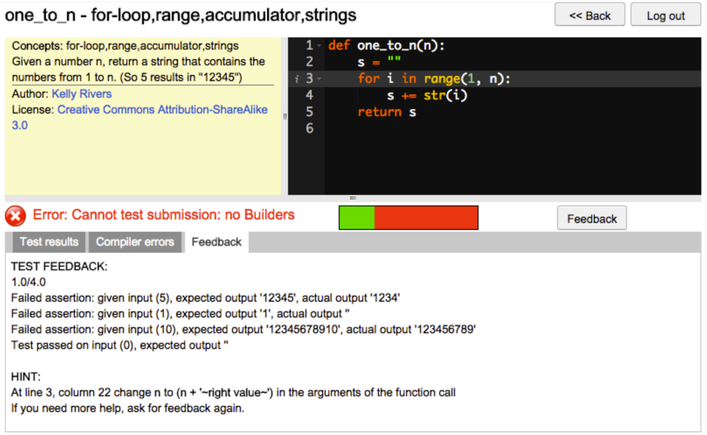
SEET@ICSE, April 2024

Learning Programming

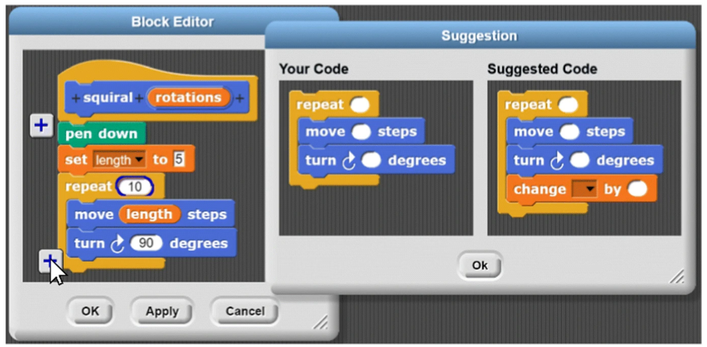
- Programming tutoring systems have long employed **automated hints**
- Many user studies on learning impact, conclusions depend on **language** or **type of hints**



Ask-Elle, Haskell



ITAP@CodeWebs, Python

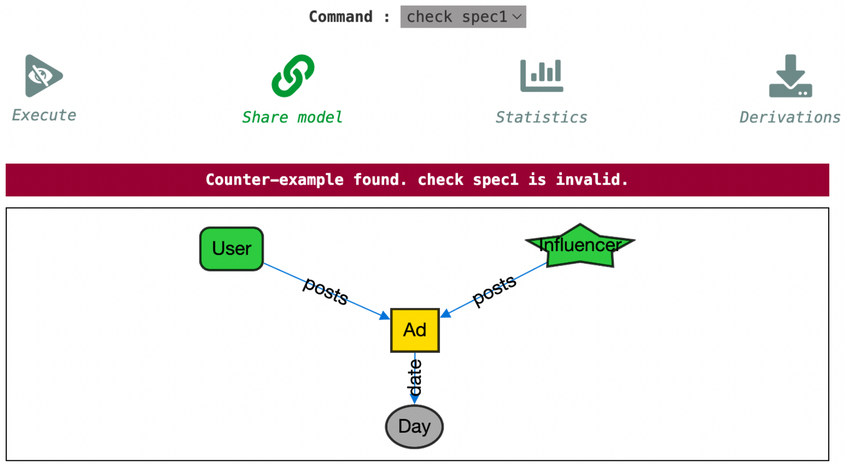


iSnap, Snap!

Learning Specification

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

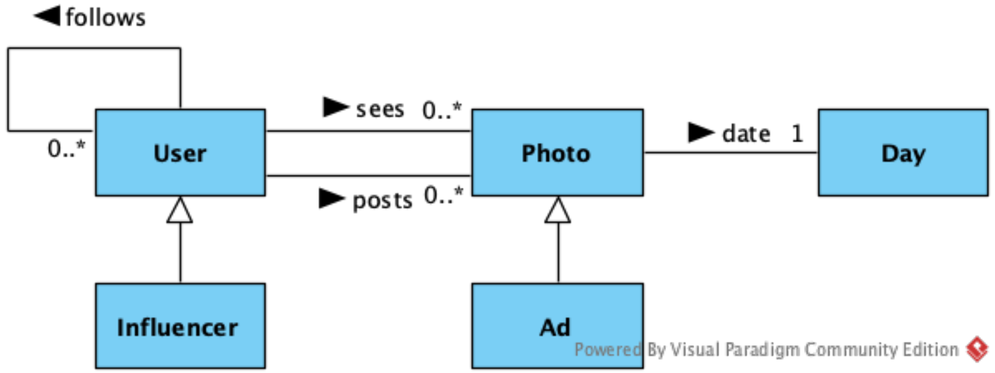
```
sig User {
   follows : set User,
   posts   : set Photo
}
sig Influencer extends User {}
sig Photo {
   date    : one Day
}
sig Ad extends Photo {}
sig Day {}

/* Every photo is posted by one user. */
pred spec1 {
  all p:Photo | some u:User | u->p in posts
}
/* Influencers are followed by everyone else. */
pred spec2 {

}
```



