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Development of Digital Courseware in Trannsmission Genetetics

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DEVELOPMENT OF DIGITAL COURSEWARE IN TRANSMISSION GENETICS

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In Partial Fulfillment of the Requirements for the Degree
MASTER OF ARTS IN SCIENCE EDUCATION
with Specialization in Biology

by

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APPROVAL SHEET

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Dedication

I dedicate this work to my family especially mom who gives love and supports me on my decisions in life. This is the least craft that I could offer for you as payment for your continuous love and support.

I also dedicate this to my beloved partner for understanding and inspiring me to give my best effort to finish this study and look forward to our goals in life.

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I would like to convey my sincere and deepest gratitude to all those people who have supported and helped me, whether directly or indirectly, to make this study possible.

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My Family who gave unconditional love & support and inspired me when I feel doubtful of myself;

My beloved partner who continuously understands and motivates me to finish this paper and look forward to achieve our goals in life;

Above all, to Almighty God, the source of all wisdom and skills who has given me the blessings to make this study possible.

ABSTRACT

NAME : Nikko Lorenz P. Lawsin

TITLE : Development of Digital Courseware in Transmission Genetics

KEY CONCEPTS : Digital Courseware, Transmission Genetics, Computer-Assisted Instructional Material (CAIM), Instructional Material Development

DEGREE : Master of Arts in Science Education

SPECIALIZATION: Biology

ADVISER : Prof. Genelita S. Garcia

THESIS : Improving conceptual understanding and lessening the misconceptions to promote mastery in transmission genetics can be addressed by developing digital courseware on this topic.

This study aimed to develop a digital courseware in transmission genetics, have it validated and try it out to the Grade 8 students as a learning tool. Needs analysis was done with in-service biology teachers in order to contextualize the problems cited in the literature towards this competency based on Philippine settings. The results of literature review, need analysis and principles of Mayer's Cognitive Theory of Learning were used to develop the digital courseware. After the development of the courseware, it was validated by the three content-experts and three IT Experts to evaluate the content, format and design, and organization and technical content of the digital courseware.

In the expert validation, both criteria of Content and IT Expert validations, the digital courseware obtained a remark of "very appropriate" which means it is suitable as a learning tool in transmission genetics. The validated digital courseware underwent pilot-testing to the two groups of grade 8 students. One group was assigned as Digital Courseware class (DCC) in which digital courseware was utilized and another group was assigned as Direct Instructions Class (DIC) in which Lecture-Discussion was employed. Both groups of students took parallel questions in the pre- and post-test about

Mendelian Genetics to measure the improvement of the scores. It was found out that the students of DCC group had the same positive average gained score after the treatment as compared with the DIC. Based on this, the digital courseware can be used as alternative learning tool to learn transmission genetics.

The researcher would like to recommend the following: (1) pilot test the third lesson of this material to grade 9 students since this topic is in this grade level; (2) this digital courseware is encouraged to be used by the junior high school science teacher in the Philippines in order to attains its goals such as to improve conceptual understanding, promote mastery and lessen the misconceptions in transmission genetics; (3) a similar study that utilizes this digital courseware in transmission genetics with other grade 8 respondents to verify and firmly establish its effectiveness and statistical validity; and, (4) more educators are encouraged to develop other digital courseware that will address the result of conducted needs analysis especially in the competencies like Cellular Respiration, Photosynthesis and Protein Synthesis in which it occupied the highest ranks in terms of low level of conceptual understanding and least-mastered competency with numerous misconceptions.

Keywords: Digital Courseware, Transmission genetics, Computer-Assisted Instructional Material (CAIM), Instructional Material Development

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CHAPTER I
THE PROBLEM AND LITERATURE REVIEW

Introduction

"Twenty-first Century" is a period where technological advancement is highly evident. Integration and use of computers and other software applications as instructional materials are just evidences of revolutionizing the world of teaching. Computers play a major role in the delivery of instructions such as in visual aids, classroom activities and other online tasks where ICT can be integrated. According to Bayani (2011), integrating well-designed multimedia instructions has advantages like multi-sensory involvement, greater enjoyment of learning and increased motivation through immediate feedback.

Many studies considered genetics as one of the most difficult and least mastered competencies in Biology as perceived by teachers and students. This discipline studies the heredity and variation. One of the reasons why students find it hard is because some concepts are highly theoretical and some require intensive analysis with applications of mathematics. In the study of Karagöz and Çakir (2011), prospective biology teachers have inconsistent and incomplete understandings and misconceptions of several basic Mendelian genetic concepts. Although they were able to describe some concepts, they frequently failed to apply them in problem solving situations. Due to this, students carry or sometimes formulate alternative conceptions. These analyses also revealed in the study of Yates and Marek (2014) that students typically exit the Biology 01, which includes genetics, classroom more confident in their biology knowledge but holding greater numbers of misconceptions than they initially possessed upon entering the course.

One of the topics in Genetics is transmission genetics which covers Mendelian and Non-Mendelian genetics and utilizes punnett square, pedigree analysis and identification of genotype and phenotype. These topics are very challenging since it requires analytical thinking especially in the determination of genotypes or phenotypes based on the given problem or using the pedigree diagram. According to Karagöz and Çakir (2011), Conceptual understanding of fundamental genetics concepts is a prerequisite requirement for successful problem solving in genetics. If the students fail to comprehend the concepts, application in solving problems may be of difficulty.

Students fail to identify the proper genotypes of the organisms since they cannot sort and break down the thoughts of the problem into smaller pieces with sense and, also students get discouraged if the problems are getting complicated. It is either the problem requires a dihybrid crossing, or it is difficult to identify if the trait is dominant, intermediate or recessive. According to Chu (2008), in order to reach students' acquisition of meaningful understanding of genetics, suggestions have been advanced for dealing with problems of preconceptions terminological language, basic mathematical requirements and of spatial and conceptual issues involved in segregation of alleles and chromosome behavior in cell divisions.

