Graph-Based Modelling of Students' Interaction Data from Exploratory Learning Environments

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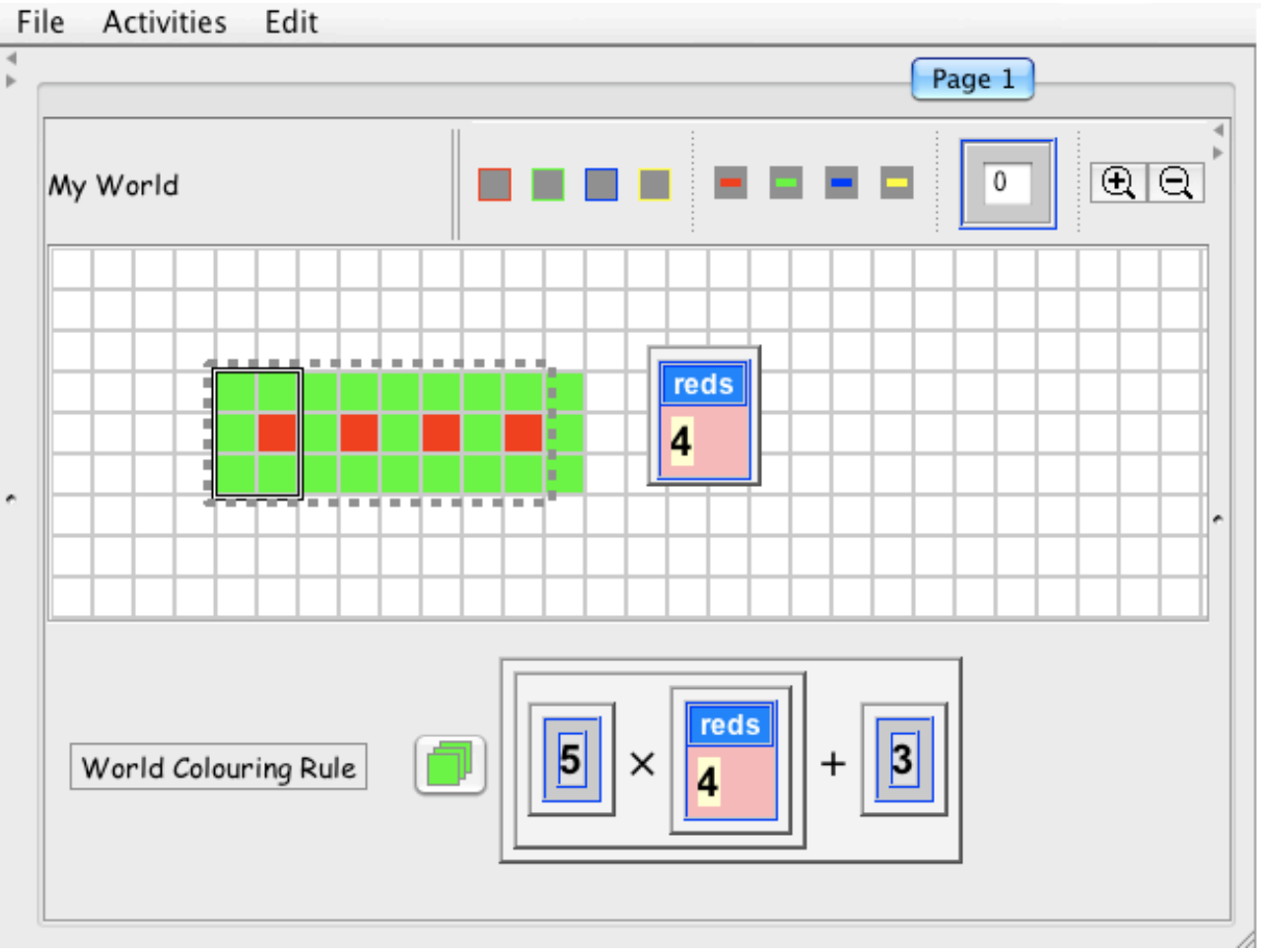
The Problem

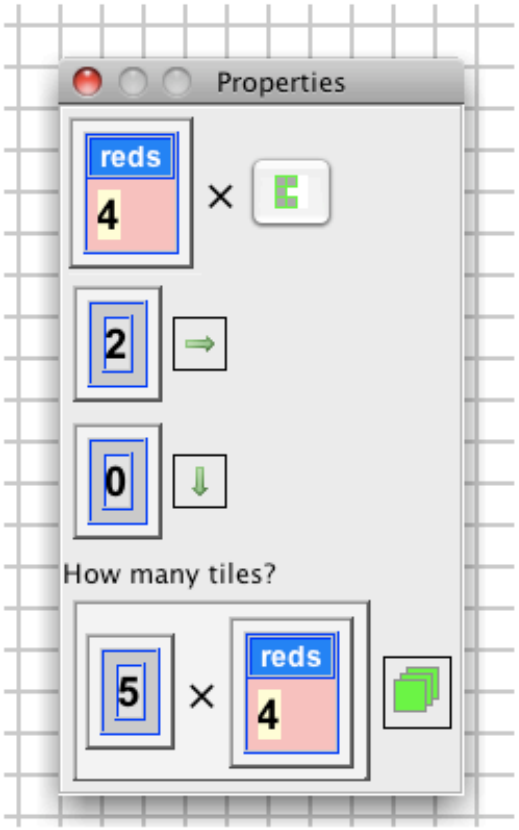
- Much research focuses on interactive educational applications that encourage students' open-ended experimentation within a knowledge domain
- For students to benefit from interaction with such ***Exploratory Learning Environments*** (ELEs) there is a need for explicit pedagogical support to be provided
- Has led to research in intelligent techniques for providing ***personalised***, ***adaptive support*** to students, to foster their productive interaction with ELEs
- Data gathered from students' interactions in ELEs has the potential to help pedagogical experts understand how students are interacting with the system, and technical experts to develop enhanced intelligent support features

