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Towards Outcomes-based Practice in Science Education

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ABSTRACT

To advance the field of science education in general and biology education in particular. This study presents the development and evaluation of a teaching sequence for teaching and learning quality K to 12 science education newly implemented in the country. The study aimed to develop and evaluate a Constructively Aligned Teaching Sequence (CATS) on organ systems for K to 12 Senior High School Biology curriculum anchored on Outcomes-based Teaching and Learning (OBTL). This study anchor on the theoretical and methodological assumptions of educational design studies. The drawing method, researcher-made pretest/posttest, questionnaires, checklist, videotaped lessons, and recorded interviews composed the research instruments. The respondents were an entire class of 47 university freshmen and ten science instructors in one of the country's normal schools. Quantitative data were analyzed using relative frequency distribution, percentage method, nonparametric tests, and t-test. Thematic approaches examined qualitative data like student's drawings, interviews, and observations. Quantitative and qualitative data corroborate that the use of CATS contributed to the attainment of the students' learning outcomes. The study recommends further that CATS may be redesigned to strengthen correct conceptions, enhance limited conceptions, and remediate students' conceptions in conflict with the accepted biological concepts. CATS offers an innovative teaching material and an avenue for further research on its improvements such as construction, usage, handling, and storage of the organ system model outputs.

KEYWORDS

OBE, Science education, Constructive Alignment, Design studies.

INTRODUCTION

Implementing the K to 12 Enhanced Basic Education Program in the Philippines is a significant revision to align its educational systems with the larger majority of educational institutions of the world. The Philippines' educational system's reform includes Outcomes-based Education (OBE) as mandated by CMO No. 46, 2012 (ched.gov.ph). Therefore, for a Filipino child to compete internationally, the education curriculum ensures a mandatory kindergarten year and two additional senior high school years. Added to the former 10 – year education curriculum making the enhanced primary education curriculum 12 years.

As mandated, higher education is all committed to bringing outcomes-based education. An example of OBE is constructive alignment (Biggs 2014). OBE is mainly referred to by Biggs and Tang (2003, 2007, 2011) as outcomes-based teaching and learning (OBTL) to distinguish it from other OBE forms. Constructive alignment is the means of enhancing teaching and learning at the classroom level. Hence, OBTL was designed to enhance teaching and learning through reflective practice using constructive-alignment as the reflection framework. OBTL is concerned with curriculum design to ensure that the contents, delivery, activities, and assessments align to help students attain specific intended learning outcomes.

A constructive alignment is an approach to curriculum design that optimizes quality learning conditions (Biggs, 2012). According to Biggs and Tang (2009), there must be alignment. The teaching-learning activities (TLAs) and the assessment tasks (Ats) activate the same verbs as stated in the intended learning outcomes (ILOs). The ILO is a statement of what the learner is supposed to do and at what standard. The TLA is where students apply, invent, generate new ideas, diagnose, solve problems, and do other things they expected to do. The AT shows can the students use it academically and professionally appropriate ways. As pointed out, constructive alignment represents a marriage between constructivism and instructional design. The constructive alignment model combines a constructivist understanding of the nature of learning and an aligned design for teaching (Biggs 2003).

Literature shows various studies (Özsevgeç, 2007; Procop et al., 2006; Khwaia and Saxton, 2001; Reiss et al., 2001; Cuthbert, 2000; Texieria, 2000; Toyoma, 2000; Magtolis, 2013) on the understanding of human organ systems. These studies showed the students' knowledge and several erroneous ideas even after exposure to formal instruction. As in the other fields of science like chemistry and physics, reports in biology involve alternative conceptions. Specifically, of K to 12 Biology 2, Özsevgeç (2007) study listed topics studied extensively in biology. This report includes cells, respiration, photosynthesis, and genetics. Recent studies show students having problems understanding biology's key issues such as internal organs, organ systems, and their bodies' processes.

Several research pieces explored and employed varied methods on children's concepts about the human body for different purposes. A considerable literature now exists about using interviews or written tests with open-ended questions that may effectively elicit students' in-depth thinking. A substantial literature now exists about the use of drawings as a research technique in education. Drawings are simple research instruments for comparative studies at the international level (Reiss et al., 2001; Procop et al., 2006).

