Developing Question Sets to Assess Systems Thinking Skills

Kiumars Dorani[1], Armina Mortazavi[2], Amin Dehdarian[3], Hesam Mahmoudi[4], Masoomeh Khandan[5], Ali N. Mashayekhi[6]

[1] Industrial Engineering Department, Sharif University of Technology, Tehran Iran

[2] Chemistry Department, Sharif University of Technology, Tehran Iran

[3] Department of Management of Technology, Ecole Polytechnique Federale Lausanne (EPFL), Lausanne Switzerland

[4] Graduate School of Management and Economics, Sharif University of Technology, Tehran Iran

[5] John F. Kennedy School of Government, Harvard University, Cambridge, MA, USA

[6] Graduate School of Management and Economics, Sharif University of Technology, Tehran Iran

Abstract

Assessment of systems thinking has been a topic of interest in the last decade. Although there have been some noticeable methods in the literature, the lack of an assessment method which can be regenerated to obtain numerous assessment packages and applied to a large number of examinees is still felt. The proposed method of using question sets to assess the different systems thinking skills results in an assessment package without requiring large amounts of time and effort to interpret the data. Following the guideline presented here, the assessment package can be regenerated to achieve new question sets. The classification of systems thinking skills is based on Richmond's classification scheme with minor variations to accommodate an accurate assessment (Richmond 2000).

Keywords: Systems Thinking Assessment, Systems Thinking, Systems Thinking Skills

Introduction

The education of system dynamics concepts and systems thinking have been a point of attention in the past two decades. As the body of research on the subject grew and the advocates of systems thinking preached the benefits of the subject, questions were raised on the effectiveness of systems thinking education. Such research questions could not be approached without a tool to measure the level of the systems thinking skill in individuals. The studies of Huz et al. and Cavaleri and Sterman, which aimed at assessing systems thinking interventions, were the first steps toward a methodology for assessing systems thinking skill levels (Huz et al. 1997; Cavaleri & Sterman 1997). Huz et al. used qualitative methods to assess the shifts in understanding of system functioning, including recorded audio and video from meetings in which examinees are self-assessing their progress, records of informal reflection on the meetings, and in-depth analysis of archival notes and products. Cavaleri and Sterman used self-reported cognitive changes together with results of a Beer game simulation to measure the examinee's capability to think systematically. Obviously, the data collected in these two studies were mainly self-reported and were limited to measuring the systems thinking level before and after an intervention. Moreover, these measurement approaches were time- and resource-consuming and almost impossible to be expanded to large numbers of examinees.

Booth Sweeney and Sterman introduced the systems thinking inventory as an assessment tool to evaluate the examinees' level of understanding of three basic systems thinking concepts, i.e. feedback, delays, and stock and flows (Sweeney & Sterman 2000). The examinee is asked to draw the stock level of a stock-flow structure when the graph of the net flow is given. The same tool has been used in various studies, occasionally introducing new tasks, to measure the systems thinking understanding of different population samples (Sterman & Sweeney 2002). Kainz and Ossimitz utilized the three original systems thinking inventory tasks to evaluate the effects of a ninety-minute crash course on stock-flow thinking and Lyneis and Lyneis compared the results of students from an introductory system dynamics class to those of microeconomics students (Kainz & Ossimitz 2002; Lyneis & Lyneis 2003). In another study, Pala and Vennix used three of the systems thinking inventory tasks, i.e. department store, manufacturing, and CO_2 zero emissions tasks, in a pre- and post-test format to study the effects of an introductory system dynamics course on the examinees' performance in the systems thinking inventory test (Pala & Vennix 2005). The systems thinking inventory as an assessment method suffers from two main deficiencies: being limited to specific basic systems thinking concepts and not being easily reproducible.

