Exploring the usefulness of a systems-based model from the perspective of biology students

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This study explored students' opinions about a systems-based model and its usefulness in terms of teaching and learning biology. The sample included 55 female college students aged 18-20 years, studying biology in two different colleges in Abbottabad, Pakistan. A two dimensional systems-based conceptual model was developed involving the notion of systems thinking, specifically the idea of levels of biological organisation. This model was used during and after the two teaching sessions. Students' opinions towards this systems-based model were collected through questionnaires and also through students' group presentations. The findings indicated that the systems-based model was found helpful by the students in a number of ways. These included retention and easy recall of information, organisation of thought, arrangement of information, development of their mental models, internalisation of the concept of levels of biological organisation and thinking in terms of levels of biological organisation. On the basis of the findings a systems-based model is recommended as an effective educational tool in biology education. However, the extent of its impact on students' learning has yet to be explored. This study also has identified some issues for further future research in biology education.

INTRODUCTION

In science education, different types of teaching aids are used by science teachers. Models are one of these aids to facilitate the process of learning. However, in spite of such endeavours, science education is often reported to be fragmented, promoting a view of knowledge which results in incoherent learning (Gulyaev *et al.* 2002). To deal with this fragmented learning and also to cope with the complexity of the biological systems (Capra 1997), it has been recommended that systems thinking should be used as a teaching and learning tool (Chandi 2008; Knipples 2003; Verhoeff 2003). This article reports on students' opinions about systems based model which employed the idea of systems thinking as a teaching and learning tool.

MODELS AND SCIENCE EDUCATION

The educational importance of models has been so extensively argued in science education that it has even been stated that it is quite impossible to teach and learn science without using models (Harrison & Treagust 2000). The reason for this is that science teaching and scientific discourse deal with two types of objects: firstly, the things that belong to the everyday world and thus are familiar, their meaning rooted in direct experience and defined by commonly accepted conventions; secondly, unfamiliar things belonging to a different world - scientific world - such as genes, microbes, ecological niches, atoms, entropy etc. which are either microscopic and macroscopic objects/entities or abstract concepts which are defined within the scientific community, their use often being different from everyday life. Thus, a variety of invisible and intangible entities are dealt with in science education which are either too small or too big to be directly experienced and which need to be grasped at a conceptual and abstract level. Hence, it is important that someone has to do the imagining before the explanation of the scientific phenomena (Boohan 2002; Harrison & Treagust 2000).

This does not mean that students' minds are a *tabula rasa.* They bring with them their backgrounds, their own mental models and their thinking patterns (Zohar 2004; Gilbert *et al.* 1998). It is well known that learners construct their own imagined worlds but it is also argued that these may be different from the world of science. Their conceptualizations may be incomplete, unscientific, without firm boundaries and parsimonious with little explanatory power (Norman, 1983 in Harrison & Treagust 2000). Therefore, it is very important to help learners to imagine the world in the way that science sees it and which can assist them in developing coherent understanding. To make more accessible what is difficult to imagine, models are used with the purpose of bringing out the imagined world (Amos & Boohan 2002; Ogborn *et al.* 2002). Models can be of different things such as objects, ideas, events, systems or processes (Gilbert *et al.* 1998).

In science education, different types of models are used: dynamic models, static models, two dimensional and three dimensional models, physical models, computer modelling and simulations (Amos & Boohan 2002; Ogborn *et al.* 2002; Mayer 1989*;* Harrison & Treagust 2000; Van Driel & Verloop 2002; Gilbert *et al*. 1998; Justi & Gilbert 1999). Models have been categorised from different perspectives such as that of appearance and function. Van Driel and Verloop (2002), quoting Gilbert 2000, characterized three types of models from the perspective of function: descriptive (to describe processes and object), explanatory (to explain phenomena in terms of causal or evolutionary relationships) or predictive (to predict the course of an event or its transformations). Similarly, keeping in view the role of models in science education, models have been classified according to their different types. These include scientific consensus modesl, curricular models, teaching models, mental models and expressed models (Gilbert, 2000 in Van Driel & Verloop 2002; Gilbert *et al.*1998; Justi & Gilbert 1999). The models which are used by teachers and textbooks to present science knowledge have been termed *analogical models* by Harrison and Treagust (2000). They have also presented an elaborate typology of analogical models reporting that they can be concrete, abstract or theoretical. These models can have different representational modes such as scale models of object; symbols, equations and graphs; diagrams and maps and simulations (Gilbert *et al.* 1998).