Since transmission genetics is one of the competencies in K-12 Science specifically in Grades 8 and 9, this study is intended to address the low conceptual understanding and numerous alternative conceptions of the students and teachers in Transmission Genetics by developing digital courseware that discusses these concepts which are utilized in their respective grade levels. Moreover, this digital courseware promotes the enhancement of technological skills of the students while learning the concepts of transmission genetics.

These skills are important for 21^{st} Century Learners or Millennial Learners and hopefully students find their interest to grasp the content of the subject-matter through exploring the digital courseware.

Background of the Study

1.1 Transmission Genetics as least mastered topic, with low conceptual understanding, and numerous misconceptions

Conceptual understanding involves the ability to apply knowledge across a variety of previously unencountered instances. This refers to what learners know and understand about a concept. This includes the generalizations that learners can develop about the nature or properties of that concept and the understanding of core concepts and principles and their interrelations in a certain domain, Bramaje (2013).

In Donovan and Venville (2012), it has been shown that all students in their samples were able to demonstrate at least a *rudimentary understanding* of inheritance in terms of parents and offspring sharing physical similarities but noted that students did not understand the relationship between DNA, genes and chromosomes, and that some believed that daughters inherit most of their characteristics from their mothers, and boys from their fathers. Similar results were also obtained from the study of Infante-Malachias et.al, (2010) that most students from secondary school, after formal teaching, do not understand genetic concepts and they cannot describe the relationship between some cellular structures like chromosomes, DNA and genes. Likewise, many biology students struggle to understand key terms such as gene and allele even after classroom and laboratory instruction (Yilmaz et al., 2011). These students face difficulties in comprehending related concepts such as dominance and recessiveness (Freidenreich et al., 2011), thus impeding their knowledge-building process in fundamental genetics. Also, in the study of Chu (2008), the following has been shown: (1) Students do not fully understand chromosomes, genes, or alleles, (2) They cannot adequately interpret some concepts such as homozygous or heterozygous, (3) they have alternative views of some processes such as mitosis and meiosis, and (4) they do not understand the meanings of probability in relation to genotype and phenotype frequencies in offspring. As a consequence, when they are not able fully to understand these matters, students depend on rote learning to pass examinations.

In the study of Haambokoma, (2010), genetics has been identified as one of the most difficult topics in Biology for high school students in Zambia and found that students had difficulties understanding among others genetic crosses, genetic terms, mitosis and meiosis, as well as mutations. The factors that were identified are as follows: inability by teachers to explain clearly the lessons, the topic was taught near the examination time or inadequate time allocated to teach the topic, fast presentation of the lessons by some teachers and belief of some students that genetics was difficult to learn.

According to Smith and Knight (2012), students hold deep misconceptions about genetics due to outdated genetic models remain in textbooks or if teachers are not sufficiently familiar with contemporary knowledge of genetics and its development. Jamieson and Radick (2013) responded that textbooks might need to be rewritten to be freed from any overly simplistic-deterministic language. But achieving a kind of genetics literacy that will allow citizens of the 21st century to engage in the growing number of genetics socio-scientific issues will require coordinated efforts by educators and scientists.

In the results of a new study released in the journal Genetics (American Society of Human Genetics, 2015), it indicates that, although all state science education standards in the U.S. include genetics content, there is still a widespread lack of understanding that includes several common misconceptions which appear to be prevalent among U.S. high school students. Moreover, in the study of Condit (2010) public understanding of genetics is characterized by serious shortcomings and as a result, students' conceptions mainly reflect naive genetic determinism.

1.2 Digital courseware and Computer-Aided Instructional Materials

Instructional materials are significant to the teachers in delivering the classroom routines. Functionality, format and way of presentations are some of the factors that are considered by the teachers to make the classroom discussion effectively. According to Awolaju (2016), the role of instructional materials if thoroughly considered cannot be either partially or totally isolated from teaching–learning process. For any meaningful educational program to be achieved in terms of its implementation, the aspect of instructional materials must be given serious priority. Also, the study of Nwike and Catherine (2013) revealed that those students taught with instructional materials performed better than those taught without instructional materials.

Courseware and Computer aided instructional Materials (CAIM) are the common ICT tools and instructional materials used by the teachers in classroom activities, lesson delivery and assessment believing that use of ICT in classroom teaching has good effect on students. In the study of Osborne and Hennessy (2003) cited in Lee, et.al (2011), the use of ICT in science classes benefit students by developing their critical thinking skills, handling and collection of data as well as by increasing their access to knowledge presented in a visual format, raising motivation and engagement. In the study of Kareem (2015), it is recommended that computer-assisted instruction be used in the teaching of biology at secondary school to improve students' academic performance on the subject. Also, according to the findings of Eick and King (2012) and Kay and Kletskin (2012), visual media along with traditional methods of teaching can increase student performance, indicating that students learned more with the visual media.

1.3 Effects of Digital Learning Tools in the Achievement, Attitude, Lessening the misconceptions in Biology

In terms of its effects in the achievement and cognitive improvement, Owusu et. al (2010), states that the performance of low achievers in Biology within the experimental group improved after they were instructed by the Computer-Assisted Instructions (CAI) and the students in the CAI group perceived CAI to be interesting when they were interviewed. In the study of Gambari et.al (2014), it was found out that students under video-based multimedia instruction performed better than their colleagues in the conventional teaching method based on their achievement and concepts retention in Biology. In Ko (2010), use of Computer-assisted instructional materials (CAIM) has positive effects. It gives quite high cognitive level and decreases 19% level of misconception in a CAI group, in understanding the concept of photosynthesis and cellular respiration. Additionally, Wolf (2012), states that many proponent of pedagogical learning emphasizes technology's capacity to personalize learning and improve student's achievement. Moreover in the field of chemistry, the result of the study of Karadeniz and Bayram (2010), found out that teaching of acid-base subject supported with computer aided teaching had a positive effect on the achievements of students in science and technology course. In the findings of Vebrianto and Osman (2011), it can be concluded that the teaching and learning process using various constructive teaching multimedia has significantly improved the Science Process Skills and Science achievement among students.