Several studies conducted in various countries imply that designing and evaluating teaching sequences can be a natural way to research science classroom education (Perez, Andrade & El-Hani, 2014; de Sά, 2014; Lawson, 2011; Nurkka, 2006; Leach etal., 2003). Given that, design studies have been gaining attention from researchers in education, as the study of Alzaghibi (2010) reported. According to Collins et al. and Gorard& Taylor (cited Alzaghibi, 2010), design studies are approaches to conducting research concerned with developing and testing teaching/learning methods, instructional materials, or software tools.

Studies of Gorard and Taylor and van den Akker et al. (cited in Alzaghibi, 2010) provided a comprehensive discussion about design studies. There were three characteristics: design activity, grand theory, and domain-specific theory, and multiple methods to gather various data sets. As described by these authors, the design activity like teaching innovations embodies the researcher's theoretical intentions, shaped and provided with general principles. The principles guide developing and testing the grand theories' design and testing in natural settings for its workability employing different methods to gather data. In this current study, innovation is the teaching sequence anchored on constructivism and OBE's grand theories using constructive alignment principles.

The curriculum restructuring calls for appropriate methodologies and innovative approaches to teaching and learning quality K to 12 science education and outcomes-based education. Cognizant of this challenge and as a biology teacher, the researcher intends to develop a research-based teaching sequence anchored on the principles of outcomes-based teaching-learning (OBTL) on organ systems.

This study intends to answer some of the challenges that couple the Implementation of the revised curriculum in science education in the Philippines, mainly using more effective curriculum material. Likewise, the developed teaching sequence will address teachers' teaching difficulties and students' initial conceptions on the topic. This study will contribute to the country's emerging literature on K to 12 science curriculum, outcomes-based education, and students' conceptions on organ systems.

Specifically, this study aimed to develop and evaluate Constructively Aligned Teaching Sequence (CATS) on organ systems for K to 12 Senior High School Biology 2 curriculum. The development of CATS considered the initial conceptions of the students and the content standards for Biology 2. The evaluation of the developed CATS focused on students' final conceptions and the teachers' evaluation.

This study anchored on the Theory of Constructive Alignment as the theoretical underpinning of Outcome-based Teaching Learning (OBTL), a version of Outcomes-based Education (OBE) intended to improve the quality of learning at the classroom level. Biggs and Tang (2004) developed the Theory of Constructive Alignment, a theoretical underpinning of OBTL, and a framework that translates some essential constructivism features into classroom decisions on teaching and assessment. The Theory of Constructive Alignment proposes that student attributes, intentions, and behaviors must be congruent with the learning environment's characteristics, demands, and preferences if effective learning occurs (Lawson, 2011).

The study aligned in education anchored on Constructivism as a theory for teaching and learning. Constructivism comprises views with implications to teaching and how learners learn. The Theory of Constructive Alignment served as the framework in the teaching sequence's instructional design for teaching organ systems. Thus, as constructivist views learners as active constructors of knowledge based on their existing experience, it may be done by providing carefully designed learning approaches. The constructive alignment theory enables learners to achieve learning as they should.

Materials and Methods

This study adopted the design research approach. Employing qualitative and quantitative methods for developing, designing, and evaluating an aligned teaching sequence on organ systems draws inputs from teachers and university students' concepts on the topic. The study's implementation was in one of the Philippine normal universities, which take part in curriculum reform with the Implementation of OBE as mandated by CMO No. 46, series 2012. The said university caters to students from both public and private schools all over the region.

The content validated proposed teaching sequence, CATS, was administered by the researcher to the freshmen university students enrolled in Sci 101. The study's conduct was at the time of the transition period from the existing curriculum to the K to 12 curricula. Senior High School was still in the implementation process. At the same time, the university freshmen are the last batch of the current curriculum. These freshmen were the equivalent of the coming Grade 11 of Senior High School. Biological Sciences (Sci 101) is among the general courses offered to Senior High school Biology 2.

For this study, the selection of the class was determined by random sampling through the fishbowl technique. The majority of the participants (n=47; age range 16 – 22 years; mean = 17 years old) were female, comprising

79% of the total population. They were generally in their first year of either Bachelor of Elementary Education or Bachelor of Secondary Education students. Students with incomplete data were not included in the analysis.

In the case of the teachers, the respondents were chosen purposively. Ten teacher participants, 60% were females, and 40% were males, 25% were below 25 years old, while 20% were the oldest between 40 and 49. Over half (60%) of these teachers were full-time holding master's degrees or units in masters or doctorate degrees. In terms of teaching experience, 50% of the teacher participants were teaching human organ systems for two years. Forty percent taught for more than five years. In contrast, ten percent taught for 20 years and more.