Addressing the drawbacks of these methods, it has been suggested that cognitive methods can be employed to measure systems thinking skills and system dynamics interventions effectively (Doyle 1997). Maani and Maharaj proposed the use of Verbal Protocol Analysis (VPA) to investigate complex thinking mechanisms at work when one confronts a systems thinking challenge (Maani & Maharaj 2004). The VPA, as an assessment tool, comprises asking examinees to "think aloud" while working on a simulation exercise, and recording and transcribing examinees' verbalizations to be later organized and analyzed. This study suggested that the classification of the different critical skills, which was a growing research subject then, should be taken into account when designing an assessment tool for systems thinking. For this purpose, Richmond's seven-classification scheme was used as the theoretical basis of this research (Richmond 2000). The VPA approach to measuring systems thinking skills has the advantage of giving an in-depth understanding of the mental models and mechanisms at work in the process of thinking; however, applying VPA based methods to large numbers of examinees can be impossible on the accounts that the process of VPA is extremely time and resource consuming (Doyle 1997). Moreover, the skill level measured using VPA is prone to being mixed with other irrelevant skills such as presentation skills.

Plate developed the Cognitive Mapping Assessment of Systems Thinking (CMAST) as an assessment tool that can be implemented broadly but still provides a nuanced view of individuals' understanding of complex systems (Plate 2010). This method aims at discovering the causal structures that the examinees develop mentally while trying to understand complex systems and their dynamics. The CMAST consists of an article, describing events with system dynamics involved, which is handed out to the examinees. They are also provided with cards, each representing variables and concepts from the narration, and are asked to select the ones they deem necessary to explain the dynamics of the story. Then, the examinees are expected to create two maps using these cards: they are asked to form a map which shows the cards categorized in groups based on their similarity and select a name for each group (3CM); and also a second map (the causal map) by randomly choosing a pair of cards and commenting on the relationship between the two concept on the cards, i.e. whether one concept's increase causes an increase or a decrease in the second concept. The collected maps are then interpreted using quantitative criteria, together with a comparison of the examinees' maps with maps generated by experts (Plate 2008).

The interpretation of the hand-drawn maps derived from the CMAST and the comparison of these maps with experts' maps can be extremely resource consuming and thus, not expandable to large numbers of participants. Ross, in his doctoral dissertation, proposed a prototype interactive computer system in the form of a game called Causlings, based on the CMAST method, which works to assess causal understanding through cognitive causal mapping (Ross 2013). Since the results are interpreted via computers, this alternative CMAST method can be applied to large sample groups. This computational CMAST, also, gives a deeper insight into the process of thinking in participants, as the sequence of the participants' choices of cards and links is recorded in the data. However, CMAST still suffers from being limited to parts of systems thinking such as cause-and-effect and closed-loop thinking. In another thesis dissertation, Randle introduced a survey with a standard Lickert-type scale as another method to assess systems thinking as a distinct cognitive paradigm and validated his method by comparing the results with those of a modified version of CMAST (Randle 2012).

As another instrument for analyzing students' system thinking, Sommer and Lucken proposed the use of Concept Maps (CM) for this purpose (Sommer & Lücken 2010). Concept Maps consist of nodes, which stand for concepts, lines which link the nodes to each other usually with a specified direction, and phrases which are assigned to links and describe the specific relationship. The CMs, which can vary in structure, are external representations of mental models (Yin et al. 2005). In the CM method for assessing systems thinking skill level, the examinee is provided with a short story and asked to create a card for each concept in the narrative and connect every two related cards with a labeled link. This link does not necessarily have to represent a causal relation. A number of studies have implemented this method of assessment for systems thinking skills. Sommer and Lucken suggest a framework of using CM to assess the level of systems thinking skill based on the System Thinking Hierarchical (STH) model (Assaraf & Orion 2010).

Brandstadter et al. tested the effectiveness of different CM practices in measuring systems thinking skill level (Brandstädter et al. 2012).

An assessment method employing question sets to assess systems thinking skills is proposed which addresses the above mentioned issues and can be regenerated using the offered guideline.

