Individual Learning Based on Elementary Knowledge Concept: Experiments and Results

Milan Houska, Martina Berankova

Czech University of Life Sciences in Prague

Key words: Elementary knowledge, knowledge as an object, knowledge as a process, object-oriented representation of elementary knowledge, knowledge transfer, knowledge text

Abstract:
Elementary knowledge concept and its object-oriented representation are possible to use as a tool for educational text analysis. They should be written in so called “knowledge form”; it means they should content knowledge, not pure information only. Thus, some requirements to text in “knowledge form” as well as experiments for efficiency of their application in educational process measurement have been formulated in previous works. The article describes the methodology of experiment, in which the standard and “knowledge” form of text were compared from the point of view basic educational process criteria.

1 Introduction

Knowledge arises from a result of successful solution of some problem [1]. Before it, the problem had to be identified, solved and someone had to implement the solution and evaluate its efficiency and effectiveness [2]. Kind of the problem e.g. problem situation and its solution influence the form of knowledge; explicit, which is possible to share, or tacit, which is difficult to share.

It is possible to understood knowledge from two basic points of view: as a product (object) and as a process [4]. In the first case, knowledge is understood as an entity that can be identified and processed. In the other case, the main focus is aimed to assistance, motivation and management of educational process as a source of knowledge acquisition. Elementary knowledge concept enlarges standard definition of knowledge as a production rules system about two aspects:

- connection to problem situation,
- goal of the problem (situation) solution.

Then, the elementary knowledge (EK) can be defined as a set that consists of four elements [4]. Formally,

\[ EK = \{X, Y, Z, Q\} \]

where

- \(X\) is the problem situation (context of problem solving),
- \(Y\) is elementary problem that is solved in specified problem situation (hypothesis),
- \(Z\) is the goal of problem solving and
Q is a successful solution of the elementary problem with regards to goal Z (consequence).

Knowledge elementarity corresponds with elementarity of the problem; elementary knowledge is a result of elementary problem solving. Elementary problem is a problem or a part of some complex problem that is not possible and/or useful divide into more sub-problems. Criteria and conditions for problem elementarity classification are determined by the user of knowledge; the most important criterion is the user’s ability to understand and apply the rules contained in the elementary knowledge.

Object-oriented elementary knowledge definition goes out from class-instance structure. It is possible to understand elementary knowledge as an instance of some class that sums it in the frame of some problem situation. Inheritance between classes of knowledge allows obtaining knowledge structure with one root. Internal structure of the knowledge object can use assembling method for expressing the functional relationships between rules. Thus, the elementary knowledge can be represented by object-oriented paradigm as follows:

![Figure 1: Object-oriented representation of elementary knowledge](image)

Elementary knowledge concept and its object-oriented representation are possible to use as a tool for educational text analysis. They should be written in so called “knowledge form”; it means they should content knowledge, not pure information only. Thus, some requirements to text in “knowledge form” as well as experiments for efficiency of their application in educational process measurement have been formulated in previous works.

For educational process efficiency measurement some quantitative and qualitative criteria has been set: mainly time of learning, quality of understanding (successful application), remembering (successful application after some time), but also subjective perceiving the texts by the students. This article deals with results analysis of these experiments; compares outputs of the educational processes, when “normal texts” and “knowledge texts” has been used.

### 2 Normal text, knowledge text

Professional aim of authors of this article is area of management science/operations research. Thus, educational text that deals with basic algorithms of graph theory [3] (minimum spanning tree) has been chosen for experiments. Normal text is written as follows:

"Algorithm for finding minimum spanning tree is very simple. It is so called Boruvka’s algorithm. Suppose that E is set of all arc of the graph G.

Step 1: Arcs of the graph G are ordered by their cost coefficients $c_{ij}$ and set $E^* = E$ is created.

Step 2: Arc $(r,s)$ is selected, $c_{rs} = \min_{(i,j) \in E} c_{ij}$

Step 3: Arc $(r,s)$ is included into minimum spanning tree $G^{min}$, if the arc does not close a circle."
Step 4: Arc \((r,s)\) is removed from the set \(E^*\)
Step 5: Procedure is finished when \(E^* = \emptyset\)

This procedure is possible to modify, when \(c_{ij}\) represent some benefit criterion. Then the maximum \(c_{ij}\) in the Step 2 will be selected.”