Mayer (1989) termed the text book models as *conceptual models* and defined as follows:

> A conceptual model is defined as words and /or diagrams that are intended to help learners build mental models of the systems being studied; a conceptual model highlights the major objects and actions in a system as well as the causal relations among them. (Mayer 1989: 43)

Gilbert *et al.* (1998) called such models *teaching models.* In this study, a traditional, two dimensional model building approach which is normally found in textbooks, has been employed to develop a model for biology teaching. Mayer's definition of a conceptual model (Mayer 1989) was adopted and used as a conceptual framework for the development of a systems-based model.

The effectiveness of the use of models in teaching and learning for sciences has been acknowledged widely. All the above mentioned models have been reported as very powerful educational tools, assisting teaching and enhancing learning (Amos & Boohan 2002; Ogborn *et el.* 2002; Mayer 1989*;* Harrison and Treagust, 2000; Van Driel and Verloop, 2002; Gilbert *et al*., 1998). For example, models have been found useful as organizational frameworks to teach a large number of otherwise isolated facts accumulated by science (Gilbert *et al*., 1998). Mayer (1989) supports the use of models by providing empirical evidence. Firstly, he observes that models help learners to improve their conceptual retention, and argued that conceptual models assist the learners to focus their attention towards the conceptual objects, locations and actions described in the lesson. Secondly, he reports that models reduce the verbatim retention by helping students to organise information to fit in with their own conceptual models. Thus, when they reorganise this information they are less likely simply to repeat the words. Finally, he concluded that students can answer questions related to that particular concept presented in the conceptual model even if the information is not directly present in the text or in the model.

Apart from being helpful in developing understanding, it has been reported that students can learn to think and work scientifically through models. Moreover, exposure to models helps students to build and manipulate their mental models of abstract and non-observable phenomena (Harrison and Treagust, 2000). It has been argued that models bring changes in the way students perceive the text and think of it. In this regard, Mayer has commented that *'conceptual models for scientific text can lead to change in the way that students think about the material'* (Mayer; 1989: 59). Models have also been pronounced as thinking tools. They have been shown to work as memory-aids, explanatory tools and learning devices if they are sufficiently straightforward (Harrison and Treagust, 2000; Gilbert *et al.,* 1998). It has also been argued that image-based models are more memorable; their simplification and ready accessibility make less of a demand on memory capacity and thus reduce the load on both long and short term memory (Gilbert *et al.,* 1998).

Although the importance of models underpins their applicability in scientific discourse and science teaching, the underlying thinking pattern is also important for influencing and shaping students' thinking. Systems thinking has been specifically suggested for biology education (Chandi, 2008; Knipples, 2002; Verhoeff, 2003). The aim here is to explore the educational importance and usefulness of systems thinking in biology teaching and learning. Before addressing this, the rationale for bringing the notion of systems thinking in the development of model is discussed.

SYSTEMS THINKING AND BIOLOGY EDUCATION

Although it originated from the field of biology (Bertalanffy, 1965), systems thinking has been traditionally defined in the fields of engineering, societal organisation, and business (Assarf and Orion, 2005). It has been used in a number of disciplines but little is known about systems thinking in the context of science education (Assarf and Orion, 2005; Keli *et al.,* 2003). Recently, it has caught the attention of biology educationists but still very few studies exist regarding biology education and systems thinking, notably those conducted by Knipples (2002) and Chandi (2008) in genetics and by Verhoeff (2003) in cell biology.

'Systems-thinking' is defined in different ways in different disciplines, acquiring also different meanings in different contexts. Even within the same discipline, there is a great diversity and variability of meanings and uses as well. Thus, there is no consolidated tradition in the way systems thinking is employed and this accounts for a certain degree of openness in the way systems thinking can be used for the development of systems-based teaching and learning materials. However, there is a common feature regarding its definition, even in different disciplines. This feature is the aim to bring coherence and integration into the study and research of whatever system is involved to develop better understanding about the nature and function of a system. It is argued here that the definition or elements of systems thinking determine the elements of systems-based educational material. Although the elements of systems thinking are context specific, nevertheless there are some common features as well. In different educational contexts, specific features of systems thinking are used. For example cyclic thinking is applied in earth science education (Assarf and Orion, 2005; Keli *et al*., 2003; Gudovitch, 1997) to explain repeated patterns of activity, whereas horizontal and vertical thinking has been used in biology education (Knipples, 2002; Verfoeff, 2003; Chandi, 2008) to develop awareness of structural organisation of living entities.

In the present study, the intention was to develop a model which would help learners to see the whole, the components and the links between them in the context of the phenomenon of transposition. To do this, the major elements of systems thinking, the notion of levels of biological organisation (LOBO), was employed in developing a systems-based model.