Classification of Systems Thinking Skills

In order to properly define systems thinking, different studies have presented models which break the systems thinking skill down to its building blocks. The System Thinking Hierarchical (STH) model offered an eight level hierarchical model in the specific context of Earth Systems (Assaraf & Orion 2005). Another hierarchical model was the System Thinking Continuum (STC) which argues that the different skills of systems thinking skill set lie on a continuum, starting from the simplest task of recognizing interconnections all the way to testing policies as the most advanced skill (Stave & Hopper 2007). Richmond, however, offers a non-hierarchical classification and suggests that doing good systems thinking means operating on at least seven thinking tracks simultaneously (Richmond 1993). Richmond's updated set of skills is as follows: 1. Dynamic Thinking; 2. System-as-Cause Thinking; 3. Forest Thinking; 4. Operational Thinking; 5. Closed-Loop Thinking; 6. Quantitative Thinking; 7. Scientific Thinking (Richmond 2000). These seven skills complement one another in that each one is used at a different point during the design of a systems thinking intervention (Richmond 2000).

As a basis for assessment, a classification of six skills is employed, mainly based on Richmond's model combined with ideas from the STH and STC models and also systems thinking definitions by Sterman and Senge, but simplified more deeply to the building blocks of systems thinking (Sterman 2000; Senge 1990). This classification is specifically designed for the purpose of assessment, since employing this classification provides the opportunity to clearly isolate the skills from one another in the assessment process and results. The following is a brief explanation of the six different skills in this classification.

Dynamic Thinking

Dynamic thinking is the ability to see and deduce behavior patterns rather than focusing on, and seeking to predict, events. It is thinking about phenomena as resulting from ongoing circular processes unfolding through time (Richmond 1993). It enables us to frame a problem or issue in terms of behavior over time. Dynamic thinking contrasts with Static Thinking (cross-sectional thinking), which leads people to focus on particular events, rather than on the longer term patterns within which such events reside (Richmond 2000). Dynamic thinking suggests that the time horizon of our mental models should be wide enough in the past to see how the problem has emerged and also it should be expanded enough in the future to show delayed and indirect effects. Although it seems obvious that everything is changing; people usually tend to take note of the events instead of the gradual changes that cause the events. For example, if someone is asked "Is everything changing?", the probable answer will be "Yes, definitely". However, Dynamic thinking is acknowledging this gradual change in the process of one's thinking.

Cause-Effect Thinking

In classical causality literature, x is said to have a causal effect on y if the following three conditions are met (Kenny 1979): (a) y follows x temporally (b) y changes as x changes (and this relationship is statistically significant) (c) no other causes should eliminate the relation between x and y. Cause-Effect thinking, on the other hand, is the ability to identify if two concepts are related, determine whether two related concepts are correlated or have a causal relationship, and in case of a causal relationship distinguish between the cause and the effect. Causal relationship means that if all other variables are constant, by changing the cause, the effect changes. It is very important to consider that cause and effect are not close in time and space (Senge 1990). In other words, the problem and its cause may be separated in terms of time and space.

System-as-Cause Thinking

System-as-cause thinking is to view the structure of a system as the cause of the problem behaviors it is experiencing rather than seeing these behaviors as being foisted upon the system by outside agents (Richmond 1994). It is usually possible to see any situation as caused by "outside forces". Such forces certainly exist, and certainly have an impact on performance. But it is also usually possible (and almost always useful) to ask, "What did we do to stimulate those forces, or to make ourselves vulnerable to them?" (Richmond 2000). This skill can help you determine which underlying set of relationships are most relevant for improving the behavior pattern of interest. System-as-cause thinking encourages us to view the system itself as the cause of the behavior it is exhibiting (Richmond 2000). As opposed to the notion of “The enemy is out there”, System-as-cause thinking looks to the internal structure for the cause of behaviors.

