A System for Developing Operationalization Skills through Problem Decomposition

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***Abstract*—Novice researchers have difficulties in operationalization (breaking down of abstract concepts to measurables) and generalization (generalize the findings to make claims). We have designed a system called OPeD (Operationalizing using ProblEm Decomposition), for teaching learning of operationalization. OPeD trains novice researchers in operationalization through problem decomposition. OPeD is based on pedagogical theories of guided inquiry, problem visualization and adaptation. In order to visualize the operationalization process, OPeD guides the learner to create a decomposition tree and construct meaningful hypotheses based on the tree. The gradual and iterative construction of this tree can help learners develop their operationalization skills. In this paper we present the design of OPeD and provide an exemplar of a learner path in the context of educational research.**

Keywords- operationalization; problem decomposition; problem visualization; guided inquiry

I. INTRODUCTION

Research involves solving open-ended ill-structured problems and the endeavors are of interest only if the results are useful to other researchers to advance the respective field. One approach the researcher could take is a top-down method - detailing the research goal into specific research statements. This involves operationalization, i.e., translation from abstract constructs to concrete variables. Operationalization is critical to the usefulness of an experiment's results [1].

Operationalization is one of the more important tasks prior to conducting any research. Literature provides the operationalization of domain specific constructs to novice researchers. But the process of operationalization itself is presented as guidelines.

Novice researchers find it difficult to come up with the right operationalization [2]. There is a need for a process as well as representation which enables novices to operationalize constructs for measurement and at the same time generalize results to make valid claims. Strategies of decomposition and recombination have been used to scope and analyze open ended design problems. These strategies are naturally suited for operationalization of constructs.

In this paper we present the design of a system, OPeD where a novice researcher is explicitly scaffolded through process of operationalization. OPeD enables the learners to visualize the process using problem decomposition strategies. We have taken a specific instance of operationalizing research constructs in the context of educational research. Though the design of the interface may seem similar to concept mapping, in OPeD scaffolds are provided to breakdown theoretical constructs to observational measures.

II. THEORETICAL UNDERPINNINGS

One of the guidelines of research design and methodology is the proper operationalization of constructs. Louis Cohen et.al [4] suggests that the researcher should "ensure that each main research purpose is translated into specific, concrete questions that, together, address the scope of the original research questions." Incorrect operationalization can lead to incorrect research designs which lead to incorrect claims and inferences [3]. Additionally incorrect operationalization of the constructs in research problem poses validity threats. Construct validity is considered as an all-embracing validity concept. Even though validity questions may not be answerable with complete certainty, researchers need to develop skills to support validity of their variables [4]. At the same time novice researchers are often confused with validity [5].

Wacker [6] provides certain questions to ask during operationalization and theory-building. Karwowski et al., [7] suggests that the operationalization process should start with a listing of different sub-dimensions of the variable. Novice researchers may still not know how to apply operationalization guidelines. Scaffolds on how these guidelines can be applied, and appropriate representation can help in the process of operationalization. Problem decomposition strategies can serve as an effective scaffold and the decomposition tree can serve as an appropriate representation for operationalization. Decomposition strategies have been used for design, requirements gathering, software development and concept elucidation. The most applicable for the operationalization of research are the Structure-Behaviour-Goal and Structure-Behaviour-Function decomposition strategies.

III. SYSTEM DESIGN

A. Pedagogical Design

In this section we bring out the pedagogical theories which have been involved in OPeD:

1) Guided Inquiry: The inquiry based learning (IBL) pedagogy begins by giving the learner set of questions to answer, a problem to solve or a set of observations to be explained [8].The questions and problems provide learners with contexts for learning. It is found that various tasks in

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the IBL directly mapped to different levels of research [9]. Since operationalization is an important step in research, we use IBL methods for teaching learning of this skill. As recommended by literature, in OPeD we start from guided inquiry and move towards open-endedness.

2) Problem Visualization: In OPeD, we start by presenting the learners with a problem. Problem solving is a cognitive task that benefits from distributed representation [10]. Diagrams facilitate problem solving more than written notes [11].