The importance of the notion of levels of biological organisation (LOBO) in biology education has been highlighted in previous studies. It has been argued that the confusion about levels (Wilensky and Resnick, 1999), along with a lack of ability and willingness to interrelate these levels causes problems in developing coherent understanding (Verhoeff, 2003; Knipples, 2002). However, this type of confusion is not restricted to any particular domain or subject.

Verhoeff (2003) and Knipples (2002) pointed out that many conceptual problems in biology at organismic and cellular levels are associated with interrelating the different levels of biological organisation. Similarly, the same kind of problem has been reported in chemistry. Miller (1990) and Meijer (2005) also highlighted the problem of establishing the links between micro and macro levels in explaining the macroscopic phenomenon where microscopic particles are involved. Similarly, Wilensky and Resnick (1999) argued that peoples' misunderstanding of different world phenomena can be traced back to a confusion of levels. This confusion starts from the classroom. It affects students' understanding in their formal study but it also has a wider range of influence resulting in misconceptions about their experiences of daily life. It means that there is a fundamental organisational structure in every domain with different levels which needs to be understood for comprehending the system.

Different types of levels can be recognised in a domain depending upon the type of systems or organisation or subject matter one is dealing with. Wilnesky and Resnick (1999) have highlighted three different approaches about the concept of level, depending upon the type of system or organisation. They have also reported the importance of understanding the levels by saying that it can enable people to use levels as a framework for seeing systems from multiple perspectives; it can transform learners' views about systems, and can help them to develop better causal accounts of the interaction and relationships among the various elements of the system.

In this study, the educational features of modelling and the concept of levels of biological organisation have been coupled together to produce a conceptual model described here as a systems-based model. This model is a diagrammatic representation, showing different levels of biological organisation, their components and their relationships. It is essential that biology education reflect the ideology regarding the nature of biological systems which have been presented elsewhere (Chandi 2008). Although the model used in this study does not reflect all the aspects of living systems, the systems-based model used here, at this introductory stage, reflects only the nested (hierarchical) and open nature of biological systems. The nested nature was presented by using circles within the circles along with arrows. Similarly, to show and emphasise the open nature of biological systems, broken lines were used, along with the directing arrows. At this stage, the nature of the living systems and the links between the levels and components is also an indication about the complex characteristics of biological systems. Furthermore, a brief textual summary was added to explain the relevance of systems thinking. The model was named as a systems-based model because it reflected the elements of systems thinking: levels, the whole, the parts and their links, explicitly (see figure 1).

It was a general systems-based model which only reflected the nature of biological systems. The intention behind the development of a systems-based model was that of making students aware of the levels of biological organisation. However, the implicit assumption which supported this study was that a systems-based model could supplement and reinforce the idea of thinking in levels (systems thinking) by presenting explicitly a model within the framework of levels of biological organisation. It would also provide a simplified and structured visual representation of biological organisation so that it could readily be understood by the students. In addition, it would also provide students with a cognitive framework for thinking in levels. This model intended to explain explicitly the relationships between the different elements and the levels of biological organisation for coherent understanding.

However, a specific model for the phenomenon of transposition in corn seed coat was also developed (Figure 2). The selection of this topic was based on a survey which showed that students found the phenomenon of transposition particularly difficult (Chandi 2008). Hence, this topic was selected to employ the idea of systems thinking as an educational tool to see if this approach was helpful from the students' perspective. Moreover, the phenomenon involves a number of levels of biological organisation lending itself easily for systems approach (Figure 2).