System-as-cause thinking is referred to as “the endogenous viewpoint” by Richardson. Endogenous viewpoint suggests guidelines for thinking: it tells us to try to understand system dynamics as generated from within some conceptual, mental boundary (Richardson 2011). In other words characteristic modes of behavior are created by interactions within the boundary. Richardson also states that systems thinking is the mental effort to uncover endogenous sources of system behavior.

Another term commonly used to describe the same concept is decentralized thinking (Resnick 1996). When trying to comprehend patterns, people tend to attribute order or coordinated behavior to a centralized source of control, even when there is none. Contrary to this centralized mindset, appreciating that coordinated behavior can occur as a result of simple localized interactions among simple parts of the system is what comprises decentralized thinking.

Forest Thinking (Holistic Thinking)

Forest thinking is the “view from 1000 meters”. It gives us the ability to rise above the local trees. It enables us to view the links connecting the different parts of the forest. Mental models that derive from a Forest thinking perspective help us to rise above the details and craft above the silo solutions. By viewing a system “from 1000 meters” we can see how relationships that may extend far in space or time can be contributing to a local outcome (Richmond 2000).

Another dimension of Forest thinking goes back to the definition of system. System is any group of interacting, interrelated, or interdependent parts forming a complex and unified whole that has a specific purpose. Without such interdependencies, we have just a collection of parts, rather than a system (Kim 1999). The key point to remember is that all the parts are interrelated and interdependent in some way. Systems have properties that are not sum of those of their elements, known as Emergent Properties, i.e. properties which cannot be observed in any one element in a system and arise from the interaction and interrelationship between elements. Separated parts of a car engine, for example, do not possess the properties of the engine. Hence, in order to obtain the proper understanding of a system, it is necessary to consider the interrelationships within the system.

Closed-Loop Thinking

Closed-loop thinking helps to recognize causality as an ongoing, interdependent process, rather than a one-time, one-directional event caused by independent factors. Closed-loop is the opposite of Straight-Line view of causality. The assumptions behind Straight-Line view are that (1) causality runs only one way -from "this set of causes" to "that effect," and (2) each factor is independent of the other factors (Richmond 2000). Closed-loop thinking means appreciating the fact that causal relations do not run one way; instead, they are reciprocal and usually form loops (Richmond 1994). Thus, Closed-loop thinking is acknowledging that our current situation is the result of our past decisions and the decisions we make now form our future state. The "ongoing process" orientation associated with closed-loop thinking raises our awareness of unintended consequences (Richmond 2000).

Stock-and-Flow Thinking

Stocks are accumulations which characterize the state of the system and generate the information upon which decisions and actions are based. Stocks give systems inertia and provide them with memory. They create delays by accumulating the difference between the inflow to a process and its outflow. It is important to note that the content of a stock can only change through its inflow or outflow and without changes in these flows, the past accumulation into the stock persists (Sterman 2000). Stock-and-flow thinking is the ability to differentiate between stock and flow variables and to acknowledge that the only way to change the value of a stock variable is changing the net flow of it and this can only be achieved with delay.

Developing Evaluation Questions

The common methods for assessing systems thinking skills seem to be all impractical or biased when it comes to testing large numbers of examinees. Those methods consisting of interviews or recordings of behavior end up taking a huge amount of time to carry out and even more resources to grade; such as the VPA method (Maani & Maharaj 2004). Other methods which gather data through self-assessment clearly suffer from the kind of bias which is attributed with self-assessment data (Huz et al. 1997; Cavaleri & Sterman 1997). Moreover, most common methods focus on assessing the skill level of the examinee on only one or two skills out of the set of 6 or 7 different skills (Sweeney & Sterman 2000; Plate 2010). The few methods which use a classification of skills state no specific strategy to separate the skill levels from each other (Plate 2010). Question sets, the proposed method of assessing systems thinking skills, can be employed to address the above mentioned concerns. Question sets are easily expandable to large numbers of examinees and the interpretation of the answers and the marking of results consumes significantly less time and human resources than the alternative methods. In an assessment using question sets, the different systems thinking skills can be easily isolated from each other and also from other irrelevant parameters such as appearance or presentation skills. Furthermore, a standardized method of interpreting and grading the answers to the questions can be achieved to minimize marking biases. It will be demonstrated in details that coming up with new question sets to assess different systems thinking skills is a simple task, based on the guideline presented here.

