Chen, W. et al. (Eds.) (2016). Proceedings of the 24th International Conference on Computers in Education. India: Asia-Pacific Society for Computers in Education

Design of TEL environment to improve Hypothetico-Deductive Reasoning skill

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Abstract: Undergraduate level science and engineering learners are required to apply Hypothetico-Deductive Reasoning (HDR) within various topics of their curriculum. HDR include steps like formation of hypotheses, checking of individual hypothesis by experimentation, designing of experiment, predicting the outcome based on experiment, collecting the observed outcome and comparing predicted and observed outcome. In order to provide causal explanation behind any phenomena, designing of experiment and for accepting or rejecting hypothesis this skill is important. Fewer efforts have been made at college level especially in the context of biology to develop this reasoning in learners. Geneticus Investigatio (GI) aims to improve learner's HDR skill in the context of genetics and was developed to address this gap. Technology affordances like agent-based modelling is used which includes functionalities like variable manipulation, providing immediate feedback and self-paced learning.

Keywords: Technology Enhanced Learning Environment, Hypothetico-Deductive Reasoning, Model based reasoning, Agent based modeling, Geneticus Investigatio, Genetics

1. Context and Motivation

Hypothetico-Deductive Reasoning (HDR) is applied in a variety of topics especially in science and engineering curricula. Learners are supposed to perform sub-skills of HDR which are formation of hypothesis, checking of individual hypothesis by experimentation, designing of experiment, predicting the outcome based on experiment, collecting the observed outcome and comparing predicted and observed outcome (Lawson 2000). In order to identify correct explanation from many competitive underlying plausible explanations learners are required to apply this reasoning. However, HDR is not taught explicitly in undergraduate curricula leading to lack of application of HDR skill when required (Jong & Van Joolingen 1998). A number of pedagogical strategies and Technology Enhanced Learning (TEL) environments like Model-It (Jackson et al., 1996), Geniverse (Concord Consortium), WISE (Slotta, J. 2002) are used to develop skills similar to HDR up to different extents. However, most of them are focused on either modeling of phenomena or reasoning at individual steps of inquiry especially within K12 level. Fewer efforts have been made at college level especially in the context of biology. Biology learners have to apply this reasoning in different contexts like identifying particular pattern of inheritance.

We developed Geneticus Investigatio (GI) aiming to improve learner's HDR skill in the context of genetics. Currently GI is designed for college level biology undergraduates with focus on concepts of pattern of inheritance. Learners can access genetics domain content within this environment which is required to answer focus question. Learning activity requires learners to read the context and focus question which s/he will have to solve. Within this agent based modeling and simulation environment, learners identify properties and behaviors of agents and define rules governing the interaction between agents. They then execute their model and compare their output with that of expert model. Then they are required to accept or revise their hypothesis. Learners are required to perform different steps of HDR while doing these learning activities. In order to perform these learning activities affordances of TEL environment like variable manipulation, providing immediate feedback and self-paced learning are used to help learners develop this reasoning.

2. Statement of Thesis/Problem

The broad problem that I am considering is "How to develop Hypothetico-Deductive Reasoning skill in Bio-Science undergraduates?" More specific research problems are:

- What are the sub-skills of Hypothetico-Deductive Reasoning skill?
    - How to develop each of these sub-skills through TEL environment?
- How to evaluate/measure Hypothetico-Deductive Reasoning skill in learners?

3. Research goals and methods

3.1 Design Based Research (DBR)

I am following Design Based Research (DBR) (Reeves 2006) methodology in which problem identification was done from literature and development of solution was done by identifying design features, interactions, affordances and scaffolds needed. In the next step, GI prototype was designed which was based on different theoretical basis (model based reasoning and agent based modeling) and pedagogical approach (formative assessment and self-paced learning) which were identified in previous step and a preliminary study was conducted. Currently I am in 3rd step of first research cycle (design and redesign of GI).

3.2 Technology Enhanced Learning of Thinking Skill (TELoTS) framework

The conceptual framework of my solution is the TELoTS framework (Murthy et al. 2016) which is a "pedagogical framework that helps researchers to design effective technology enhanced learning environments targeting thinking skills using a DBR methodology." I have mapped different steps of TELoTS framework for developing my solution (Table 1).

Table 1: Steps of TELoTS framework adapted for GI.

TELoTS Framework	**Geneticus Investigatio (GI)**
•0. Choose the thinking skill, topic and problem-solving context	HDR, Genetics, Patterns of Inheritance
• **1. Characterize the thinking skill**	
1 a. Identify the competencies of the chosen thinking skill	Mapped to Lawson's flowchart of HDR (Lawson, 2000)
1 b. Create learning outcomes	LO's created
1 c. Consider assessment measures	For now, using ISLE rubric (Etkina et al, 2006)
• **2. Design the learning activities**	
2 a. Analyse expert actions and learner needs	Need identified for learners from literature
2 b. Decide instructional strategies and supports	Adapted from CTSiM (Basu et al, 2013)
2 c. Identify technology features to realize the instructional strategies	Adapted from CTSiM (Basu et al, 2013)
2 d. Create a sequenced set of learning activities	Learning activities created
• **3. Architect the components and interfaces of the SLE**	Prototype version created in HTML