Figure 1: General systems-based model

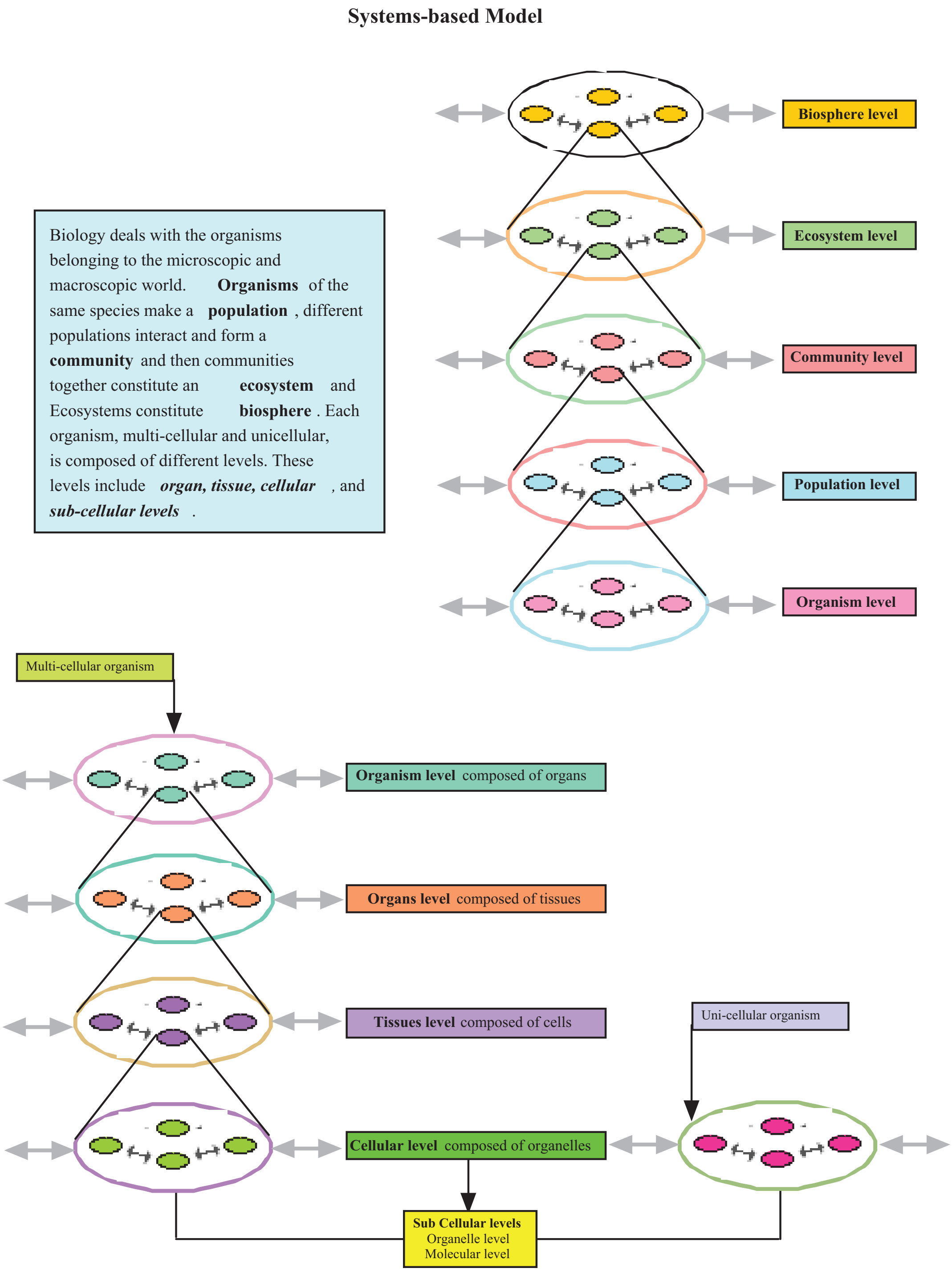
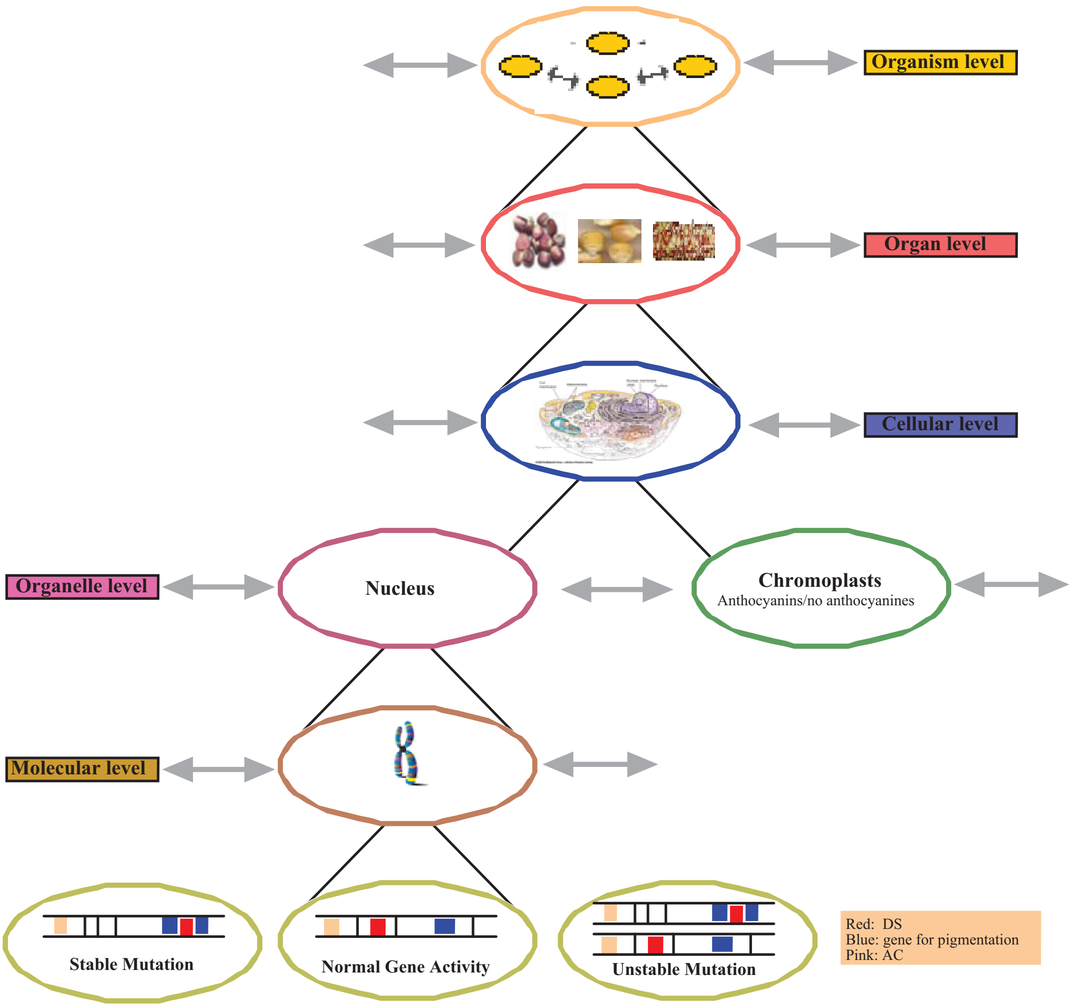