Alloy4Fun, Alloy

Feedback for Specification Challenges

- Consider the domain model:



- Fix the following incorrect specification for:

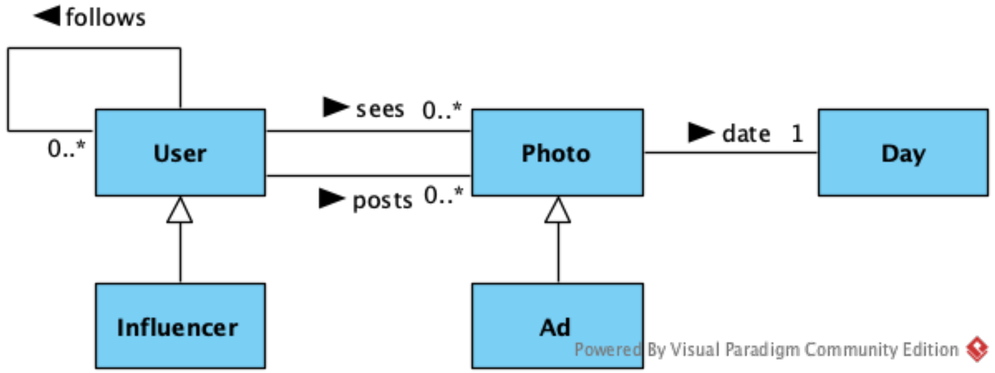
Every image is posted by one user

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

No additional feedback

Feedback for Specification Challenges

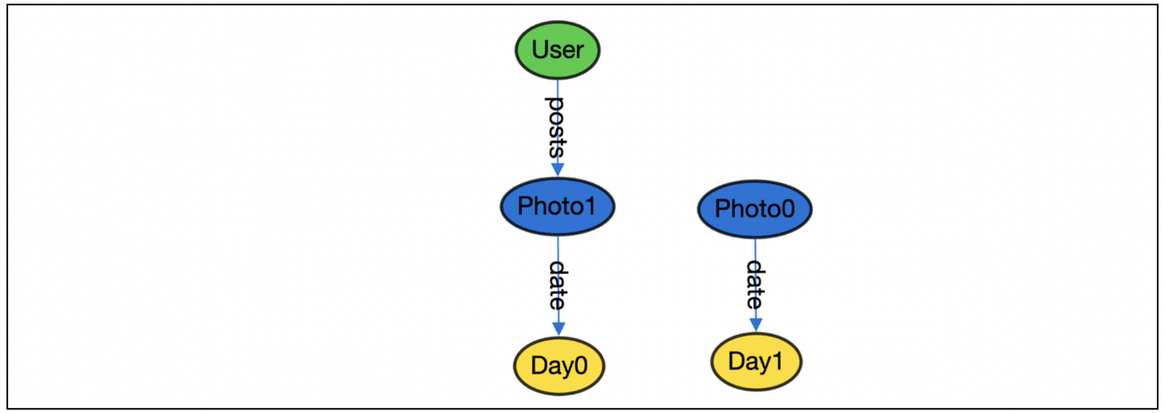
- Consider the domain model:



- Fix the following incorrect specification for:

Every image is posted by one user

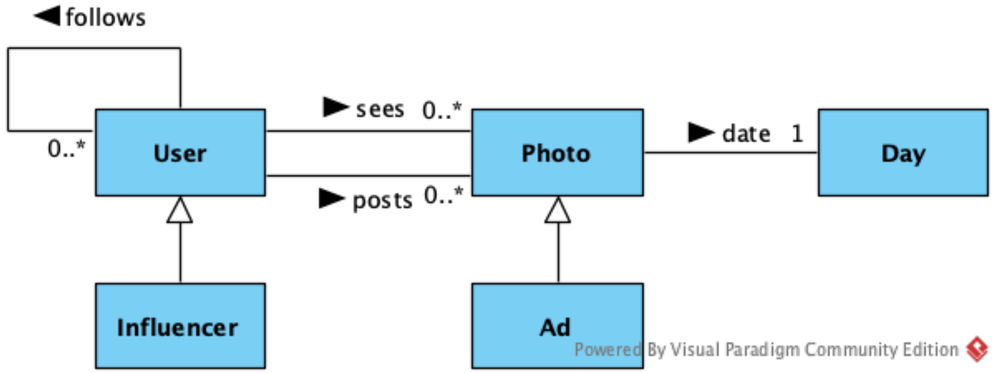
```
The example below is allowed by the following incorrect
specification but should be forbidden:
all p : Photo | lone posts.p
```