The Problem

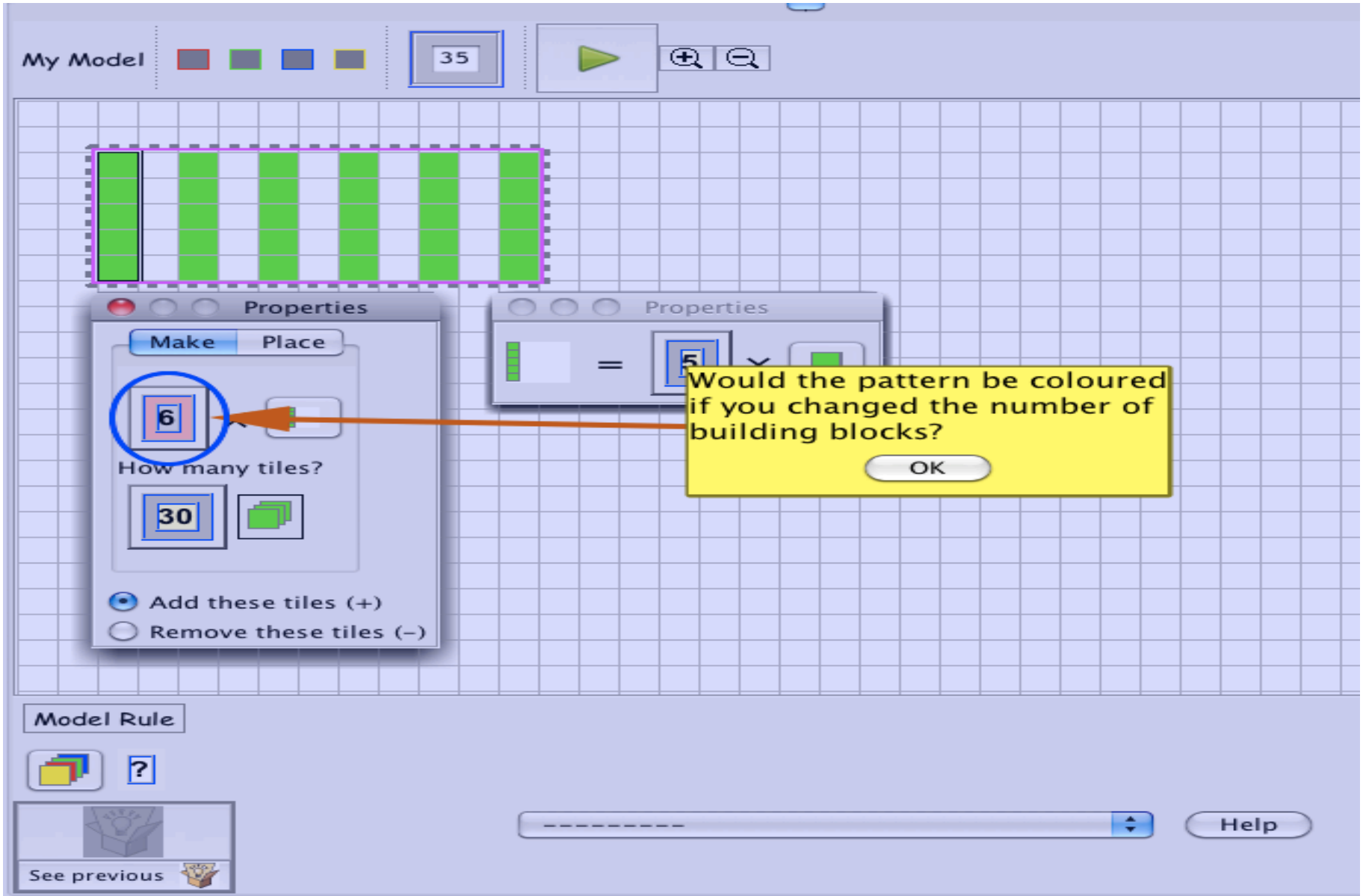
- However, log files from ELEs can contain large quantities of data, making their interpretation difficult and costly
- Also, it is not possible to always know in advance what data are relevant for analytical purposes, therefore an exploratory analysis of the data gathered may be needed
- In this paper we consider how modelling student-system interaction data as a graph makes possible graph-based queries and analyses that can provide insights into the ways that students are using the affordances of the ELE, and the effects of system interventions on students' behaviour
- Our ultimate aim is to feed back this understanding into improving the design of the ELE and its intelligent support
- Two case studies: eXpresser and FractionsLab