Figure 2 Systems-based model for transposition in corn seed.

Corn Seed Coat and Transposition

In thinking about the corn seed, it is helpful to see the many levels.
Understanding at various levels often allows us to make sense of what is happening at other levels.
Here is a picture to help.
Things happening at one level may have influences on the other levels.



METHODOLOGY

Objective of the research

This study was a part of a much large research project but only one aspect of this project is presented here: the potential usefulness of a systems-based model from the perspective of learners. The main objective of this paper is to explore students' opinion towards systems-based model. The fundamental research question is: *how do these students respond to a systems-based model?* Basically the study is exploratory in its nature and specifically, it explored in what ways this model has been found helpful by the students' in their learning of the phenomenon of transposition in corn seed.

Research design

A group of 55 biology students from two government female colleges in Abbottabad (North of Pakistan), aged 18-20, was involved. Government colleges in Pakistan are gender specific and it was easy for the researcher to have access to female colleges. Primarily, the study was exploratory and there was no intention to compare the responses of the participants from the two colleges. Thus, the participants from both colleges were treated as a single cohort.

The systems-based model had two versions, a general systems-based model (figure 1) and a specific systems-based model applied to the phenomenon of transposition in corn seed (figure 2). The two models were presented in two teaching sessions respectively. The systems-based models were not only used as a teaching tool but also in a work sheet for asking questions and supporting students' understanding of the phenomenon of transposition and the speckled corn seed. Hence, it was like scaffolding for thinking in levels of biological organisation.

To answer the research question, two data collection techniques were used to explore students' opinions about the usefulness of systems-based model in their learning. Firstly, a survey was conducted by using a self-administered questionnaire. This involved questions where responses from *strongly agree* to *strongly disagree* were used (see Likert 1932). The data gathered are ordinal in nature and were handled accordingly by using descriptive statistics (Mbajiorgu & Reid 2006). Secondly, students were divided into groups and were asked to discuss and present their collective opinions about the usefulness of the systems-based model in terms of learning and understanding the phenomenon of transposition. Thus, the exploration involved a combination of quantitative and qualitative approaches, each of which was used to enrich the other (Reid, 2003). The complementary nature of the two approaches has been demonstrated by those who have used the mixed method approach and have actually shown that integration of these two traditions within the same study has the ability to augment the findings (Sosu *et al.* 2008). Creswell (1994) argues that mixed methodology adds expansion to the scope and breadth of study by bringing richness and detail to study. Moreover, complementarity has been suggested by Green *et al.* (1989, in Niglas, 2000) as a way of using mix method approach. By complementarity, they mean clarifying, illustrating, interpreting the results from one method using the results from the other (Creswell 1994; Niglas 2000).

The data from the questionnaires were summarised to give the pattern of responses for each statement. These were converted into percentages for clarity (table 1). Although the questionnaire contained fourteen statements, four looked very specifically at the systems-based model and how the students saw this in terms of their learning (results shown in table 1). Only the pattern of responses for these statements is discussed here.