In terms of positive effects on the attitude, Yapici and Hevedanli (2012), indicate in the results of the study that pre-service biology teachers have positive attitudes toward ICT using in biology teaching. In the conduct of the study of Gürbüz et.al (2010); Eick and King (2012), it was indicated that preparing and presenting powerpoint slides and visual media had a significant effect on prospective teachers' biology achievement and attitudes towards biology.

But technically, production of specific multimedia courseware are made in order to address the learning needs of the students. In the developmental study of (Mohamed, Khan, and Masood (2015), it was revealed that lack of good quality learning materials, limited time for revision and exploring each topic, are also problems which will have to be solved to enhance the performance of the students in the subject of Biology. The implementation of Interactive Multimedia Learning Courseware with different learning strategies needs to be designed and developed to facilitate and enhance the learning ability of students in terms of the subject of biology.

In terms of its advantages in instructions on the part of the teacher, it changes and simplifies the teacher's way of presenting the lessons making it more interactive and timely. According to Wang et al. 2007, cited in Arkorful (2014), the development of multimedia and information technologies, as well as the use of internet as a new technique of teaching, has made radical changes in the traditional process of teaching. As an example, Howley, Kim and Kane (2012), digital technologies can offer improved access to real-time student data, teaching materials, professional development, mentorship opportunities, and communities of practice.

1.4 Limitations of Digital Learning tools

In terms of its limitations, digital courseware is highly dependent on technology which is costly and requires materials and facilities in delivering the lessons. In the Article of Professor Richard, quality materials take time to produce and adequate staff time as well as resources need to be allocated. Moreover, teacher-made materials will not normally have the same standard of design and production as commercial materials and hence may not present the same image as commercial materials. Moreover, based on the study of Zhang Ya-nan (2013), in operating the CAI, Teachers' consciousness of using CAI is still relatively poor, and some teachers' abilities on computer application are not high, which makes it difficult for them to make use of multimedia in their teaching activities.

1.5 Features of Computer Aided Instructional Materials (CAIM)

Biological animation and tutorials. This online digital instructional material discusses cellular structures and functions like cell division. There are icons that can be clicked like "Play button" to manually manipulate the change of animations. Changes in every stages of meiosis are posted on the left panel of the screen where the students can read those significant changes. At the end of the lecture, multiple-choice formative exam is given to assess the knowledge acquired by the students from the module. The animations, detailed way of presenting the lessons and its sequence were adapted from this digital lesson

DNA and Proteins are key molecules of Cell Nucleus. This computer simulation focuses on DNA and proteins as key molecules found in the nucleus. The online simulation contains many other animated tutorials on DNA, genes and heredity. The science behind each concept is explained using animations, an image gallery, video interviews, problems, biographies, and links. Animations and way of presenting the problems were adapted in the development of the courseware.

The Genetic Code. This online simulation provides information about the role of codons and anticodons in protein synthesis. This also contains many other animated tutorials on DNA, genes and heredity. The science behind each concept is explained using animations, an image gallery, video interviews, problems, biographies, and links. Animations and way of presenting the concepts were adapted from this simulation and applied to the digital courseware.

pHET Simulation. This learning material is a project of Colorado University and it aims to simulate different scientific concepts and processes that are discussed in Biology, Physics, Chemistry and Earth science. This application requires JavaScript to run in the computer. It is a student-centered application in which the students manipulate the software by clicking any icons or following any commands in order to simulate the process. Take gene expression as an example. This instructional material is used to simulate how genes are being transcribed by RNA polymerase to produce mRNA. There are many icons that you can find in the Biomolecule toolbox such as Positive and Negative Transcription Factor, RNA polymerase, ribosomes, mRNA destroyer, protein collection box which serves as storage of proteins after the synthesis in the ribosomes. This simulation is beneficial to strengthen the knowledge of the students in gene expression. After the lecture-discussion, the students can now apply the knowledge they gained from the discussion through manipulating the icons represented by the “Biomolecule toolbox”.

SYNTHESIS:

Use of Digital Instructional Materials such as Computer Assisted Instruction (CAI) can significantly contribute to the achievement, conceptual understanding, attitude and perception of the students towards Genetics and it is stated that utilization of these materials can significantly change the alternative conceptions of the students in this topic in Biology. Based on the background of the study, it was found out that students and even teachers display rudimentary levels of conceptual understanding of this topic or it is one of the least-mastered topic in biology.

There are various reasons why low conceptual understanding, least-mastered competency and misconceptions about genetics happen. These are as follows: the difficulty of the subjects and the teachers do not explain the topic thoroughly, the mindset of the learners towards the topic, pre-conception knowledge about the topic which may not be aligned with the acceptable scientific theories and misleading materials which contain alternative conceptions or misconceptions.

In order to address these existing problems, literature suggests that adequate instructional materials should be developed to improve students’ learning. The characteristics of instructional materials nowadays utilize computer applications making it more interactive and allows the student to learn on their own by exploring the materials with minimum supervision of the teacher. Features of the Computer Aided Instructions were gathered as guides in developing the Digital courseware and these are as follows: icon bars that can lead the user into other parts of the CAI using hyperlinks, moving pictures and objects, sample exercises provided with pictures and thorough explanation that guide the students or the users and interactive quizzes with answer keys after every lesson.

Conceptual Framework and its Theoretical Bases

Transmission genetics is one of the topics in Biology that has numerous alternative conceptions or concepts that are not aligned with the principles or practices agreed by the scientific community. One classical example of these is the question, "what do organisms transmit to next generation, is it the trait or the gene?" Many students may probably answer "the trait" since it is the obvious one. But that alternative conception passed through generations. According to Salazar (2015) Alternative conceptions are products of least mastered competencies and low conceptual understanding. Inability of the students to master the topic and having low conceptual understanding may result to numerous alternative conceptions.

Recommendations from the literatures suggest the development of instructional materials that provide adequate facts are highly encouraged. These materials may be a source of accurate pieces of information that can be utilized in learning science competencies. Nowadays, instructional materials or any learning tools are run by computers or at least technologically-inclined. One of the 21st Century skills that learners should learn and adapt is the impact of technology.