eXpresser microworld

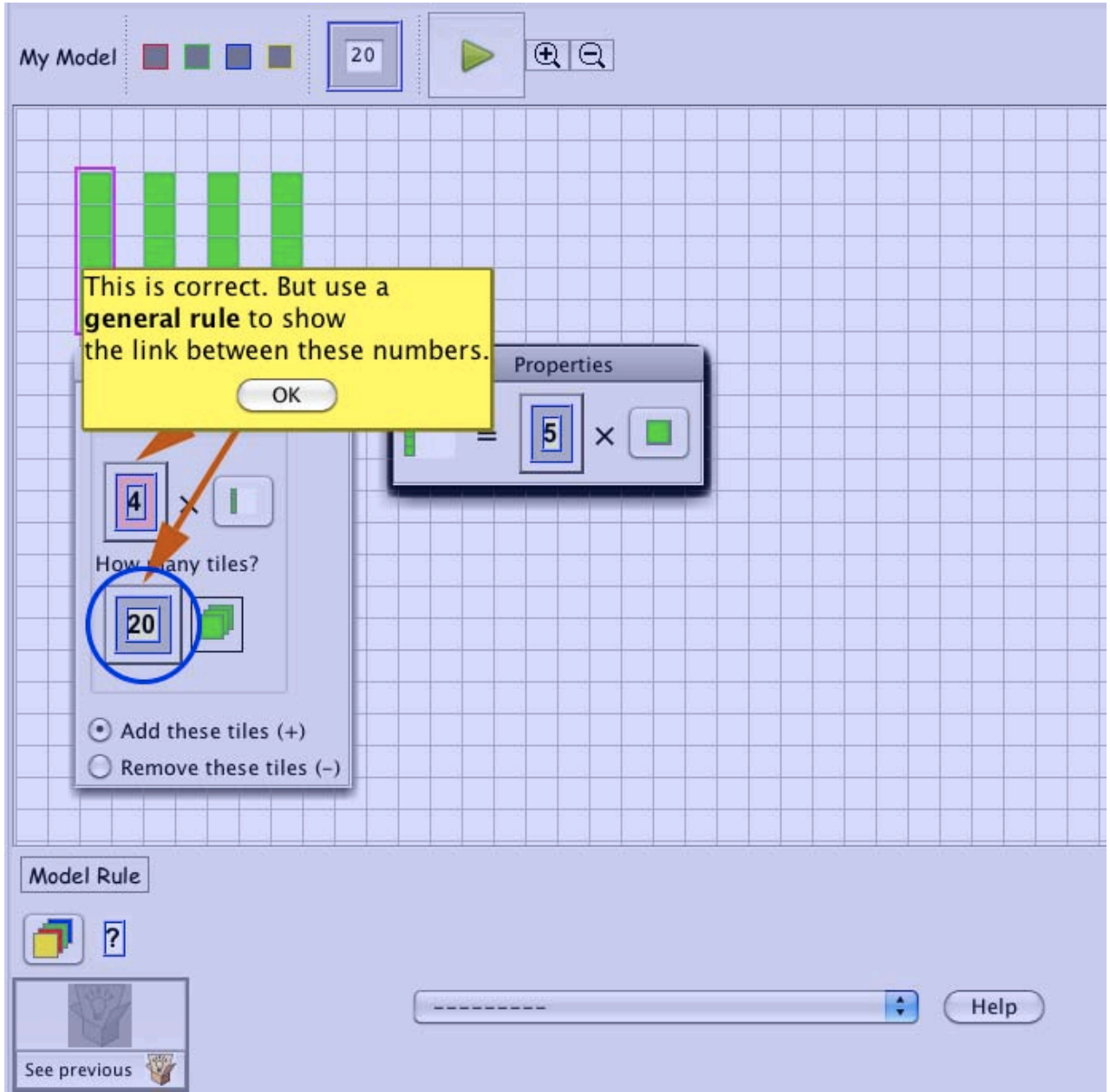




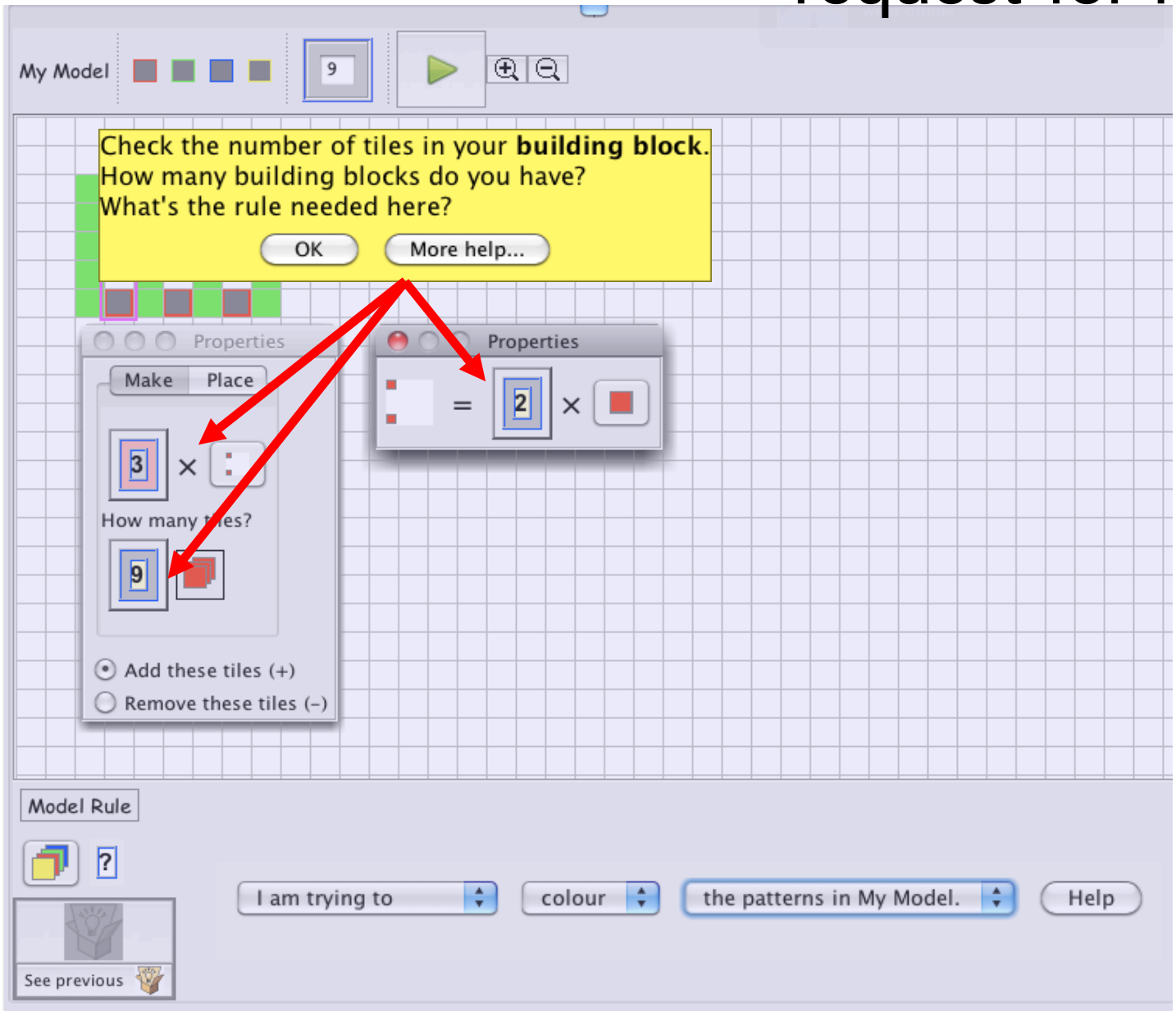
student feedback: a nudge...