Students' group presentations led to the collection of in-depth information regarding the usefulness of a systems-based model. The researcher used a set of seven main questions, these being designed merely to initiate discussion. One of the questions focussed specifically on the perceived usefulness of the systems-based model. In the event, discussion flowed freely and the students' presentations were digitally recorded, translated (as it was bilingual, Urdu and English) and then fully transcribed.

The transcripts were then analysed and all the key phrases and comments related to the system-based model were highlighted and extracted to give an overall view of how they saw the value of this approach in understanding the transposition phenomenon. In the discussion below, quoted students' comments are coded to show the group and the college: eg *g1c2* means the quotation came form group 1, college 2.

RESULTS AND DISCUSSION

The benefits of a systems-based model regarding different aspects of learning are evidently clear from students' responses to the survey statements and also from their presentations. The four statements which explored students' opinion and the pattern of responses towards these statements are presented in table 1.

Table 1 Students' responses towards the systems-based Model

		Strongly agree	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
		%	%	%	%	%
1	*I found the model useful for visualising the organisation of the living world.*	51	45	4	0	0
2	*The model helped me to organise my thoughts.*	50	38	8	2	2
3	*The model made me to arrange the knowledge in my memory.*	59	35	0	4	2
4	*The model helped me to think in terms of levels.*	69	29	2	0	0

With such high proportions selecting positive responses, the systems-based model approach seems to have had a positive impact. The model was found to be a useful framework to visualise the organisational structure of the living systems and also for the organisation of their thoughts.

It is also clear that students believed that the model has been helpful in organising information. Students will have their own ways to arrange information in the memory but they indicate that the systems-based model provided a framework in the form of levels of biological organisation. A very encouraging response was observed towards the statement number four. Almost 70% of the students have opted for strong agreement which reveals their belief that the model has provided them assistance in thinking in levels. Thus, it can be deduced that the underlying thinking pattern of any type of teaching aids used in the classroom can make an effective impact on students' thinking patterns. In this case, the systems-based model has given some help in thinking in terms of levels. However, this observation of students' belief needs further empirical evidence in that this simply reflects what students are saying.

The group presentations throw further light on the observations from the questionnaire. In the analysis of students' presentations, two things emerged repeatedly. Firstly, they mentioned their opinion about the nature of the model and, secondly, they also mentioned how the model helped them in their process of learning.

The idea of levels was unknown to the students and the following quotes reflect this opinion.

> Idea about the relation of the levels was new. (g3c1)
>
> Arrangement of level was very new for us. (g1c2)
>
> We have never used models and were never taught about the idea of levels. (g4c1)

Furthermore it was stated:

> Such models were never in our minds and we never thought that biology could be presented in such a way which would be helpful in such a broadening way. (g4c2)

Their responses provide an indication of the approach to teaching and learning which has not made students aware about the nature of biological systems. They identified that the systems-based model presented biology in a broad way which suggests that students believed that the way they had been looking at biology was somewhat narrow. Similarly, the presentation of systematic flow and build up of information, and the properties of living systems (open, nested and hierarchical nature) in the model were recognised by them. Following quotes from students' presentation support it.

> It was step wise, you go in different small steps from smaller to bigger in order to collect scattered information from all levels in order to understand. (g3c1)
>
> Models were incredible, we liked them very much… they were showing boundary, open systems, components, levels, interactions, everything was summarised. (g4c2)

They identified that the model was clearly showing the whole picture of the content.

> Model ... was giving us almost the full picture. (g4c2)
>
> ... With the help of this model we could see the whole picture and now we can use this model for studying and understanding the other topics as well. (g4c2)
>
> They present the whole picture of the text in our mind and we can easily understand what is going on in the text. (g5c1)

More importantly, they also recognised and verbalised the pattern of thinking (systems thinking, in levels) which was the very framework of this model.

> Models... were according to specific pattern and it also arranged our thinking in a specific pattern. (g2c1)

Obviously, these features were incorporated deliberately in the systems-based model. However, more importantly, they recognised levels of biological organisation as a main requirement and a prerequisite to develop understanding in biology. It was mentioned:

> Different biological levels...the main requirement for the students to understand the common and difficult content. (g1c1)
>
> ...We got the basic idea and information, you had laid the foundation and we can build upon it. We can adopt it and use it for anything, any biological topic can be shaped like these units. (g3c2)

It is encouraging to find that almost all the features of a systems-based model which were intended to be explicit had been identified by the students.