In the development of the digital courseware, principles of Mayer's Cognitive Theory of Multimedia Learning were strictly observed including the way of how genetics concepts and illustrations presented as implied by *multiple representational principle* and *coherence principle.* Moreover, *individual difference principle and contiguity principle* were also used in presenting diagrams and how it worked with the summary of procedures in solving genetics problems that can be found the courseware. Visuals and diagrams were ensured to be attractive and coherent with the definitions and summary of genetics concepts in order to address individual differences especially on the students' way of acquiring the genetics concepts and problem solving skills.

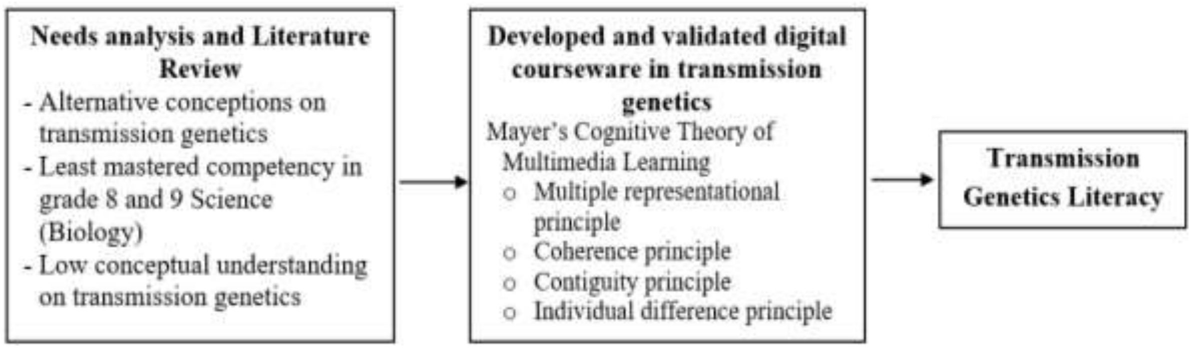

Fig. 1: Conceptual Paradigm of the study

Figure 1 shows the research paradigm of the study. Low conceptual understanding, least-mastered competency, and numerous alternative conceptions about genetics were the three reasons why there was a need to develop a digital courseware in these topics in Biology. It is highly evident in the background of the study that students and even Pre-service Teachers have low conceptual understanding and carry or formulate alternative conceptions in genetics. This is also further substantiated and contextualized by needs analysis through conducting a survey with the in-service teachers reflecting the competencies which they might perceive as least-mastered by their students and with numerous alternative conceptions. The developed digital courseware was anchored with the concept of Mayer's cognitive Theory of Multimedia learning and its principles such as multiple representational principle, contiguity principle, and coherence principle, and computer-assisted instructions. These theories or principles require use of technological skills in teaching and learning processes which are very important in the trending of 21^{st} Century skill education. In terms of developmental process, steps of modified ADDIV Model were used which are planning stage, design and development stage, validation and revision stage. The output of this study aimed to promote and improve Transmission Genetics Literacy for the students who will use this digital courseware.

1.1 Mayer's Cognitive Theories of Multimedia Learning

The more senses involved in the learning process, the more effective it will become. According to the proponent of this theory - Mayer (2009) cited in his initial paper Mayer (1992), people learn more deeply from words and graphics than from words alone. This assertion can be called the multimedia principle. It forms the basis for using multimedia instruction in which words can be represented as printed text or spoken text, and graphics such as animations, graphs and illustrations are used in delivering the lessons.

The most relevant elements in a science of learning are (a) dual channels—the idea that humans possess separate channels for processing visual and verbal material; (b) limited capacity—the idea that each channel can process only a small amount of material at any one time; and (c) active processing — the idea that deep learning depends on the learner's cognitive processing during learning (e.g., selecting, organizing, and integrating).

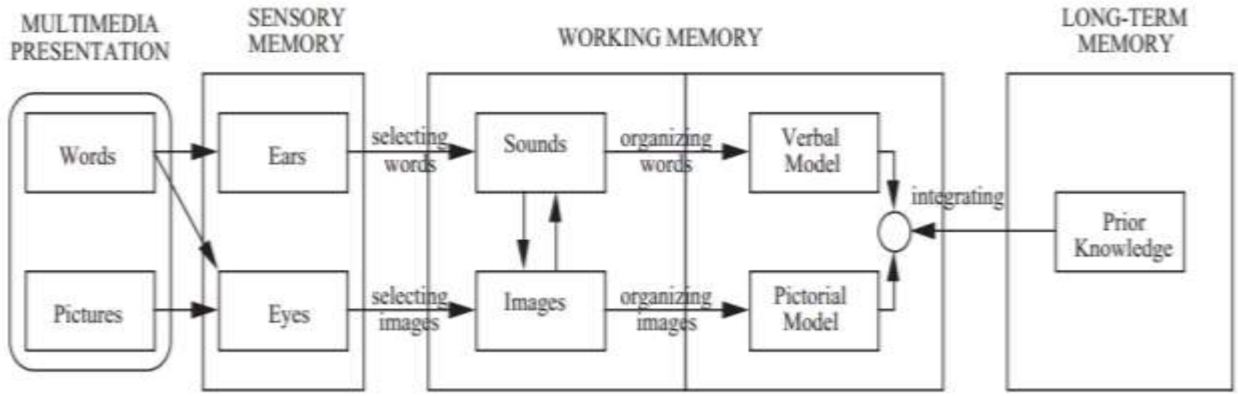

Figure 2: Summary of Mayer's Cognitive Multimedia Learning

Figure 2 summarizes the cognitive theory of multimedia learning proposed by Mayer (2001) which is intended as a framework for explaining how multimedia learning works. The boxes represent memory stores, and the arrows represent cognitive processes. The cognitive theory of multimedia learning is consistent with the three learning principles: Dual-channel, limited capacity and active processing. From the left of the figure, the learner begins to recognize words and pictures under sensory memory. It can be perceived by the ears and eyes. These words and pictures can be obtained from text book lessons, power point presentations or interactive games. After the recognition, the selected words and images are processed in the working memory to be organized and integrated to become a piece of new knowledge learned by the learner. This newly integrated knowledge is now a part of conceptual understanding of the students in which it can be recalled when needed. This learning theory had a significant role in the development of the material especially the features of the courseware like textual animations, illustrations supported with attractive motion and animations embedded with audio. According to Colasito (2011), Mayer's cognitive theory of multimedia learning has the following principles: *multiple representation principle, contiguity principle, split-attention principle, individual* *differences principle and coherence principle.* **Only four of the five principles were used in the development of the study and these are as follows**:

(1) multiple representational principle – using of words and pictures is more effective in presenting the concepts rather than solely in words,

(2) contiguity principle – in explaining the concepts using multimedia instruction, simultaneous presentation of words and pictures is better than presenting those separately,

(3) Individual difference principle – when giving a multimedia explanation, some students can catch the concepts easily with visual text but some need pictures to easily get the concept. Visuals and illustrations were highly observed in order to attract the attention of the students.

(4) Coherence principle – in presenting multimedia explanation, students learn better from a coherent summary which highlights the relevant words and pictures than from a longer version of the summary. In the development of the design, the researcher constructed a summary of concepts that are written in simple language and important words are highlighted.

1.2 Modified ADDIV Model

ADDIV stands for **A**nalyze, **D**esign & **D**evelop, **I**mplement and **V**alidate. ADDIV model is a common framework used in many developmental studies of Computer-aided Instructions since it is basically composed of the fundamental stages in developing instructional materials such as analyzing what is needed by the users, designing and developing based on what is needed by the intended users, implementing the developed materials to the target users and validating its content, format, design and even the organization of the objects in the materials.

The modified ADDIV model has these steps: Planning, Design and development, Validation and Revision stage. This model was used in the study of Rivera (2009) on her study about *"Development and Validation of Computer-Aided Instructions (CAI) in Basic Electronics"* and the study of Colasito (2011) entitled *"Development and Validation of Computer-Aided Instructions (CAI) in Ohm's Law"*. These studies used Modified ADDIV model because of the order of its stages. Validation of the experts comes first before its implementation. By this way, errors and changes have been recognized before the implementation, so error during pilot testing is diminished. This study also employed this framework (See in the research procedure part for more details).

1.3 Computer-aided Instructions (CAI) in developing Digital courseware to promote Transmission Genetics Literacy

Computer-Aided Instruction is one of the common approaches that utilizes computers in teaching. This modern approach promotes integration of computers or other technological products run by the computers. It aids the teacher to simplify the delivery of the learnings since it provides visual conceptions during instructions. In the study of Kareem (2015) and Owusu et.al (2010), it was found out that the use of computer-aided instructional materials improved the academic performance of the students in Biology. Moreover, in the study of Gurbuz (2010), it was found out that the Pre-service Teachers' attitude towards Biology has changed positively after exposing to digitized instructions. The findings of these studies gave an idea for the researcher to develop digital courseware in transmission genetics. The result of this study was hoped to be aligned with what is existing in the literature that digitized instructional materials or learning tools can be used in improving achievement and attitude in Biology specifically in transmission genetics. Using the learning theories, biology competencies that were assumed to be enhanced using this digital courseware were important terms in transmission genetics, Mendelian genetics, relationship of meiosis with laws of Mendelian pattern of inheritance and Non-Mendelian genetics. Moreover, it includes students' way of explaining the terminologies under transmission genetics, comprehending and analyzing monohybrid and dihybrid crossing of traits, how law of segregation, independent assortment and complete dominance affects variations and understanding how non-Mendelian genetics considered as rule breakers of patterns of inheritance.

Statement of the Purpose

The main purpose of the study was to develop digital courseware in teaching transmission genetics of grades 8 and 9.

Specifically, this study seeks to;

1. develop a digital courseware on transmission genetics;
2. validate the developed digital courseware on transmission genetics; and,
3. try out the validated digital courseware to the Grade 8 Students as a learning tool.

Significance of the Study

The instructional materials developed in this study intended to increase the enthusiasm in the classroom, and the curriculum through technology-enhanced types of learning and it will be beneficial to the following:

To other researchers who will work on the development of digital learning tools, this is to serve as the baseline in developing digital courseware in Biology. The detailed procedure of this study will guide them in developmental stages of digital courseware like starting with the modular format and initial validation before proceeding to digitization. Moreover, through these steps, they may also develop digital courseware about the topics that were found out in the needs analysis as areas with low conceptual understanding, least mastered and with numerous alternative conceptions.

To the Teacher, the developed digital courseware as simple technological instructional materials can be used in their teaching to improve their computer skills as well as the students' computer literacy. By this way, learning genetics becomes easy and usable for 21st Century learners since computer skills are integrated.

To the Students, the developed material was developed to serve as their reviewer or a course guide in learning transmission genetics in interactive way with the help of computers.

Scope and Delimitation of the Study

This study was focused only in the development and validation of digital courseware on transmission genetics. Specifically, it only covers the topics, important terms, principles and problem solving skills in Mendelian Genetics and Non-Mendelian

Genetics. After the development, it was evaluated by three (3) content-experts and three (3) Information Technology (IT) or Computer experts to determine its validity in terms of instructional content, format and design, and technical and organizational quality. The effectiveness of its development was tested using the two classes of grade 8 students of a laboratory school. Pilot testing in Grade 8 students was done since this grade level takes the Mendelian Genetics in their curriculum

Definition of Terms

Alternative conceptions. In this study, it refers to the genetics concepts that are incongruent to the existing validated genetics or biology concepts or out of the conventions of scientific community. According to Yates & Marek (2014), an alternative conception is defined as ‘a perception of phenomena occurring in the real world which is not consistent with the scientific explanation of the phenomena. Moreover, Bahar (2010) defined misconceptions as the concepts that have peculiar interpretations and meanings in students’ articulations that are not scientifically accurate.