The data were gathered using the student's drawings, researcher-made pre/posttest, and questionnaire. Before the study and data gathering, permission and consent of the research participants were asked. The study consisted of the following phases: preliminary, development, implementation, and evaluation phase.

The data collected from questionnaires were processed quantitatively. Descriptive statistical measures such as means and percentages described the scores in the students' drawings, teachers' difficulty in teaching the organ systems, and learning gain. Also, non – parametric and paired t-test was run to determine the significant difference between the two scores. Students' drawings, recorded interviews, and videotaped observation was examined by the thematic method. As a qualitative analytic method, the thematic analysis identifies, analyzes, and reports patterns (themes) within data (Braun and Clarke, 2006).

Results and Discussion

Development of the Teaching Sequence

This teaching material is named Constructive Aligned Teaching Sequence (CATS), which covers Animal Organ Systems and Functions under Organismal Biology for Senior High School Biology 2. This CATS development is grounded on the Content and Performance Standards for Senior High School Biology 2 Curriculum, Students' Initial Conceptions on Organ Systems' Structure and Function, and the Teachers' Perceptions in teaching the said topic. The development was anchored on Constructive Alignment Theory's principles as a framework that translates some essential constructivism features into classroom decisions on teaching and assessment. Hence, this teaching-learning material traces the learner-centered curriculum model and inquiry-based curriculum design. The inquiry-based curriculum has developed independent and critical thinking skills, positive attitudes and curiosity toward science, and increased biological content achievement. Among inquiry-based approaches, the 5 Es- model, namely Engage, Explore, Explain, Elaborate and Evaluate teaching and learning model as the framework for the TLAs of this teaching sequence. Its constructivist learning activities emphasize 5Es Approach and model making.

This CATS enables the learners to demonstrate an understanding of animal organ systems' structures and their functions. Senior High School learners should understand the hierarchy of organization that makes up the organism from the cell as the basic unit of life to tissues and organ systems. Humans obtain energy and materials for body repair and growth by nutrition. Gas exchange by breathing makes oxygen available; by communicating with all parts of the body through sensory and motor mechanisms, the brain understands what is going on at different regions throughout the body. The skeleton, skin, and muscles provide the body with form and structure, hence, a functional organism.

This teaching sequence's development's central theme is the constructive alignment in teaching-learning the human organ systems to attain the desired performance standard in the SHS Biology course. One significant feature of this CATS is applying a teaching system where teaching-learning activities and the assessment tasks align with the performance standard. In the same way, the identified scientific concepts are based on their specified Content Standards. Another essential feature is using model-making activities requiring every student's active involvement while providing them with multiple learning resources. Teaching the organ systems through model making helps teachers tackle all the organ systems within the allotted time, a solution to the chronic challenge of too much science to teach in too little time. Aside from the constructivist student activities, it also features ICT – based materials through the suggested web links and other technology-mediated activities. The proposed activities foster creativity, problem-solving among other skills in students which the new curriculum upholds. Finally, the integration of research results on students' conceptions of organ systems and teachers' approaches in teaching the said topic also plays a vital role in developing this innovation.

Evaluation of the Teaching Sequence

The effect of the developed teaching sequence was looked into through the Students' Learning Outcomes (SLO) and Teachers' Evaluation on CATS (TEC). The SLO is determined through the pre and post-assessment drawings and learning gains through the pretest and posttest scores. Examining the pre and post-assessment results laid side by side, as shown in Figure 1, shows apparent differences in the organ systems presented entirely.