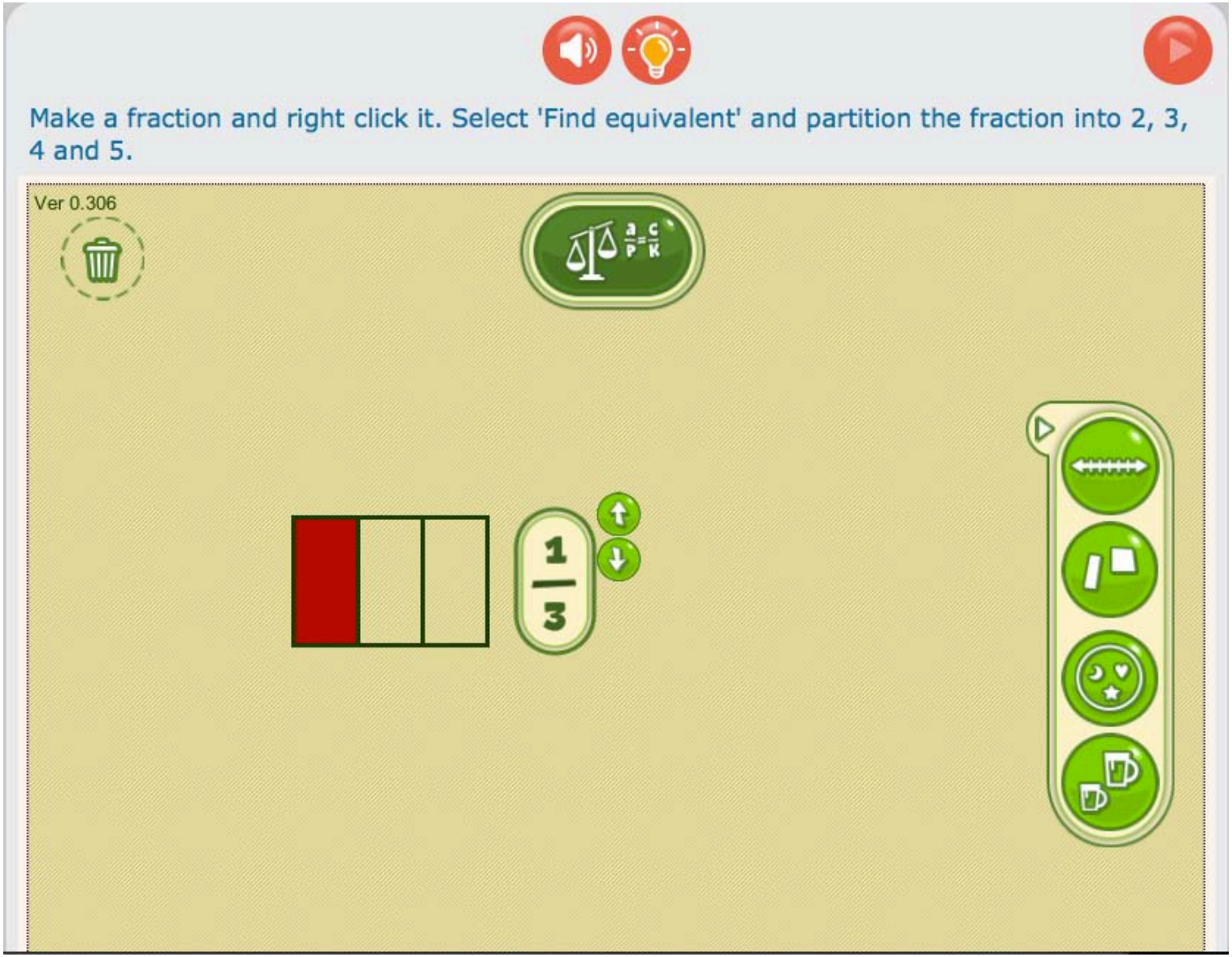
an unsolicited prompt...



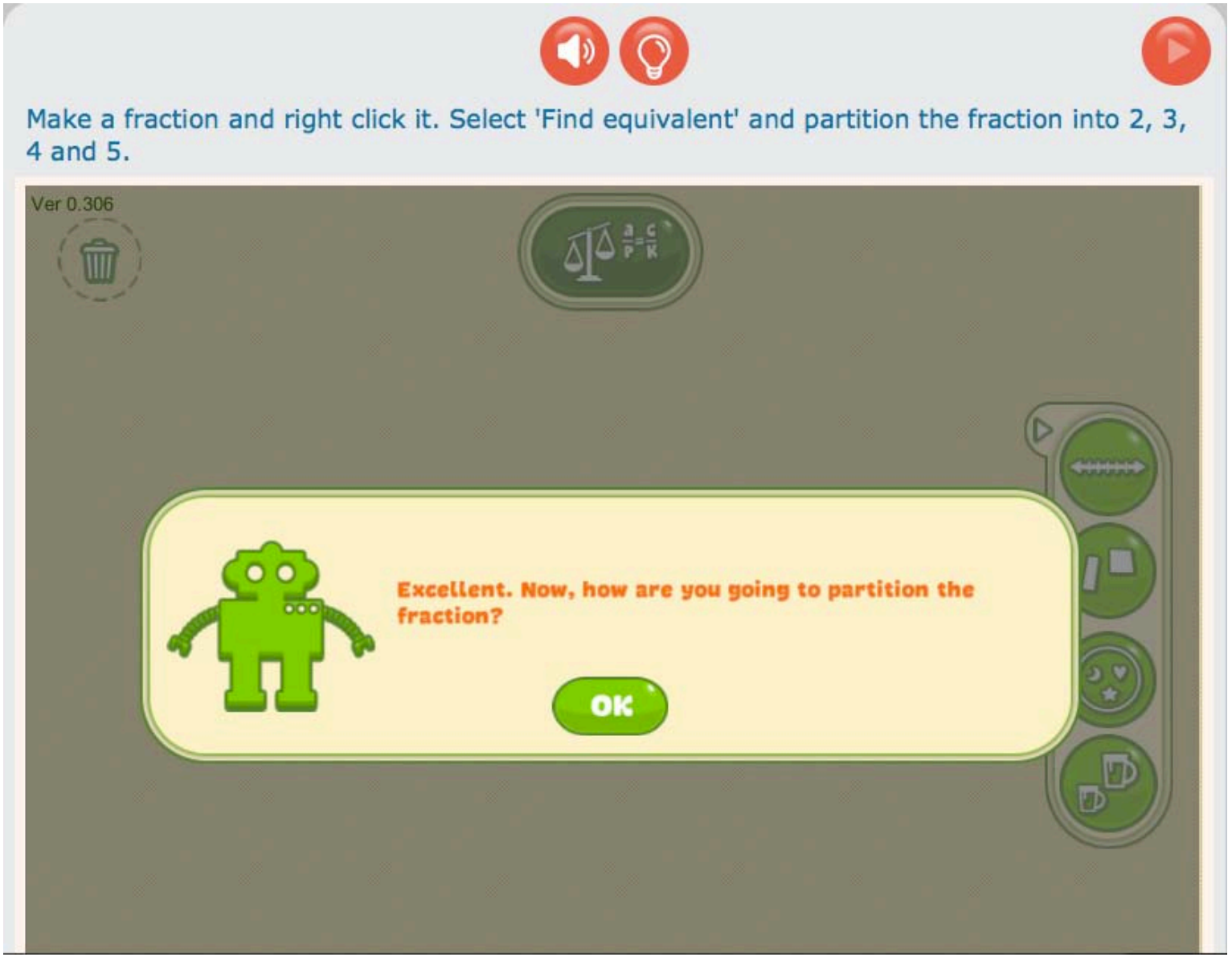
feedback after a student's explicit request for help...