The text given above may represent a procedural type of knowledge. However, the procedure of solution is divided into parts that are represented by information only. Applying elementary knowledge concept with object-oriented definition of elementary knowledge, the text can be transformed by following scheme:

<table>
<thead>
<tr>
<th>Minimum spanning tree algorithm</th>
<th>Level 1: Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>EK1: Introduction</td>
<td>EK2: Step 1</td>
</tr>
<tr>
<td>EK2: Step 2</td>
<td>EK3: Step 3</td>
</tr>
<tr>
<td>EK3: Step 4</td>
<td>EK4: Step 5</td>
</tr>
<tr>
<td>EK5: Step 6</td>
<td>EK6: Step 7</td>
</tr>
<tr>
<td>EK7: Conclusion</td>
<td></td>
</tr>
</tbody>
</table>

Level 2: Elementary knowledge

X, Y, Z, Q

Level 3: Information

X, Y, Z, Q

Table 1: Knowledge decomposition for minimum spanning tree problem

Then it is not difficult to determine all components for each of elementary knowledge:

<table>
<thead>
<tr>
<th>EK</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>EK1</td>
<td>Boruvka’s algorithm</td>
<td>Set of all arcs of the graph (G)</td>
<td>Formalization the task</td>
<td>Determine set (E)</td>
</tr>
<tr>
<td>EK2</td>
<td>Start solving</td>
<td>Cost coefficients (c_{ij}) are not the same</td>
<td>Simple search in set of arcs (E)</td>
<td>Order all arcs by (c_{ij})</td>
</tr>
<tr>
<td>EK3</td>
<td>Selecting next arc</td>
<td>Find arc ((r,s))</td>
<td>Minimize (\Delta Z)</td>
<td>(c_{rs}: c_{rs} = \min_{(i,j) \in E} c_{ij})</td>
</tr>
<tr>
<td>EK4</td>
<td>Selecting next arc</td>
<td>Arc ((r,s)) closes a circle</td>
<td>Minimize (Z)</td>
<td>Skip the arc ((r,s)), else include it into (G_{min})</td>
</tr>
<tr>
<td>EK5</td>
<td>Preparing for next cycle</td>
<td>Arc ((r,s)) included or skipped</td>
<td>Reduce (E^*)</td>
<td>Remove Arc ((r,s)) from (E^*)</td>
</tr>
<tr>
<td>EK6</td>
<td>Test the end of procedure</td>
<td>(E^* = \emptyset)</td>
<td>Finish the algorithm</td>
<td>Finish or go to step 2</td>
</tr>
<tr>
<td>EK7</td>
<td>Modification of the algorithm</td>
<td>(c_{ij}) represent benefit criterion</td>
<td>Maximize (Z)</td>
<td>Modify Step 2: (c_{rs}: c_{rs} = \max_{(i,j) \in E} c_{ij})</td>
</tr>
</tbody>
</table>

Table 2: Elementary knowledge for minimum spanning tree problem

Now, the text in knowledge form can be written as follows:
“Before using Boruvka’s algorithm, define formally a set of all arc of the graph G as set $$E^* = E$$.
For simple search in set $$E^*$$, if cost coefficients $$c_{ij}$$ of arc are not the same, order it by $$c_{ij}$$ before starting the solving procedure.
For minimizing increase of objective function $$Z$$, if some new arc should be selected, then use the one with minimum value of cost coefficient $$c_{ij}$$ from the set $$E^*$$ (step 2).
For minimizing total value of $$Z$$, if the selected arc closes the circle, then that arc will be skipped, otherwise included into spanning tree $$G^{\text{min}}$$.
For reducing the set $$E^*$$, if some arc is included into $$G^{\text{min}}$$ or skipped, then it will be removed from the set $$E^*$$.
For finishing the algorithm, if $$E^* = \emptyset$$, then finish the algorithm, otherwise return to step 2.
For maximizing objective function value $$Z$$, if cost coefficients $$c_{ij}$$ represent benefit criterion, then modify step 2: the arc with maximum $$c_{ij}$$ will be chosen.”

3 Methodology of the survey
Before starting with experiments with knowledge texts, the methodology of the survey has to be set. The survey has been done on the pilot level only for now to have a chance to correct possible mistakes before massive and robust testing.
Methodology of the pilot survey consisted from following steps:

1. Set the goal and target group of the survey
2. Experiment with a small pattern of target group
3. Analyze the results

In this phase of our research, it is the most important to know answers of following questions:

1. How long have you been studying the text without teacher’s assistance?
This is a first criterion that should determine objective characteristics of readability of the text. The question is about “studying” not only “reading”, because texts length is in both cases very similar. There was measured the time from the first view of the text to the case, when student say “Ok, I think I am ready to solve an example.”

2. Are you able to solve the example correctly?
This criterion evaluates quality of understanding. After studying, each student got the same example to solve. Because the Boruvka’s algorithm is as a whole very simple, we accepted only solutions that were completely correct.

3. Are you able to solve some other example correctly after one week?
This criterion tests quality of remembering. It was prohibited to practice this algorithm during one week from learning the algorithm and solving the first example. As well as previous case, only fully correct solutions of the examples have been accepted.