A visualization would serve as an external representation for the breakdown process Hence in OPeD we have helped the learner visualize the decomposition in the form of the tree.

3) Adaptation : Adaptation has two approaches of (i) adaptation to learner characteristics such as styles, requirements, status, performances, preferences, profiles and/or (ii) adaptation to learner context [12]. OPeD allows the learner to explore learning material and providing avenues where they chose what part of the problem they would want to solve, which could motivate the learner. The adaptation logic is built within the software to direct the learner to the appropriate learning context based on the choices and answers.

B. System Walkthrough

The goal of OPeD is to enable learners to operationalize constructs in a hierarchical manner using the decomposition strategy.

1) Broad Research Goal : Initially the learner is presented a research goal "Effect of Teaching Methods on Learning" and is asked what the initial step should be. We wish to guide the learner to the idea that identifying constructs in the research goal is one way to proceed. If the learner chooses any other option, as seen in Fig. 1 the corresponding incomplete tree is shown, along with feedback.

2) Identifying Constructs in the Research Goal : The learner has to then identify the constructs in the given research goal - "Effect of Teaching Methods on Learning". To help learners identify constructs, the definition of "construct" and examples of constructs are displayed to the learner.

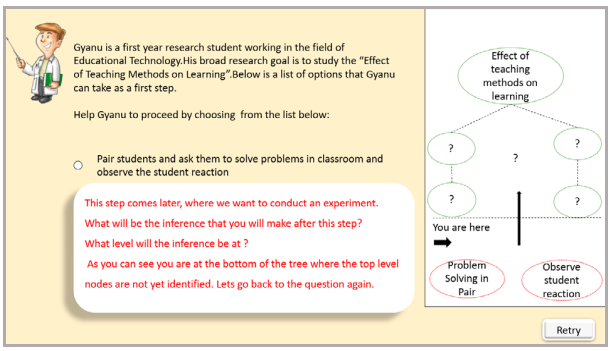

Figure 1 Depicting incomplete tree

This theory guides the learner as they identify the constructs. After the constructs have been identified, the learner is presented with a tree containing the constructs at level 1. The links to the next level are annotated with propositions, as shown in Fig 2. The propositions act as scaffolds which enable learners to explore the next level of constructs.

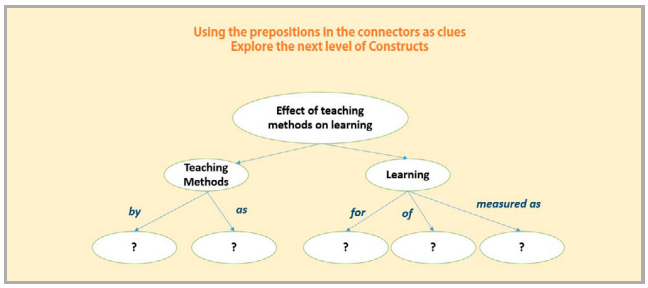

Figure 2 Linking Level 1 to Level 2 constructs using prepositions

3) Identifying Level 2 Constructs : At Level 2, OPeD uses guided inquiry to enable the learner identify the desired construct. At first, the learner is asked an open-ended question based on the proposition at the node, along with an example. As shown in Fig 3 the question "Whose learning are you measuring?" is used to identify the "target audience" node. Based on the open-ended response of the learner, OPeD shows a list of options to the learner and asks to choose the one which matches closest to their answer. The learner repeats the above step for each node at Level 2. This breadth wise construction of tree prevents fixation to a limited set of constructs.