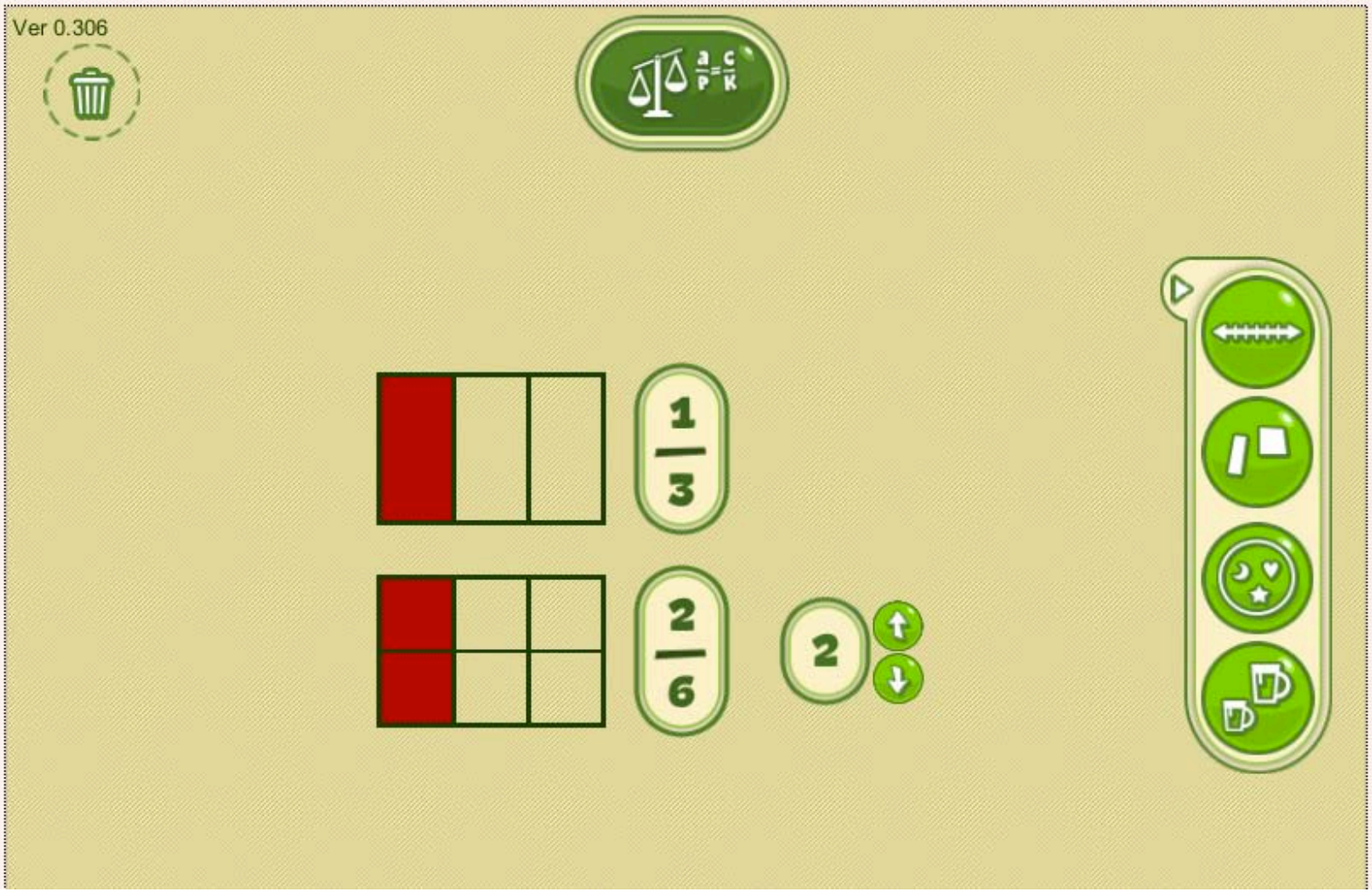
FractionsLab microworld



Low-interruption feedback



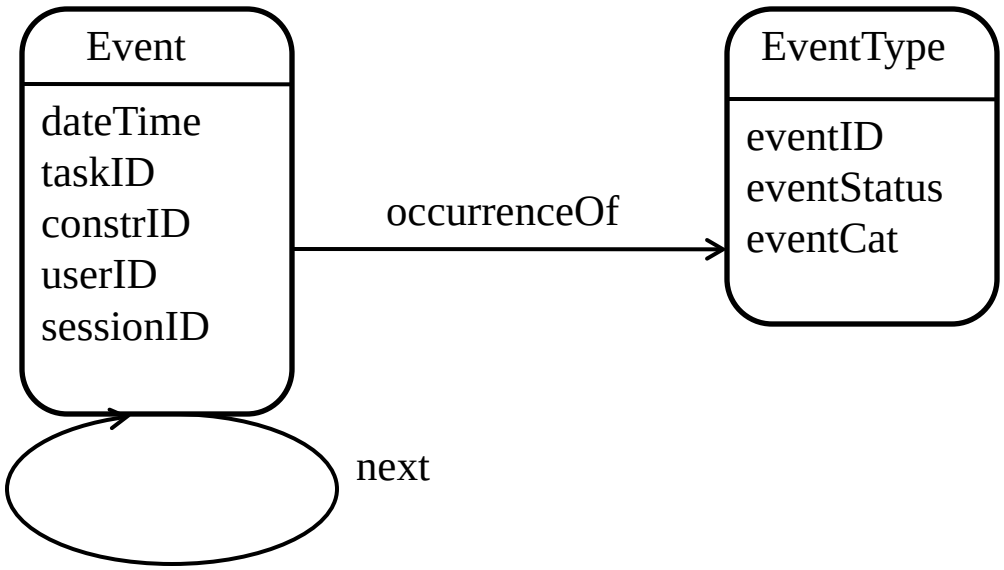
Make a fraction and right click it. Select 'Find equivalent' and partition the fraction into 2, 3, 4 and 5.