Conceptual understanding. In this study, it covers the knowledge about the terms, ability to interpret genetics problems through identifying the genotypes and phenotypes and predict possible genotypes using pedigree diagrams. Also, it refers to the ability of a student to understand and associate the pieces of presented information stored in the brain and used or applied at some latter time when needed.

Digital courseware. These are PowerPoint presentations intended to serve as kits for teachers, trainers, or tutorials for students and operated through computers.

Digital courseware class (DCC). This is the group of students who was instructed using the Digital courseware.

Direct instruction class (DIC). This is the group of the students who was instructed using Lecture-discussion method.

Transmission genetics. It is a field of genetics which concerns with the mechanism of heredity and how genes are transmitted through generations. In this study, it focuses on Mendelian and Non-Mendelian pattern of inheritance. It is also defined in Tamarin (2011) as the transfer of genetic information from genes to another generation (from parent to offspring), almost synonymous with heredity, or from one location in a cell to another.

Transmission Genetics Literacy. It was defined as the ability of the students to define genetics terms, to comprehend and solve genetics problems and to apply genetic concepts in explaining genetic inheritance.

CHAPTER II
THE RESEARCH METHODOLOGY

Research Design

This study used descriptive developmental design. It is descriptive in the sense that it conducted a need analysis through surveying in-service biology teachers and gathered literature about transmission genetics with low level of conceptual understanding, numerous alternative conceptions and least mastered competency. After the need analysis and literature review, digital courseware was developed about the selected topics in Biology, which is transmission genetics, to address the difficulties and have it validated by content and IT experts and test its effectiveness to the students.

To determine the effectiveness of this material, pre and post-tests were used. 4-item multiple-choice two-tier tests with twenty (20) points scaling were given to the two groups. The student-samples were grouped into two: the Digital courseware class (DCC) which utilized digital courseware during the instructions and Direct-instruction class (DIC) which utilized lecture-discussion in delivering the lessons in transmission genetics.

Research Locale

The developed digital courseware was tried out to a laboratory school run by a state university. The laboratory school is an integrated school made up of one section per year level from Grades 1 to 6 and two sections from Grades 7 to 10 in Junior High School. Just like other public schools, Junior High school students take up Integrated Science for their science subject. Integrated science is divided into four branches namely, Biology, physics, chemistry and Earth Science, which are arranged in spiral progressions.

Sampling and Participants

The study primarily involved student-responses, responses of in-service biology teachers, biology experts and computer experts whose responses were relevant to the development and validation of the digital courseware. In the initial procedure of the research, survey was conducted to the in-service biology teachers to determine which competencies in Biology that showed low conceptual understanding, least-mastered and have numerous alternative conceptions. The responses of these in-service biology teachers further substantiate the problems cited in different literature and studies. These responses were served as the basis in the development of the digital courseware. In terms of validation, content-experts and computer-experts responses made a contribution in improving the features of the Digital courseware.

Table 1: Profile of the Experts Validator

Expert	**A. CONTENT-EXPERT VALIDATORS**
1	Highest Educational Attainment: **Master of Science(MS) in Biology** Position & Institution: Master Teacher I, Las Piñas Science High School
2	Highest Educational Attainment: **Doctor of Philosophy in Biotechnology** Position & Institution: Researcher & Project Manager, DOST - ITRI
3	Highest Educational Attainment: **Master of Science (MS) in Biology** Position & Institution: Faculty, University of Santo Tomas (UST), Espana, Manila
	B. INFORMATION TECHNOLOGY (IT)-EXPERT VALIDATOR
1	Highest Educational Attainment: **BS in Information Technology (BSIT)** Number of Years in the Field: **3 years as Computer Programmer**
2	Highest Educational Attainment: **BS in Information Technology (BSIT)** Number of Years in the Field: **3 years as Computer Specialist and Web Design**
3	Highest Educational Attainment: **BS in Computer Science (BSCS)** Number of Years in the Field: **5 years as Computer Programmer and Web builder and design**

Table 1 summarizes the profile of the three (3) content-expert validators and Information Technology (IT)-Expert validators who validated the digital courseware. The researcher ensured that the highest educational attainment of the content-expert validators are all at least graduates of Master's degree in Biology and must be teaching genetics and courses in which genetics is integrated. While the Information-Technology (IT) Experts were ensured to be graduates of Information Technology (IT) or any course related to computer such as Computer Science and Programming and must exercise their profession for more than three (3) years.

In the Pilot test, students of laboratory school served as the sample during the implementation of the study. This laboratory school has only two sections in Grade 8 level. Grade 8 level was chosen among other levels since the competencies for pilot testing can be found in the grade 8 level competency. This phase aimed to determine the effectiveness of digital courseware as an instructional material.

Table 2: Distribution of Students and Modes of Instructions in the Intervention

Group/Section	Number of Students	Modes of Instruction in teaching transmission genetics
Grade 8 (Group A) Digital courseware Class (DCC)	28	w/ digital courseware
Grade 8 (Group B) Direct instructions class (DIC)	28	Direct-instruction
Total	56	

**Note: Case-wise deletion of sample was employed due to sample mortality during experimentation period.

Table 2 shows the distribution of students in two classes. The first group was Grade 8 students who were instructed to use Digital courseware. This group was termed as digital courseware class or DCC. The second group was Grade 8 students who were instructed to use Direct Instruction approach. This group was termed as Direct-instruction class or DIC. The two sections are said to be heterogenous classes since the sectioning of the students are annually classified and distributed based on General Weighted Average (GWA) of their academic year.

Research Instruments

This study used 4 instruments: (1) Researcher-made Checklist Inventory for needs assessment, (2) Content-Expert Validation Tool for the assessment of the content expert validators, (3) Information Technology (IT)-Expert Validation tool for the assessment of computer expert, and Researcher-made Pre and Post-tests.