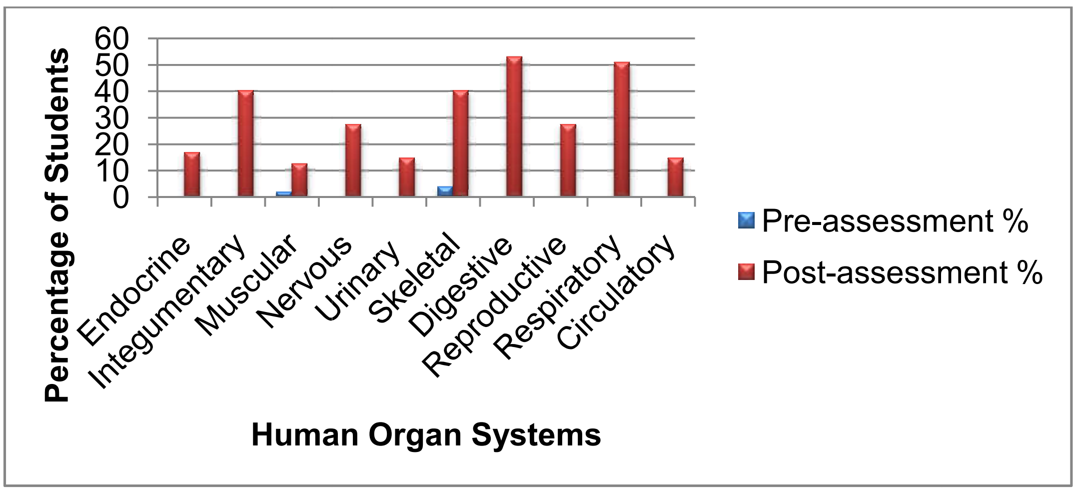

Figure 1. The percentage of students whose drawings showed complete human organ systems during pre-assessment and post-assessment.

In particular, for each of the organ systems, only a minority of the drawings produced at the pre-assessment presented a completely drawn organ system except for skeletal and muscular systems with percentages lower than 5. According to Reiss and Tunicliffe (2001), as far as students' knowledge of what was inside themselves goes, the most thoroughly studied organ system is the skeleton. Hence, it can be implied that during the pre-assessment, the students may have produced drawings out of their general knowledge. Surprisingly, some students' responses confirm that the skeletal system is the most studied organ system in elementary and high school. One of the students put it when asked about the appropriateness of model making activity to the lesson:

(Translated interview transcript)
It was useful, exciting, and engaging…which I enjoyed and learn. We learned a lot of what is new to the organs, that the organ systems are composed of their functions. And we knew it just now. During elementary and high school, the discussion was merely on the skeletal system. We were required by our teacher to memorize the bones. My realization through this activity and the lessons of the body is an organization of the organ system. And if there will be no system, our body will not function; everything will be affected to the extent that all of them will not work anymore. So we are not just composed of what we could see; there is also what is inside us.

Conversely, the drawings produced during the post-assessment showed the skeletal and muscular systems and the other organ systems revealed completely at percentages higher than 10% and about to reach 60%. A closer examination of Figure 1 bared out a visible improvement in identifying the organ systems showing the organs and their connections.

A probe on the pre and post-assessment results positioned alongside the other for the drawings' biological quality showed an apparent difference between the students' initial and final conceptions on human organ systems. Pre-assessment results showed that 50% of the students' drawings scored Level 2. Students drew one or more internal organs but were placed randomly. Nearly 25 % of the student's drawings achieved Level 1, characterized by no internal structures. However, 11 % of the drawings that showed an internal organ in an appropriate position scored Level 3. The same percentage of drawings shows two or more internal organs in a proper place but no extensive relationships. It can be implied the majority of the students knew that the human body was composed of internal organs but not the interconnections of these organs. This was before the implementation of CATS.

On the contrary, with CATS implementation, most students knew the internal organs in their correct positions in the human body and their interconnections. Furthermore, the figure for the biological quality of the students' drawings revealed the student's initial conceptions and final conceptions on extreme ends. However, 4% in the post-assessment drawings stayed at Level 4 or did not show complete organ systems and their connections in their drawings. When the records were looked into, it was found out that these specific students had several absences in the study's conduct.

Table1 below indicated the pre-assessment and post-assessment scores to describe the students' conception through the drawing method before and after the use of CATS. Normality test results showed that the data were not normally distributed. Hence, the nonparametric test was utilized. In the pre-assessment, the scores for the biological quality of the drawings ranged from 1 to 5 with a median of 2. This indicated that the students could identify one or more internal organs but were placed randomly. After using CATS, the students' conception of the organ systems ranged from Levels 4 to 7 with a median of 6. The results indicated that, on average, the students can identify two or three organ systems sufficiently drawn with its composing organs at the right places. A Wilcoxon Signed-ranks test indicated that the conception of students on the organ systems after the use of CATS ($Mdn = 6.00$) was significantly higher than the conception of students of the organ systems before the use of CATS ($Mdn = 2.00$), $Z = 6.015$, $p < .001$, $r = .88$.