High-interruption feedback

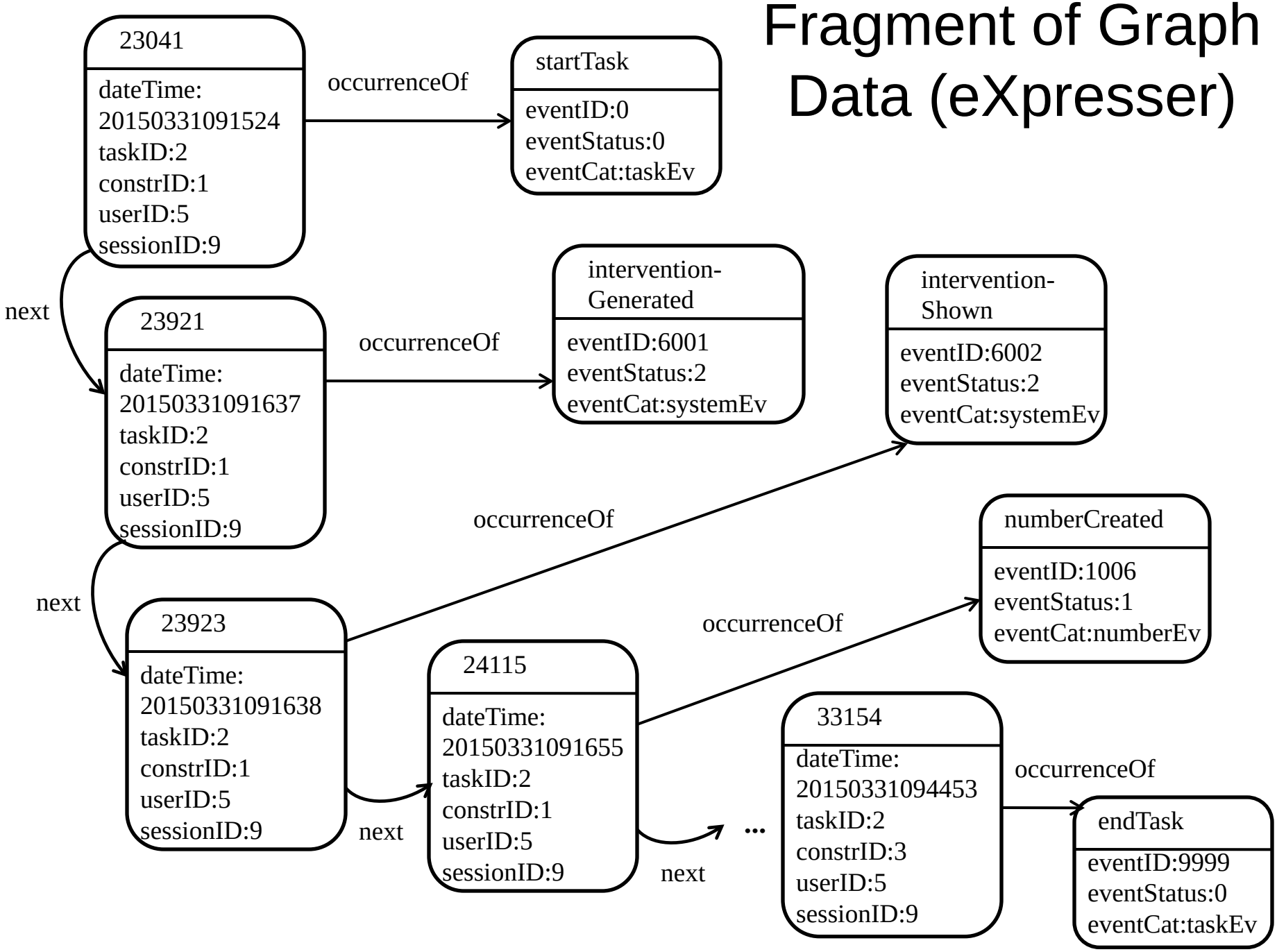
The data gathered

- Event-based data:
  - Students’ interactions with the ELE
  - Occurrence of key ***indicators*** as students interact with the ELE
  - Provision of feedback by the ELE to students
- Students' constructions:
  - including history of development of these
- Task information: learning goals, solution approaches
- Students' learner models