The proposed method of assessment consists of a set of 6 questions, each targeting one of the systems thinking skills discussed above. Each question starts with one or two paragraphs narrating a series of events in the form of a short systems-related scenario. The scenarios are formed in a way that the systems thinking skills are isolated from each other. Each of these scenarios have a structure, i.e. the dynamic model which describes the dynamics and behavior of the scenario, independent of the context and elements used in the question. Once a specific question is at hand, targeting one of the systems thinking skills, a new question for the same target skill can be derived simply by keeping the structure of the scenario and changing the context of the story and the elements in the dynamic model. Therefore, identifying the structure of a skill and the structure of its corresponding question are the bases of creating new question sets. The following step is to rewrite the question in the new context and its elements. This has to be done with a few rules kept in mind, in order to arrive at a well-formed question (Table 1). What follows is the detailed explanation on the structure of each systems thinking skill and its typical question.

Developing Evaluation Questions for Dynamic Thinking

Based on the definition of Dynamic thinking, a Dynamic thinker is one who can notice gradual changes and successfully perceive trends and behavior patterns which are spanned in time. The first type of questions targeting this skill consist of a decision making question offering two options. The current state of the first option is better than the second, however, the second one has been progressing and may become better in the future. The examinees are expected to choose between the two options explaining their reasons.

Example: Kramer was looking into some real estate options to invest in. Two of his realtor's offers seemed more interesting to him: the first one was a small house located close to the heart of the city where real estate is valuable, and the other one was a large house in a less expensive but emerging neighbourhood. If you were Kramer, which one would you choose?

Answer: A typical correct answer includes the consideration of the changes over time and the fact that the value of the different choices may vary differently as the time passes.

Table 1. The rules to be kept in mind to obtain well-formed questions

Tip	Brief Description	Example
1. The examinee should not be able to answer the question with skills other than the target skill.	The question should be in such a way that no skills other than the target skill helps the examinees to answer the question correctly.	If in a dynamic thinking question, the state of alternatives are plotted or tabulated, examinees may employ their mathematical skills to find the trends and the correct answer.
2. The examinee should not be able to answer the question with past experiences.	If the answer to a question adjusts to experiences the examinees have, they will be able to answer the question using their experiences instead of the target skills. Hence, it is advised that the environment and circumstances created by the question not be fully accordant to an actual occurrence.	Imagine the widespread news of a sports team which has recently risen from low ranks to fame and success. If the answer to a question relates to the possibility of such an occasion, the examinees may take advantage of their recent acquaintance with the issue to answer the question, instead of employing their systems thinking skills.
3. The question should not have multiple correct answers	It is possible that a particular answer to a question is expected, while the question may have other correct answers too. If multiple ways of answering were possible, the question should be modified in such a way that the unintended answers would no longer apply.	The question may ask about the reasons of the fall of a king, and an unintended answers may be "*the unethicality and dictatorship of the king which sealed his doom*", instead of the dynamics which has caused the fall such as reduction in supporters, and civil unrests.
4. The examinee should not need other skills to arrive at the correct answer.	If the examinees fail to answer the question, the reason should not be the lack of skills other than the intended. One should make sure that the only required skill to answer the question correctly is the target systems thinking skill.	Questions with complicated plots may not be appropriate for elementary school students, since they probably do not possess plot analyzing skills.
5. The context and appearance of questions should be both comprehendible and attractive to the selected group of examinees.	Unless the questions are made visually and intellectually understandable and attractive, the examinees will not take the questions seriously enough to spend the necessary time and effort. Based on the age, level of education and experience of the examinees, the context and vocabulary of the question should be selected carefully.	Intercompany and intracompany issues, or matters concerning university admissions, universities, and such complicated issues have no attraction for children. Alternatively, including pictures and drawings make the questions interesting to young children.
6. The question should not directly refer to the quiddity of the target skill	Most of the systems thinking skills become trivial subjects once brought to the examinees' attention and thus, a direct reference to the quiddity of the target skill somehow places the answer into the question itself.	In dynamic thinking questions, reference to the passage of time and changes over time, may attract the examinee's attention to the dynamic features of the question which makes the question trivial. Similarly, in a closed-loop thinking question, reference to the fact that a solution presented by an individual may result in unintended consequences, causes the same situation.