Table 1. Results of Wilcoxon signed-ranks Test on the Pre-Assessment and Post- Assessment Scores

Variables	Minimum	Maximum	Median	Z
Pre-Assessment Score	1.00	5.00	2.00	6.015
Post-Assessment Score	4x.00	7.00	6.00	

$p < .001$

Students' learning gain as another SLO was determined by comparing the students' pretest and posttest scores. The pretest and posttest scores of the students were recorded, tabulated, and analyzed. The scores yielded a high performance in all the organ systems processes, with nutrition as the highest and sensory and motor mechanisms being the lowest. The posttest results indicated that after the CATS, the students could better grasp the organ systems' processes. Specific to this study, the students still showed a certain level of difficulties when it came to the organ systems' processes. It was also found out that these teachers were also having difficulty teaching the organ systems' functions. As Trigwell etal. (1999) put it, it was inevitable that teachers approach their teaching to influence the learning outcome. Nevertheless, the students in this study still exhibited significant improvement in their post achievement scores.

A t-test for dependent samples was conducted at the $\alpha = .05$ level of significance to compare the pre and posttests and mean scores. Results show that the mean score after the lesson using CATS ($\bar{x}$= 57. 36) was higher than the test score before the lesson using the CATS ($\bar{x}$= 25. 17). Moreover, after the lesson, the students' scores were more spread than their test mean score before implementing the lesson implementing CATS. The analysis resulted in a p-value of $p < .001$. Since the p-value was lesser than the significance level, the null hypothesis is rejected, $t(46) = 34.940$, $p < .001$. This indicated a highly significant difference in the test mean scores among the students before and after the lesson on human organ systems using CATS. This result suggested enough evidence to conclude that the significant increase in the test mean scores among students after the lesson was likely due to CATS use.

The high significant results in the post-assessment using the drawing method and achievement posttest scores of the students provided sufficient evidence to claim that the improved students' final conceptions on human organ systems was not due to chance but may be attributed to the use of the CATS in teaching the said topic. The students' feedback was confirmatory towards using the developed CATS in teaching human organ systems issues. Furthermore, the results showed improved students' human organ systems conceptions manifested in their drawings' biological quality and achievement scores after CATS. The statements below were the responses of interviewees 1 and 3 when asked about the factor that could have helped them do better in the post-assessment.

(Translated interview transcript)
The activity of the lesson helped a lot. Like before, I draw the heart at the left side to learn to be at the centre. I saw our lessons' exact flow from the start of what should be known on structure and functions and our lesson's emphasis until exams and other activities. The model helped me learn those, and I realized its locations. During high school, we were not taught much about the organ system. It was amazing even though the classes were extended for one week; we have many things we learned.

(Translated interview transcript)
Yes, we were asked to make a model of the system and discuss its responsibility. Then in the activity, we were given the time to do it individually and worked with group mates to learn the other systems and their functions. Then we were required to present the model to show the human body as a whole. We were working with the model, and we should know to give it to the group and be ready for the presentation. In the end, it was easy.

These students' feedback expressed that they have become aware of the expectations and the standards required in the subject. Structuring learning to help students understand the criteria and standards required in their knowledge was imperative for students to maintain a realistic perception of their achievements (O' Donavon etal. (2008). This is achieved by making assessments and objectives transparent to students by providing easily understood feedback about the objectives and promoting self-awareness (Boud, 1995 as cited in Lawson, 2011).

This study's results indicate that the CATS contributed to improving the organ systems' final conceptions. This can be an outcome of the design principles applied in CATS development, specifically clarification and analysis of science content, the investigation into students' and teachers' perspectives, and design of learning environments (Nurkka, 2008; Duit etal., 2005). This study complements Akir et al. (2012) work affirming the use of OBTL in improving students' academic performance. To some extent, the study revealed the attainment of the students' learning outcomes, which agrees with Chu et al.'s (2010) findings. It also confirms the studies of Lui and Shum (2012), Barbrand (2007), and Biggs (2003) on the use of constructive alignment as an approach for curriculum development and science teaching.

Teachers' Evaluation on CATS

The evaluation of CATS revealed that the innovation achieved promising results. The teachers-respondents were teaching the subject to college freshmen and the teachers in the Junior High School. In developing and evaluating a teaching sequence, the conception of teachers who have not been part of the research process and designing the teaching sequence should be considered (Leach and Scott, 2002). Nurkka (2008) also shared that the usefulness and applicability of lesson materials could be increased based on teachers who are not involved in designing the lesson materials.