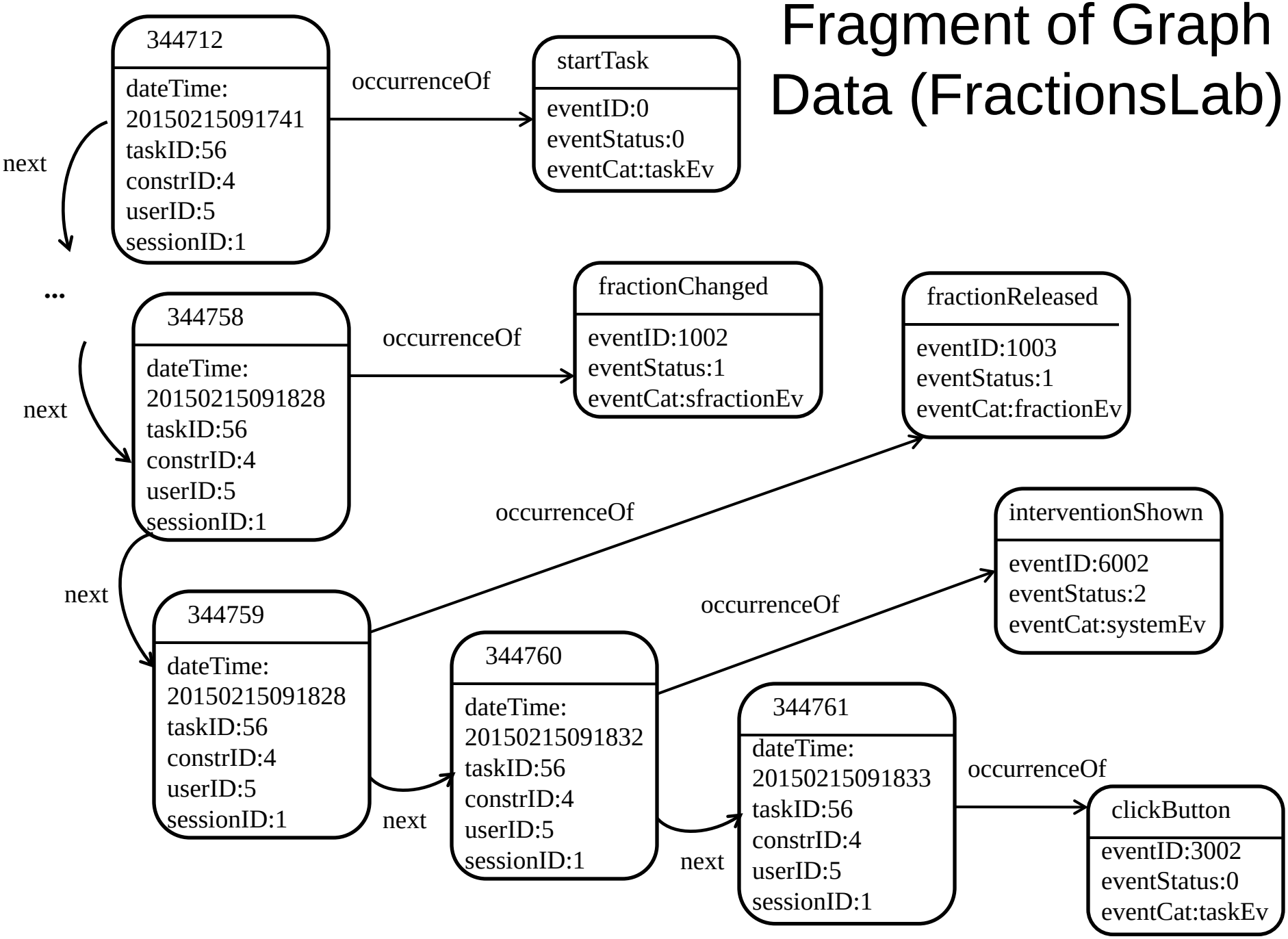


Core Graph Data Model

Fragment of Graph Data (eXpresser)



Fragment of Graph Data (FractionsLab)



Some Exploratory Queries

(?X,?Y,?Z) <- (?X, occurrenceOf, interventionShown),
(?X, next, ?Y),
(?Y, occurrenceOf, ?Z)

allows researchers to see types of events directly follow the display of an intervention message; allows confirmation/contradiction of their expectations regarding the immediate effect of intervention messages on students' behaviours

(?X,?Y,?Z) <- (?X, occurrenceOf, interventionShown),
(?X, next+, ?Y),
(?Y, occurrenceOf, ?Z)

allows researchers to see types of events directly *or indirectly* follow the display of an intervention message; allows confirmation/contradiction of expectations regarding longer-term effects of intervention messages on students' behaviours

Some Exploratory Queries

modify the query to retain only pairs X, Y that relate to the same construction:

```
(?X,?Y,?Z) <- (?X, occurrenceOf, interventionShown),
              (?X, constrID, ?C), (?X, next+, ?Y),
              (?Y, constrID, ?C), (?Y, occurrenceOf, ?Z)
```

use a *path variable* to return the matched paths through the data as well:

```
(?X,?P, ?Y,?Z) <- (?X, occurrenceOf, interventionShown),
                  (?X, constrID, ?C), (?X, next+ : ?P, ?Y),
                  (?Y, constrID, ?C), (?Y, occurrenceOf, ?Z)
```

use *approximate matching* to return increasingly longer paths to the user:

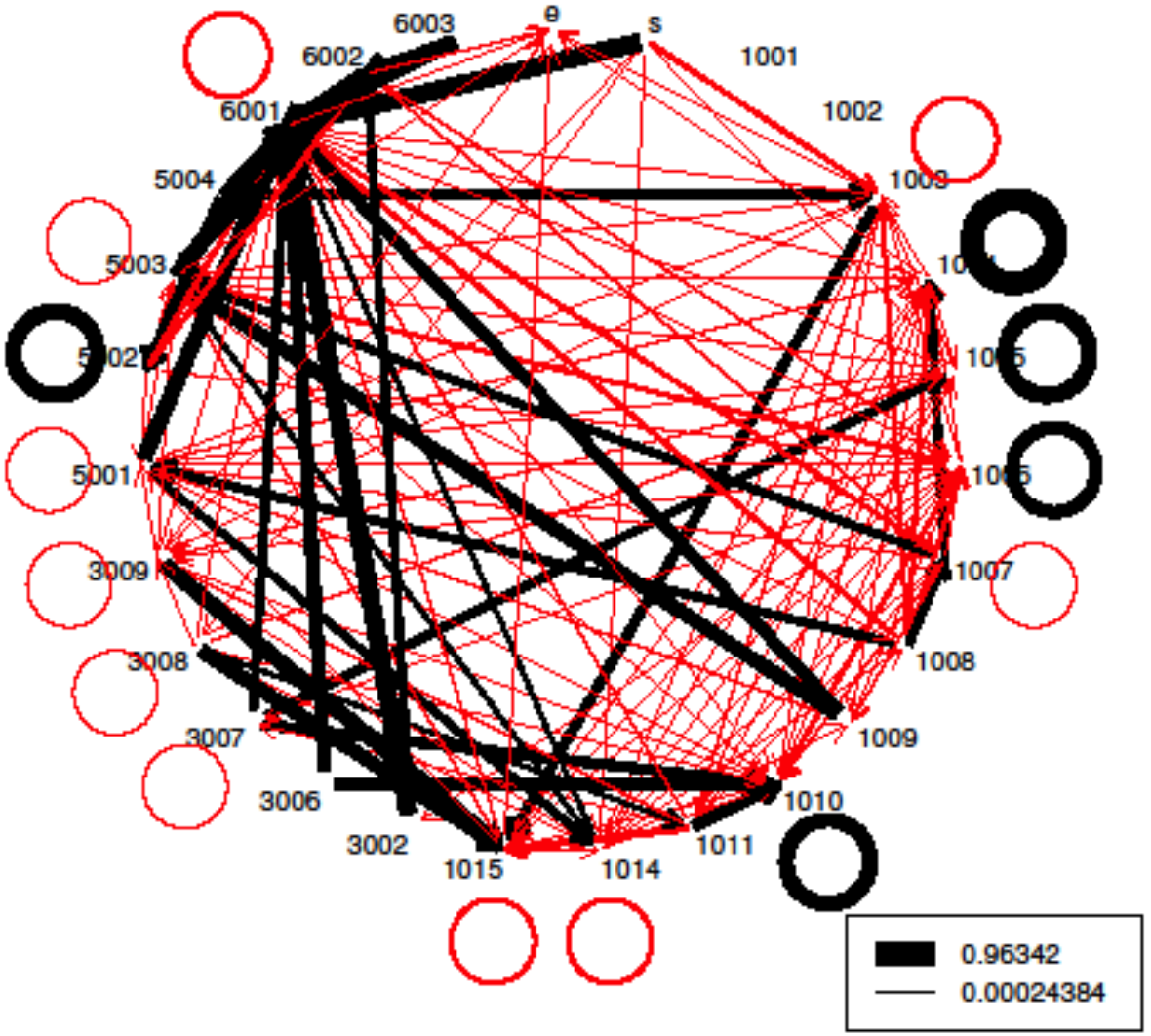
```
(?X,?P, ?Y,?Z) <- (?X, occurrenceOf, interventionShown),
                  (?X, constrID, ?C), APPROX (?X, next : ?P, ?Y),
                  (?Y, constrID, ?C), (?Y, occurrenceOf, ?Z)
```