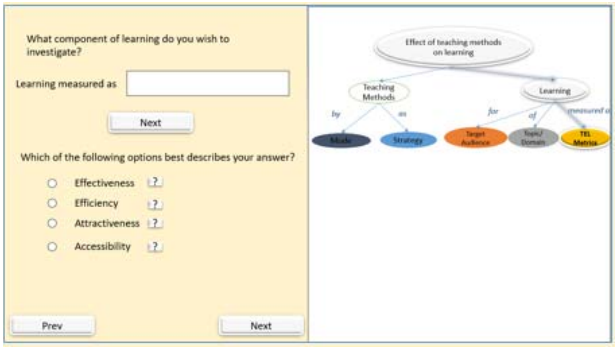

Figure 3 Identifying Level 2 constructs

The goal of identifying all the nodes at Level 2 is to enable them to construct an intermediate hypothesis. In this case, the intermediate hypothesis is "Effect of Teaching Methods by [Mode] through [Strategy] for [Target Audience] of [Topic] increases/decreases in [TEL Metrics]" as shown in Fig 4.

4) Identifying Constructs at further levels : In order to arrive at measurable hypotheses, the constructs have to be operationalized further. Similar guided inquiry process is applied at level 2 nodes for further breakdown. For example, the learner breaks down "effectiveness" as measureable variable "test score".

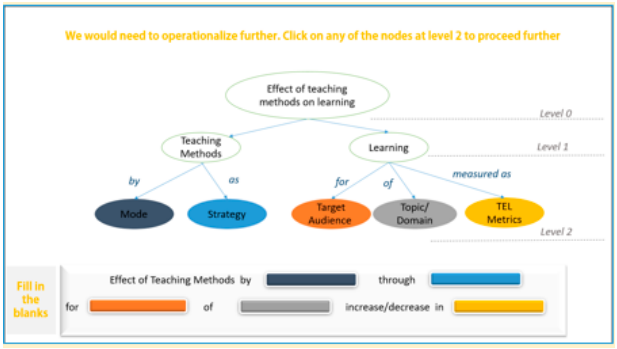

Figure 4 Constructing Intermediate Hypothesis

5) Construct Hypothesis : The learner continues the process of adding nodes, till all the nodes at level 2 have reached a leaf node. The learner can now construct a meaningful hypothesis using a combination of the leaf nodes as shown in figure 5. OPeD then allows the learner to construct the tree further and generate hypotheses based on the new nodes added.

C. Evolution of the Operationalization Tree

In OPeD, the process of operationalization has been mapped to the construction of a decomposition tree. As the decomposition tree evolves, the process of operationalization becomes clearer to the learner.

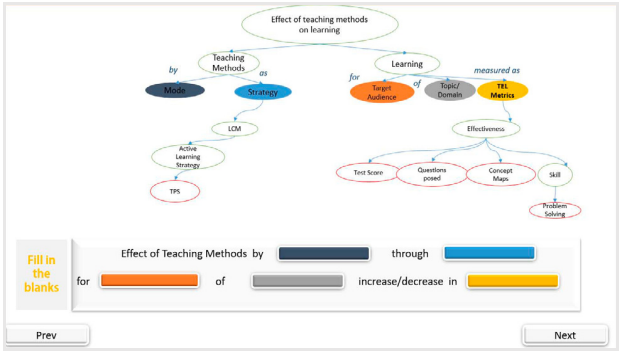

Figure 5 Hypothesis Construction

The software platform of OPeD can be further leveraged to include features such as: (i) peer review and feedback of tree as well as constructed hypothesis, (ii) learner's hypothesis tracking for their reflection.

IV. EVALUATION PLAN

Initially we intend to test OPeD's usefulness and usability. Novice researchers will work on OPeD to decompose a research goal to hypotheses. After working on OPeD they would be provided with questionnaires to capture the perceived usefulness and ease of use of OPeD. A follow-up interview with novice researchers will be done for understanding the difficulties encountered while using OPeD. OPeD will be redesigned based on the feedback received.

V. CONCLUSION

Accurate operationalization of constructs is essential for conducting research. In this paper, we have presented the design of a teaching learning system, OPeD for novice researchers to operationalize constructs. OPeD employs problem decomposition to operationalize a broad research goal by constructing a decomposition tree. Appropriate prompts and questions are provided, in order to construct this tree, with the main node being the broad research goal and the leaf nodes being the measurable of the hypotheses. The gradual and iterative construction of this tree can help learners develop their operationalization skills. Based on the current design, we intend to develop a smart learning environment for the teaching learning of operationalization skill.

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