The picture that emerged from students' comments also indicated different ways in which the systems-based model had been found helpful by the students in the process of learning. It is clear that the responses to the four survey statements outlined above are very consistent with the expressed views given in the student presentations. For these students, the systems-based model has been regarded as an effective teaching and learning aid in providing a framework for:

- Organising their thoughts;
- Dealing with the scattered information;
- Visualising what was happening;
- Thinking in terms of levels.

One group noted that:

> Models helped us in organising our thought and also enabled us to think in terms of levels and to understand the real concept of the topic, models made us familiar with the new topic easily and by this method we can pick the new concept of genetics and organise the things by means of the model from a single thing to whole systems, by the model we can organise our diagrammatic concept in mind. (g4c1)

The organisation of the information in a systems way and the presentation of the whole picture are connected together. If information is not knitted together and is presented as isolated pieces, then the picture does not appear. Reid and Yang (2002) found that bringing ideas together was extremely difficult in the context of open-ended problem solving. Systems-based thinking perhaps offers a mechanism for assisting in the process of bringing ideas together. However, students have found the model useful because it offered a unified picture of the system under consideration. This is consistent with what has been reported by Gilbert *et al.* (1998) that models can be used as a framework for holding the fragmented information together and it has been confirmed by the students, as they said 'With the help of this model we could see the whole picture' (g4c2). Students have also found the model useful in answering the questions and in drawing a diagram in their work sheets. 'It was helpful in answering the test questions and also in the diagrammatic representation in the work sheet... We can use it in other topics. We can understand what is happening at what level and we can use the representation as an example to be followed in the future…

‘(g3c2). Their recall of information is also consistent with what Gilbert *et al.* (1998) reported about the use of models to assist in having a quick access to the information stored in the memory.

The model was found helpful by the students to internalise the concept of levels of biological organisation and having such a framework has assisted them to develop their mental models: ‘It helped us to develop picture of the text in our mind’ (g2c2) and also ‘by model we can organise our diagrammatic concept in mind’ (g4c1). They also indicated: ‘Models were useful… we can understand, visualise, and recall and think according to this specific pattern’(g2c1). In line with such expressions, Harrison and Treagust (2000) have reported an effective use of a model in learning and teaching: development and the manipulation of the mental models.

Students’ opinions reflect that the underlying thinking pattern of the model has had an impact on them. It was mentioned:

> It has changed our thinking... we want to use this type of thinking with the other topics as well. (g2c2)
>
> ... now we can use this model for studying and understanding the other topics as well. (g4c2)
>
> Models were useful… we can understand, visualise, and recall and think according to this specific pattern. (g2c1)
>
> We can make models of the other difficult topics to understand in Diagrammatic form, we can see level, components and links between them. (g1c2)
>
> ... We can use it in other topics...we can use the representation as an example to be followed for the future… We can adopt it and use it for anything, any biological topic can be shaped like these units. (g3c2)

Students' opinion about their thinking is also supported by reports of Mayer (1989) and Treagust (2000) and Gilbert *et al*. (1998). They have described models as ‘thinking tools’ which can bring changes to the way students think about the text given to them. It was indicated:

> We liked the models because they helped us to understand the given content in the booklet and also to understand the vertical and horizontal relation and we come to know the levels of biological organisation from simple to complex and vice versa. We can visualise things given in the content in a systematic manner…We can understand the content which is given and can correlate with the model which help us in studying and imagining the thing which is given ...it is easier to understand the content with the help of model. (g3c1)

In the light of the results and discussion presented, a summary is derived about the usefulness of systems –based model and is presented here.

This systems-based model enabled students to

- See the whole picture
- Organise their thought
- Organise the information in a better way (a systems way)
- Develop their own mental models
- Think in specific pattern (more like a systems way)
- Visualise and imagine in levels
- Understand the content more clearly
- Recall information for answering questions
- Draw diagram in the test and work sheet
- Internalise the concept of levels of biological organisation and their links

It can be inferred that this system-based model has been demonstrated to be a framework for a number of things: thinking and imagination, presentation and arrangement of information and also in understanding the content given in the text. Students were also positive about the potential usefulness of such models for developing understanding of the other topics in genetics and even to use the model in their examination. Most of the comments made by them resonate with the observation that the model helped them in their learning processes by providing a way of thinking which is required for learning biology.

Some of the weaknesses of the model were also identified by the students. It was perceived as too simple and lacking in presenting the minute details of the sub-cellular levels. This is a valid observation but the model was developed with an intention to introduce the levels of biological organisation in a simplified way and the minute details were not the focus of the model. Nonetheless, it illustrates an important point: the students wanted to see things in more detail:

> It would be better to picturise the levels... we would like to see what is happening at the molecular and cellular levels... should be in detail. (g5c1)

They have indicated that this approach is beneficial in terms of developing their understanding, involving different aspects of learning, and also thinking in terms of levels. Thus, findings reflect a very positive educational implication of the model.