The first instrument used was **researcher-made checklist inventory** (See Appendix A). It contained the competencies of Biology from grades 7 to 10 based on K-12 Curriculum Guide in Science. This survey instrument was administered to In-service biology teachers. They selected and ranked the top ten (10) topics which they consider as competencies which are least mastered and have numerous alternative conceptions (item with remarks of 1 will be considered as the least mastered or with numerous alternative conceptions). Its main purpose was to validate and further substantiate that transmission genetics is really one of the topics in Biology which is least mastered and has numerous alternative conceptions aside of what is existing or mentioned in many literature and studies.

The second instruments used were the Content-Expert Validation tool and Information Technology (IT) Expert Tool which were adapted and modified from the study of Rivera (2009) about Development and Validation of Computer Aided Instructional Material in Basic Electricity and Electronics. The facets of the instruments were modified by the researcher in order to align its content specifically to genetics. The **Content-Expert**

validation tool, presented in table 3, determined its appropriateness in terms of instructional content such as these subsets: Objectives, Information Content, Instructional Events, Learners' Activities and Evaluation. Each facet was rated with 4 as the highest and 1 as the lowest. The average per facet was determined including the standard deviations. This tool was given to teachers who earned at least Master's degree and teaching Genetics or science subjects where Genetics is included (See Table 3 for the profile of the validators). Contents of the facets were observed to be free from biases by focusing directly on the Instructional content of the digital courseware (See Appendix C for the facets).

Table 3: Distribution of facets under Instructional Content

Facets of Instructional Content	**Number of Facets per subsets**
a. Objectives	4
b. Informational Content	4
c. Instructional Events	6
d. Learner's Activities	6
e. Evaluation	3

Note: See Appendix C to view the full details of the instruments

The facets of Instructional content applied the principles of Mayer's cognitive theory of multimedia learning. In terms of learning objectives, it observed if the content experts agreed with the shortened sets of genetics words instead of whole sentences and if the provided pictures supported those sets of words. This was based on coherent and multiple representational principles of Mayer's cognitive theory of multimedia learning. In terms of informational contents and instructional events, it observed if the experts agreed with all prepared pictures, diagrams and summarized genetics concepts were presented coherently and the summarized procedures of the genetics problems with supported pictures can address students' individual differences in terms of following the procedure using texts or diagrams. These were all based on the contiguity, coherence, multiple representational and individual difference principle of Mayer's cognitive theory of multimedia learning. In terms of learners' activities and evaluation, it observed if content experts agreed with the sequences of genetics problems and its correct answers were presented as suggested by *contiguity principle* that the givens of the problems were followed by detailed procedures and its diagrams and explanations that concepts are better to present when accompanied with illustrations or diagrams.

The **Information Technology (IT)-Expert Validation tool**, presented in table 4, determined the appropriateness of the digital courseware in terms of (I) format & design and (II) technical & organizational content. The two criteria are composed of eight (8) facets each. Also, each facet was rated with 4 as the highest and 1 as the lowest. The average per facet was determined including the standard deviations. This tool was given to computer experts who finished Computer-related courses like Programming, Computer Science and Web-designing. Contents of the facets were observed to be free from biases by focusing directly on the format and design and technical organization of the digital courseware. See Appendix D for the facets.

Table 4: Distribution of facets per component under format & design and technical & organizational content

Components of Instruments	Number of Facets per subsets
1. Format and Design	
a. Language Component (3)	8
b. Media Component (5)	
2. Technical and Organizational Content	8
TOTAL	**16**

Note: See Appendix D to view the full details of the instruments

The facets of this instrument also observed the Mayer's cognitive theory of multimedia learning. In terms facets under the format and design, the content of the courseware were observed if the computer experts agreed with the design of the digital courseware such as the background colors, types of pictures used and presentation or animations in presenting genetics concepts or solutions for genetics problems. In terms of organizational content and technical content of the courseware, it observed if the computer experts agreed with the visual presentation integrated with the sequence of the model as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning and if the visuals contributed adequately to the understanding and enrichment of genetics concepts. Moreover, it also observed if the texts and pictures were synchronized as suggested in the coherence and contiguity principles of Mayer's cognitive theory of multimedia learning.

In determining the validity of instructional material, the means of Instructional Content, Format and Design, and Technical and organizational quality were used in this interval. Table 5 shows the interpretation of the mean given by the validators. According to Colasito (2011), the instructional material is valid if the instructional content, format and design, and technical and organizational quality are appropriate or very appropriate.

Table 5: Interpretation of means given by the content-expert and IT-expert validators

MEAN	INTERPRETATION
3.01 – 4.00	Very Appropriate
2.01 – 3.00	Appropriate
1.00 – 2.00	Not Appropriate

The last tool used was the researcher-made Pre and Post-test Written Assessment Tool (Appendix D). It is composed of 4-questions Multiple choice two-tier test with parallel stem in a single item. Systems of pointing is provided as follows: when item A and B is correct, five (5) points was given to the item. When item A is correct while Item B is incorrect, two (2) points was given. When Item A is incorrect and B is correct, one (1) point was given because the student might probably guessing since the first items are related with the second items. The scores in this instrument were interpreted as follows:

Table 6: Interpretation of scores in the researcher's pre- and post-tests

For 10-items questionnaire used per lesson		***For combined scores of Lesson 1 and 2***	
Mean	Interpretation	Mean	Interpretation
7.01 – 10.00	High	14.01 – 20.00	High
3.01 – 7.00	Average	6.01 – 14.00	Average
0.00 – 3.00	Low	0.00 – 6.00	Low

Research Procedure

Adequate and accurate concepts on transmission genetics possessed by a learning tool, as the primary goal of the study, is the researcher's purpose of developing the Digital courseware. Mastering the concepts of Transmission Genetics while integrating technology in learning tools or instructional materials simplify the learning process of concepts. To attain these goals, important procedures in the study were followed which primarily involved the stages in developing the learning materials.

Figure 3 shows the development of Digital courseware which involves four (4) major stages adapting the ADDIV Model (**A**nalysis, **D**esign, **D**evelop, **I**mplement and **V**alidate) with modification, namely: Planning, Design and Development, Validation and Revision Stage. Modified ADDIE Model was used in order to give emphasis on the revision stage which was not emphasized in the original ADDIE Model. These stages were followed thoroughly including its sub-stages. The last stage which is the revision stage includes the feedback and suggestions of the validators which further improved the quality of the digital courseware.