In the second type of questions to assess this skill, a person who pays little or no attention to gradual changes in the environment should be characterized. His/her disregard for the change causes problems and/or weaknesses in his/her performance. The question asks the examinees to comment on the causes of the problem or to express what they think should have been done to prevent the problem from happening.

Example: The grassland has been the habitat of a pack of mighty lions for many years. The first time that the lions encountered a hyena in the grassland, they did not take the creature seriously. Back then, hyenas only ate the remains of lions' preys, which even helped with keeping the grassland clean. The lions were surprised to see a pack of some hyenas hunting zebras. Despite a few lions being unsettled about what they just saw, their queen asserted that: "The loss of a bunch of zebras is not a big deal". However, one of old lionesses claimed that the hyenas will cause problems in near future and they should be kicked out from the grassland before it's too late. Why do you think the old lioness thought this way?

Answer: The correct answer should include the notion that the hyenas may not be a manifested problem at present, but passage of time may cause their numbers to grow and them to grow into a large problem for the lions

Developing Evaluation Questions for System-as-Cause Thinking
A System-as-cause thinker is one who includes the system itself in the possible causes of the behavior the system is exhibiting. This means that, observing a complex outcome of a system, a System-as-cause thinker acknowledges that the observed behavior can be caused by the dynamics of the system rather than a specific agent's decisions and acts. Such a person, when encountering a problem, starts his/her approach to the problem with trying to identify the system creating the problem behavior. The corresponding question of this skill pictures a problem or a desired outcome created by system structure which is attributed to some agent by the observer. The examinees are asked to comment on this observation.

Example: A fly who was watching the bees at work noticed the order in their activities and how they were managing to achieve so much by working with discipline. As he was comparing the bees' colony with his own family he thought to himself that the bees must have a really good queen and if the flies had such a good leader they would have been able to live a good life too and maybe even be productive like the bees. Why do you think he was wrong?

Answer: A typical correct answer should include a notion of the fact that the order in the bee colony is a result of the system structure established among them rather than the queen leading them.

Developing Evaluation Questions for Cause-Effect Thinking
As defined before, one who excels in the skill of Cause-effect thinking can distinguish the causal connection between two phenomena, even if they are separated in time and space. The corresponding question of this skill consists of a problem which originated by a main cause. The main cause of the problem is ignored by the main character of the question, and he/she identifies other things as the cause.

Based on this wrong identification, the person proposes a solution to the problem. Then, the examinees are asked to comment on the proposed solution or state the mistake made in the deduction process.

Example: In the past few years, the Indian tribe has been experiencing rough times due to shortage of food. The tribe holds a Hunters Contest every year and all the tribe's eligible youngsters participate in it. Although only the most competent of the contestants are chosen as hunters, what the hunters bring back to the tribe is not enough. Exaybachay, the head organizer of the contest, claims that the new generations of the tribe are too lazy to work hard on hunting exercises. On the contrary, the old wise leader of the tribe believes that the youngsters are not lazy, and the reason of this problem must lie somewhere else. What mistakes do you think Exaybachay have made?

Answer: The examinees are expected to note that the cause of such a problem is not necessarily the young hunters being inept, or the difficulty level of the contests, but another reason may be the main cause of this effect such as the decreased number of animals to hunt.