CONCLUSIONS

The aim of the study was to explore how students respond to a systems based model. Overall, the findings suggest a very positive answer to the research question as students' response towards the use of a systems-based model is very encouraging. It has been indicated above that two things were mentioned repeatedly in students' presentation: characteristics of the systems-based model and its usefulness in their learning. It has to be recognised that students indicated that the whole idea of levels was completely new to them. Apart from the idea of levels of biological organisation, students perceived other characteristics of the systems-based model as well. For example it was identified that,

1. There was a systematic presentation of information in the systems-based model.
2. There was a specific pattern of thinking.
3. There was a coherent presentation of the topic/concept (phenomenon of transposition)
4. There was a reflection of the properties of living systems.

Students' opinions also indicated that the systems-based model had a great impact on their thinking. Similarly, a willingness to employ the idea of levels in developing this type of model for studying and learning other topics in biology was also evident in students' comments. From their responses to the questionnaire and, even more clearly, their positive reactions during the group discussions, they clearly saw the value of this approach in a number of ways:

1. The systems-based model offered a framework to show the structural organisation (levels of organisation) and the nature (open, nested and hierarchical arrangement) of living systems, involving links between levels and their components.
2. It helped to present information in a systematic and organised way. In this way, knowledge may become more coherent. Part of this relates to visualisation, shown to be a very powerful feature of successful learning (Hindal *et al.,* 2008).
3. It offers ways to explain biological phenomenon from different levels of biological organisation and thus provide a broader view of the biology domain which is important for holistic biology teaching. It provides a fuller picture rather than one which is disintegrated or fragmented.
4. It offers a framework to think in a systems way. This also adds greater coherency as well as encouraging a specific thinking skill.
5. More specifically, systems-based model offered an assistance in presenting the unified picture of the topic thus enabling students in the understanding the text and also in answering the questions.

Of course, one short experience of systems thinking is unlikely to change the students' perceptions radically. There will be need to use such thinking consistently and its repeated use in the classroom will offer, reinforce and enhance the thinking pattern of students in a systems way (thinking in levels) which is appropriate for the domain of biology. Once students internalise and develop a framework for thinking in levels, then they can go on to use that framework to understand and explain the biological phenomenon at different levels. In this way, teaching that involves a systems-based model to explain biological phenomenon explicitly advocates and illustrates the importance of thinking in levels (systems thinking). The systems-based model approach can probably be used with many topics in biology; however, the framework of the model has to be filled with the information relevant for the explanation of the phenomenon under consideration. However, as levels of biological organisation play a vital role in almost all the topics involved in biology education, it is argued here that a systems-based model is suitable for teaching many biological topics.

The potential benefits in terms of retention of information, organisation of thoughts, arrangement of information, presentation of unified picture, thinking in levels, development of their mental models, and internalisation of the concept of levels of biological organisation may well make the effort very much worthwhile.

The very nature of biology where thinking in multiple levels is so important makes a systems approach appropriate. The evidence offered in this paper about the use of a systems-based model does suggest that the approach is welcomed by students of biology as a way to enrich their learning. It may offer a step forward towards finding a solution to the problem of compartmentalised teaching and learning which is typical of much biology education. It may also suggest a way to deal with the complexity of biological phenomenon.

Future Research

With only a few studies about systems thinking in the context of biology education, the study described here has only explored the potential benefits of systems-based model, as seen from the perspective of biology students. Much more research is needed to test and extend the findings of the present study and to take the research further in biology education with reference to systems thinking. Some immediate questions include:

1. To what extent does the incorporation of systems thinking in the model actually improves information retention, enable learners to think and visualise in levels as well as organise information in a systems way? Most importantly, does this approach actually bring about better understanding?
2. Is there any difference between the performance (understanding) of the students who used and those who do not use systems thinking models? This is a very difficult experiment to develop in that it very difficult to control all the variables while gaining a large enough sample. Nonetheless, this key work is vitally important to attempt.
3. The study here was limited to females. Other work has suggested gender differences related to ways of viewing of systems (Chandi, 2008). Is there a difference of perception among male and females about the systems-based model?

This study offers some hope that a system-based approach may have some potential in biology education in seeking to overcome some of the fragmented learning in an area of very considerable complexity. However, it does suggest an agenda for further work which may offer a clearer picture of the potential or otherwise of this approach.

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