Presentation of Content

The teacher – respondents were given the checklist in evaluating the CATS. Their answers indicated their degree of agreement with the indicators mentioned. A numerical value of **1** indicates disagreement, **2** for somewhat, while **3** for very well in agreement.

When the presentation of content was considered, all 10 or 100% of the teacher participants gave this dimension 2.65 as general mean. This rating was close to 3, which was Very Well. Hence, the teachers perceived the CATS content's presentation to be Very Well as it emphasized scientific inquiry. Its presentation was enjoyable, engaging, and appropriate for the scientific language that facilitates understanding and connected science to society. The teachers were asked for their comments and suggestions to improve the material in terms of content presentation. Specifically, common to the teachers' remarks for this dimension was to check the organ systems' topic to be consistent with the competencies and skills prescribed in the K to

12 curriculums. The activities were task-based geared towards developing and enhancingthe scientific process recommended in the new curriculum.

Curricular Alignment

As to the Curricular Alignment of CATS, the teacher-respondents analyzed the curriculum material for the alignment between ILOs, TLAs, and ATs. This facet of CATS was rated 3 for its general mean by all teacher participants. This result of the evaluation showed that the ILOs, TLAs, and ATs were very well aligned with a rating of 3.

The practicality of Implementation

For this facet, the teacher – respondents examined the CATS' practicality of implementation by looking into Inquiry as the approach for the students' learning experience, the effective use of instructional approach, and the presentation and format of CATS.

Inquiry and Activities as the Basis of Learning Experience

On the aspect of Inquiry and Activities as the Basis of Learning Experience, all teachers rated 3. CATS was deemed by the teachers as a teaching material focusing on concrete experiences, provides opportunities to gather and defend their own evidence, and expressed their results in various ways.

Using an Effective Instructional Approach

As to the effective use of CATS, an average rating of 3 was given, as shown in Table 9. CATS was judged as a learning material that promotes a balance of student-directed and teacher-facilitated activities, incorporating effective strategies for the teacher and/or students to assess student learning. The students have opportunities to work collaboratively and alone.

Presentation and Format

Another aspect for evaluation was the practicality of implementation, where the teachers considered the presentation and format of CATS. Some teachers rated 2 or somewhat and 3 or Very Well the indicators under this aspect. Such that the rates yielded 2.6 as its general mean. For this, the teachers suggested the following: (1) for illustrations properly labeled to supplement the text; (2) improve layout, (3) uniformity of materials to be used in making the model for uniformity and avoid bias in the scoring; (4) make instructions more straightforward in the assembly of the systems to produce whole body; and, (5) develop a plan in displaying or storage of the models as the students' outputs.

The designed teaching interventions must be generally adapted to be usable by teachers not involved in their development (Nurkka, 2008). According to Millar etal. (2006), as Nurkka (2008) cited, teachers, are not ready to change their practice unless their research results are by their experiences or beliefs. Other teachers' successful experiences may help teachers adopt a new teaching approach (Millar, 2005). Communications with other teachers and teaching materials and guidelines that can be used directly in the classroom are more likely to impact teachers' practice (Nurkka, 2008).

Conclusion

This study's findings showed the success of the developed CATS regarding attaining the desired student learning outcomes. This was evident in the students' final conceptions on organ systems and learning gains. Evaluation of teachers on CATS has been affirmative. There were expressed suggestions for its improvement, specifically in implementing instruction, handling, and storage of model outputs. CATS contributed to the achievement of the learning outcomes. This result is attributed to the design principles applied in the development of CATS, specifically clarification and analysis of science content to be within the standards of the Senior High School K to 12 curriculum, the investigation into students' conceptions and teachers' perspectives, and design of learning environments through an aligned teaching system.

Further analysis of the results provided vital elements for a better understanding of the students' conceptions on organ systems and engaged teachers in actions that can better promote its goals. It also provided essential features that may be applied in designing and developing teaching-learning sequences in teaching other biological concepts. CATS offers these groups of students opportunities to improve human organ systems' conceptions as manifested in their final conceptions, achievement, and positive feedback. Moreover, CATS exposes students to learning activities enabling them to acquire life skills relevant to their daily decision-making.

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