Developing Evaluation Questions for Forest Thinking (Holistic Thinking)

A Holistic thinker, as described earlier, is a person who is capable of distancing from a phenomenon and above its details to observe the relationships and links connecting different parts of the system. In the corresponding question of this skill a situation is presented in which some or all the elements of a system improve; however, the behavior of the system not only does not show an improvement, but also worsens. The question asks the examinees to explain why this has happened.

Example: The Reds team demonstrated the most inspirational performance possible in their last season. They had a number of young motivated players who were not really famous; however, their team effort stunned all the sports fans. They were the underdogs of the league and they managed to perform amazingly against all the big names. When their extraordinary season ended with them placing third in the league, the rich owners of the team pressured the coach to acquire a few stars to replace the less outstanding members of the team. They carefully picked these players and although the coach did not agree with them at first, he was finally forced to go along with the plan. Everyone expected so much of the team with the newly added stars, however, the team's performance was nothing close to their last year's. Why do you think the team could not perform as well as their previous season?

Answer: The correct answer should include the notion of the nature of the team being more than just its members; i.e. a team's performance does not necessarily improve when the elements are improved without taking the relation between the elements into account.

Developing Evaluation Questions for Closed-Loop Thinking

A Closed-loop thinker is one who understands that every decision and action has unintended consequences which are responsible for shaping the situation in which future decision making takes place. The question to assess this skill pictures a solution chosen to address a specific problem; however, the unintended consequences of the solution have not been taken into account in the decision making. These consequences come back to worsen the situation and the examinees are expected to comment on the source of the deterioration of the system status.

Example: A farming village was facing a pest problem due to two different bugs: green and red bugs. The green bugs fed on the red ones as well as the crops and thus, the population of green bugs exceeded the red bugs and accordingly were the main cause of crop loss. The villagers gathered to find a solution to protect their crops against the green bugs. They used a special pesticide to destroy the green bugs; yet, after a while, their crops was still being destroyed. What do you think was the reason?

Answer: Examinees are expected to note that the farmers' decision to wipe the green bugs affects the future state of the problem, i.e. the number of the red bugs.

Developing Evaluation Questions for Stock-and-Flow Thinking
A Stock-and-flow thinker is one who is capable of distinguishing between stock and flow variables and understands that stock variable cannot be changed directly but rather through changes of flow variables and with an inherent delay. To assess this skill, the question can picture a situation in which a stock variable has caused a problem; however, the problem is not taken seriously because of its small magnitude. In this case, the large flow variable, causing the problem to grow, is ignored and not after long the situation is out of hand. Alternatively, the question can describe a situation in which changes in a stock variable is desired. To achieve such a desired change, one of the flow variables changing the stock level is mistakenly ignored and only one of them is taken into account, thus, causing an unimproved situation. The examinees are asked to explain why the desired situation is not achieved.

Example: In the beautiful city of Oran, which was always filled with tourists, a new problem was emerging: rats! The city was filled with rats who were gradually eating up everything. The kind mayor of the city, who was concerned about his citizens and the city's tourists, required his assistant to find a solution to the rats problem. The assistant worked hard to find a poison that most of the rats, except for a few, were drawn to its scent; they would eat it and die shortly afterwards. The number of rats had become so high that the mayor approved the idea instantly.

The rats ate the poison and died soon after. When the people got rid of the dead rats in their city, they organized a big celebration and thanked their kind mayor for his efforts. Although no other rats had entered the city from outside and the problem seemed to be solved, it did not take very long before the city was once again filled with rats. Why did the number of rats grow back again?

Answer: A typical correct answer should take note of the birth rate of the rats and the fact that the number of rats will grow rapidly because of the rate governing this state variable.

Conclusions

A systems thinking assessment method is proposed which consists of a question set, each of its six questions assessing a systems thinking skill of the six skill classification of systems thinking. This method can be applied to large numbers of examinees as the interpretation of the collected data is less time and effort consuming than the common assessment methods. Also, using the guideline presented, the question set can be replicated to obtain new sets of questions.

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