4. Please, compare understandability of your version of the text with the other one.
This subjective criterion has been used for obtaining students opinions about level of working comfort with texts. This criterion enlarges the information got from the criterion 1 (time of learning).

In the frame of the pilot survey, only small group of students has been used as a pattern of target group. Students were divided into two groups: each of them had 8 members. The group A worked firstly with original version of the text, group B obtained text in knowledge form. Students were chosen for participation in the pilot survey targetly; it was necessary to have
two balanced groups from the point of view of quality of respondents. Quality of respondents has been measured by their results in previous testing in the frame of optional subject “Mathematical methods in economics”.

Before starting the experiment with knowledge texts, it was necessary to ensure that the problems to solve in Boruvka’s algorithm are really elementary problem for students of target group. It was analyzed in following table:

<table>
<thead>
<tr>
<th>Elementary problem (Y) …</th>
<th>…is elementary problem for students, because…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of all arcs of the graph G</td>
<td>Students already know definition of term “graph” as G = {U, E}, where U is a set of graph nodes and E is a set of its arcs.</td>
</tr>
<tr>
<td>Cost coefficients c_{ij} are not the same</td>
<td>Students know term “cost coefficient” from optimization model that has been already taught. Of course, they know what does mean “the same” (value).</td>
</tr>
<tr>
<td>Find arc (r,s)</td>
<td>Arc are in the set E or E*, respectively</td>
</tr>
<tr>
<td>Arc (r,s) closes a circle</td>
<td>Definitions of cyclic and acyclic graph are known.</td>
</tr>
<tr>
<td>Arc (r,s) included or skipped</td>
<td>Its obvious that still the same arc is processed</td>
</tr>
<tr>
<td>E = ∅</td>
<td>Students know the term “empty set” from first class of primary school.</td>
</tr>
<tr>
<td>c_{ij} represent benefit criterion</td>
<td>Relationship between cost and benefit criteria has been already explained.</td>
</tr>
</tbody>
</table>

Table 3: Elementary problems analysis

4 Results and conclusions

Results of the pilot survey (quantitative criteria only) are in following table:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average learning time (minutes)</td>
<td>3:48</td>
<td>4:15</td>
</tr>
<tr>
<td>Quality of understanding 1* (correct/all)</td>
<td>6/8</td>
<td>7/8</td>
</tr>
<tr>
<td>Quality of understanding 2* (correct/all)</td>
<td>7/8</td>
<td>7/8</td>
</tr>
<tr>
<td>Quality of remembering 1* (correct/all)</td>
<td>6/8</td>
<td>7/8</td>
</tr>
<tr>
<td>Quality of remembering 2* (correct/all)</td>
<td>6/8</td>
<td>7/8</td>
</tr>
</tbody>
</table>

Table 4: Results of pilot survey – quantitative characteristics

*Note: Two examples were solved in each phase of testing; both cases cost and benefit objective function were tested.

It is not useful to analyze these characteristics because of small number of respondents. But it is interesting to summarize opinions of respondents to the other form of text. Typical reactions are in the table.
Table 5: Opinions of the respondents on their and the other text

<table>
<thead>
<tr>
<th>Group A about A</th>
<th>I am used to use this form of algorithm explanation. In the first view it is not fully clear the reason of the sequence of steps, but after repeating I understand.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A about B</td>
<td>Interesting, transparent, but the form is strange for me.</td>
</tr>
<tr>
<td>Group B about B</td>
<td>Looks difficult, necessary to spend more time to read but very clear and easy to understand, all is explained, when required.</td>
</tr>
<tr>
<td>Group B about A</td>
<td>Standard algorithm syntax, well structured, but not explained.</td>
</tr>
</tbody>
</table>

On conclusion, the pilot survey showed some problems that have to be solved before massive testing. The most important are following two:

1. Key factor of success of texts in knowledge form is their precise language processing. Students are not used to read such text and so it is difficult for them understanding it. Language has to be optimized and absolutely clear.

2. The algorithm that is an object of educational process has to be more difficult than for example Boruvka’s algorithm described in this article. Students who understand it “recode” it in their mind and when solve some examples after some time (test of remembering), they knows everything, because it is trivial for them. So the test looses its validity.

5 Dedication

The paper is supported by the grant project of Ministry of Education Czech Republic No. MSM6046070904.

References:


Author(s):

Milan Houska, Dr., Martina Berankova, Dr.
Czech University of Life Sciences in Prague, Department of Operational and Systems Analysis
Kamycka 129
165 21 Prague 6
Czech Republic
houska@pef.czu.cz, berankova@pef.czu.cz