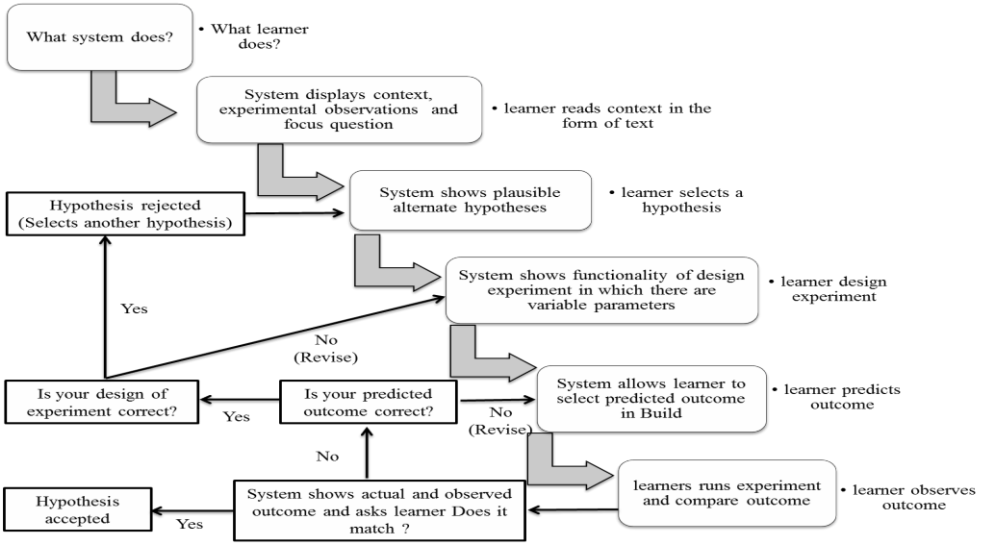
3.3 Geneticus Investigatio (GI) learning environment:

The GI learning environment focuses on development of HDR reasoning in the context of genetics. GI has functionalities like experiment designing, modeling agents and their properties, running and comparing of models. Brief descriptions of different functionalities are:

- Experiment Design: Learners selects the hypothesis and state their reason for selection.

- Model: Learners identify agents and specify their properties along with their values. They also specify values of environmental variables like no of generations, no of plants, type of cross.
- Build: Learners define rules which govern interaction between agents.
- Run and compare: Learners runs the model and compare their output with the experimental output. Within this learners sees a summary of values chosen in different functionalities and they are prompted whether they want to revise their values.
- HDR: Summarizes about what is HDR with an example from real-life context and definition of terms like hypothesis, prediction and observation.
- Domain: Learners are provided with domain content related to problem context which is for reference purpose.
- Focus question: Displays the context with expert result and focus question which is to be answered.

Summary of learning path in GI:



3.4 Evaluation Plan

I am planning to evaluate GI environment from three different perspectives (engagement, learning and interaction). Evaluation from these three perspectives will help in assessment of learning (HDR and domain), design and re-design of TEL and motivation to interact with TEL. Table 2 describes broad goal, sub-goal, research questions (RQ) for sub-goals and data collection method and analysis. I am planning to focus on engagement in the beginning because before learning from any TEL environment learners should find the environment engaging. In the beginning i will focus on these RQ's:

- What are learner's perceptions of GI?
- How much HDR skill do learners learn?
- How does learner's interaction pattern (learning path, time, scaffolds used) with GI relate to HDR learning?

For this, research studies will have to be both qualitative and quantitative in nature.

4. Pilot Study

I did a pilot study with the prototype of GI with 22 learners (convenience sampling) from 3rd year Bachelor of Science (Zoology) undergraduate course to answer RQ's:

RQ1: What are learner's perceptions of usability of GI?

RQ2: What are learner's perceptions of learning from GI?

Learner's responses to the survey and open-ended questions helped me to validate some design features. Based on observations during study and learner's difficulty, we decided to incorporate some

user interface changes in GI.

Table 2 Evaluation Plan

Broad Goal	Sub-Goal	Research Question	Data collection and analysis
(Engagement perspective) Determine how engaging the learning environment is.		What are learner's perceptions of GI?	Perception survey questionnaire on Likert scale/observational study
(Learning perspective) Determine how much learning has happened in learners who interact with GI	Learning of HDR skill	How much HDR skill do learners learn?	Pre-Post test measuring HDR skill based on ISLE rubrics
	Learning of domain	How much content knowledge do learners learn?	Pre-Post test measuring HDR skill within genetics content
(Interaction with TEL perspective) Design and re-design of TEL environment	Validating pedagogical design and identify aspects which needs to be re-designed.	How does learner's interaction pattern with GI relate to HDR learning?	Screen recording and analysis of time spent on each functionality, scaffolds used etc.
	Validate user interface and identify aspects that needs to be re-designed.	What is the usability of GI?	Interview questions focusing on ease of use of different functionalities of GI, SUS survey

5. Expected Contributions

Since this research is focused on developing learner's HDR skill through a TEL environment, as an outcome of this research project a tool (GI) will be developed which will focus on developing this skill. It will help a bio-science researcher to do research independently e.g. designing experiments instead of following regular protocols. For a learner this tool will help them both in developing this skill and practice different problem solving context. For a teacher this tool will help them to develop this skill among their learners since this skill is not taught explicitly in existing curriculum. Other anticipated future contribution includes validation of scaffold design framework (Quintana et al. 2004) for designing pedagogical scaffolds. It also includes assessment of effectiveness of the tool in development of this skill. Also within the first step of DBR which is problem identification phase, difficulties faced by learners in its various sub-steps will be identified and validated.

Acknowledgements

I would like to thank Prajish Prasad, Kavya Alse, Soumya Narayana and T. G. Lakshmi of IDP-ET, IIT -Bombay for developing and guiding this TEL environment development and research process.

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