Counter-example

Feedback for Specification Challenges

- Consider the domain model:




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

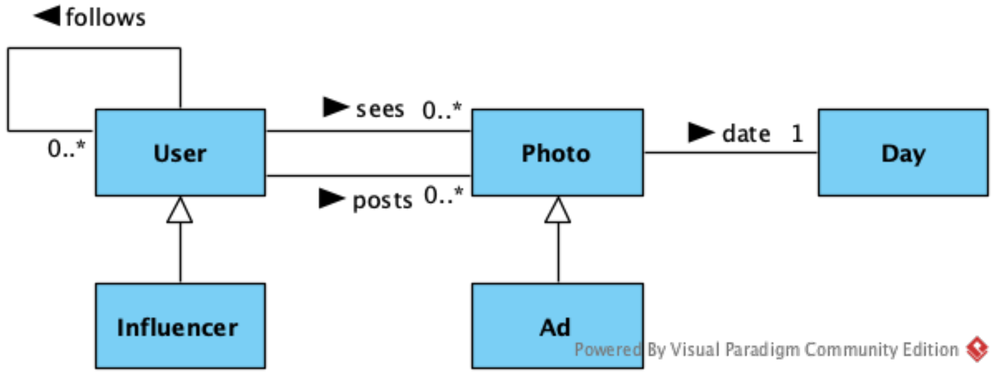
- Fix the following incorrect specification for:

Every image is posted by one user

Highlight location

Feedback for Specification Challenges

- Consider the domain model:




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

- Fix the following incorrect specification for:

Every image is posted by one user

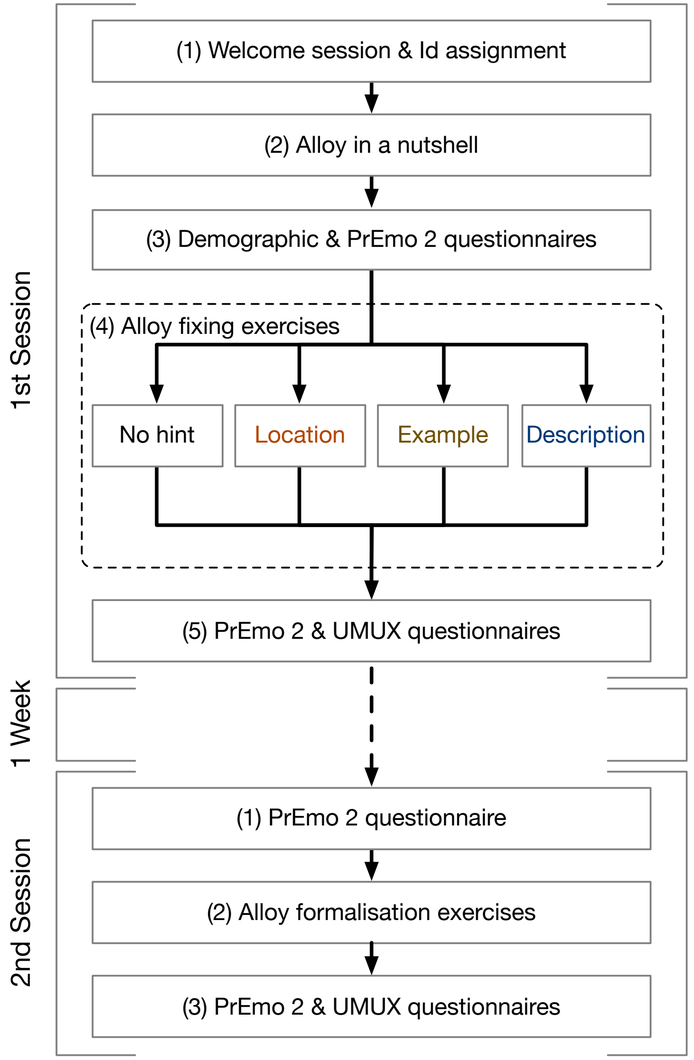
Error description

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
  - 4 hint groups
  - Curated hints, hardcoded but automatizable
- 2nd to assess retention
  - No hints
- 12 tasks
  - Only basic set and relational operators
  - 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

```
sig User {
    follows : set User,
    sees : set Photo,
    posts : set Photo,
}

sig Influencer extends User {}

sig Photo {
    date : one Day
}
sig Ad extends Photo {}

sig Day {}

/** Every image is posted by one user. **/
pred spec {
    all p : Photo | lone posts.p
}
```

Test specification *Next Challenge*

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

Discussion

Discussion

- 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

Discussion

- 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

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“information is not specific enough”

“At first, I didn’t find it very clear, but over time, with practice, I understood it better”

- Despite varied emotional response to hints when learning, no lasting impact, even considering withdrawal

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

Open-ended feedback

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This work is financed by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project EXPL/CCI-COM/1637/2021.

SpecRep, https://haslab.github.io/SpecRep/