Possible Graph Structure Analyses

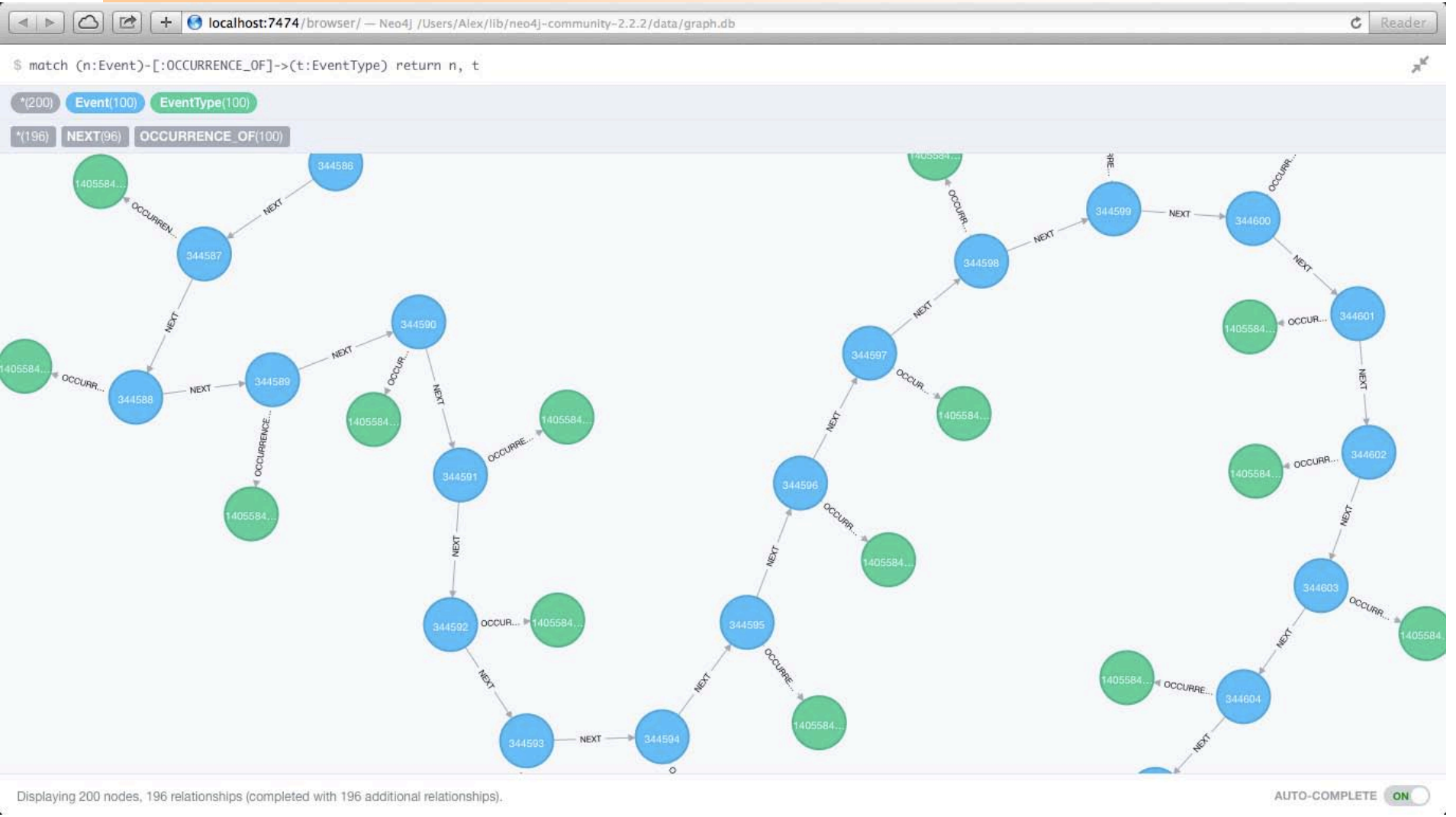
In addition to evaluating queries over the interaction data, by representing the data in the form of a graph it is possible to apply graph structure analyses such as the following:

- *Path finding and clustering:* for determining patterns of interest across a whole dataset, or focussing on particular students, tasks or sessions
- *Average path length:* determining the amount of student activity
- *Graph diameter:* determining the most long-running or most intensive task(s)
- *Degree centrality:* identifying key event types occurring during students' interactions
- *Betweenness centrality:* identifying event types that play key mediating roles between other event types

Ad hoc analyses:
Transitions between indicator types



Implementation in a Graph DB (Neo4J)



Conclusions

- We have presented a general graph model for representing event-based student-system interaction data arising from ELEs
- We have explored the possibilities that evaluating regular path queries over this graph-based representation provides for exploring the behaviours of students as they are working in the ELE and the effectiveness of the ELE's intelligent support
- We have also identified additional graph algorithms that may yield further insights about learners, tasks and significant interaction indicators
- In recent work, we have transformed and uploaded an interaction data set gathered during a trial of FractionsLab into the Neo4J graph database

Future Work

- Design, implementation and evaluation of meaningful queries, analyses and visualisations over the graph data, in collaboration with pedagogical experts and teachers
- Aiming to lead to improved understanding of student-system interaction, and to feed back into enhanced design of the ELEs
- Investigation of how existing flexible querying processing techniques for graph data might be applied/adapted/extended to fine-granularity student-system interaction data, and to the pedagogical setting of providing effective intelligent support to learners undertaking exploratory tasks in ELEs

Acknowledgements

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