Planning Stage
I. Gathering of empirical data
II. Selection and preparation of validation instruments that were used as guide in developing the Digital courseware

↓

Design and development Stage
I. Consulting the components of transmission genetics based on the competencies set in K to 12 Biology
II. Designing and developing the module format of the digital courseware
III. Initial validation of the content of the module format with the content-experts
IV. Digitization of the digital courseware in transmission genetics

↓

Validation stage
I. Second content validation with the Content-expert validators
II. Validation of the digital courseware with the computer or IT experts

↓

Revision and implementation stage
I. Revision of the digital courseware based on the comments and suggestions of the computer experts.
II. Pilot testing

Fig 3: Developmental Stages of the Study

PHASE I: Planning Stage

1.1 Gathering of Empirical Data

The researcher-made checklist inventory was prepared and administered to the ninety in-service biology teachers of National Capital Region (NCR) during PNU-BioTA Conference. This event enabled the researcher to gather information from the teachers coming from different schools in NCR. This survey determined the least mastered competencies in Biology and has numerous alternative conceptions. Moreover, it validated and further substantiated the problems cited in the literature which also claimed that transmission genetics is really one of the topics in Biology which is least mastered and has numerous alternative conceptions.

The checklist inventory was given to the in-service biology teachers before the conference started. Twenty minutes were given to the teachers to rank the competencies which they considered as least mastered, with low conceptual understanding and have numerous alternative conceptions. After administering the survey, the responses of in-service biology teachers were tallied. The results of the ranking based on the conducted survey with in-service biology teachers are presented in table 7. It was found out that transmission genetics was one of the topics in Biology which they considered as the least mastered competency, low conceptual understanding and with numerous alternative conceptions.

Table 7: Competencies in Biology with Low Conceptual Understanding, least mastered and with numerous alternative conceptions as perceived by in-service biology teachers

	Competencies in Biology			
RANK	With low conceptual understanding and least mastered competency	Mean of Ranks	With numerous alternative conceptions	Mean of Ranks
1	Cellular respiration	1.68	Cellular Respiration	1.47
2	Photosynthesis	1.80	Protein Synthesis	1.91
3	Protein Synthesis	3.28	Mitosis and Meiosis	2.23
4	DNA Replication	3.80	Non-Mendelian Genetics**	2.56
5	Non-Mendelian Genetics**	6.16	Photosynthesis	2.68
6	Mendelian Genetics**	7.21	Circulatory System	6.72
7	Nervous System	7.35	Nervous System	7.10
8	Circulatory System	7.43	Endocrine System	7.45
9	Mitosis and Meiosis	7.50	Mendelian Genetics **	8.20
10	Endocrine System	7.58	Species Diversity	8.92

Among the 28 competencies written in the researcher-made checklist inventory (see appendix A), Mendelian Genetics is rank #6 among competencies with low conceptual understanding while rank #9 among competencies with numerous alternative conceptions. Non-Mendelian Genetics is rank #5 among competencies with low conceptual understanding while rank #4 among competencies with numerous alternative conceptions. This initial result further substantiated the findings in different literature that transmission genetics (Mendelian and Non-Mendelian Genetics) is one of the topics in Biology that students find difficult. Students and even teachers find transmission genetics as difficult because of the following reasons: (1) this area is highly theoretical and some require intensive analysis with application of mathematics, (2) they have inconsistent and incomplete understandings and misconceptions of several basic Mendelian genetic concepts, (3) they cannot differentiate the concepts and find the relationship between chromatin, chromosome, chromatid, genes and alleles. (4) In terms of solving genetics problem, they cannot break down the thoughts of the problem into smaller pieces with sense resulting to failure in identifying the proper genotypes of the parents & its offspring. Lastly, (5) the problem requires two or more traits to be crossed, or if in the problems, it is difficult to identify if the trait is dominant, intermediate or recessive. If the students fail to comprehend the concepts, application in solving problems may be of difficulty. Because of the following reasons, development of the courseware was done to address these problems since it is timely and relevant because it is an example of multimedia instruction.

1.2 Selection and preparation of validation instruments that were used as guide in developing the Digital courseware

The researcher searched and selected validation instruments that were used as guide in developing an instructional material. These instruments played an important role in determining the characteristics or attributes that can be possessed by a Digital courseware. In terms of Instructional content, these characteristics were considered and here are as follows: Learning objectives, Informational content, Instructional Event, Learner's Activities and Evaluation. Another factor that was considered by the researcher in selecting instrument was the format and design, technical and organizational contents. Facets of Instructional contents, format and design, and technical and organizational content were evident in the instruments in the study of Rivera (2009) which also focused on the development of instructional material in science. The researcher adapted this instrument with some modifications to align with the concept of genetics not just only in science.

PHASE II: Design and Development

2.1 Consulting the components of transmission genetics based on the competencies set in K to 12 Biology

K to 12 curriculum guide was consulted to determine the sub-topics that are under transmission genetics which are Mendelian Genetics and Non-Mendelian Genetics. Grade 8 competencies contain 3 competencies about Mendelian pattern of inheritance and these are as follows: (1) definition of terms; alleles, genes, homozygous gene, heterozygous gene, genotype, phenotype, dominant and recessive; (2) Mendel's laws of inheritance - Law of Segregation, Law of Independent Assortment and Law of Complete Dominance; and, (3) Monohybrid and dihybrid crossing of trait. While in Grade 9, it contains 6 competencies about Non-Mendelian pattern of inheritance and these are as follows: (1) Law of Incomplete dominance (2) Codominance, (3) Multiple alleles, (4) Sex-linkage, (5) Sex-influenced trait, and (6) sex-limited trait. All those topics were selected to be part of the digital courseware.

2.2 Designing and developing the module format of the digital courseware

After determining the topics, the researcher developed a module format of the digital courseware. This module format was developed to validate its content by content-expert in biology. By this way, errors were minimized before the digitization. The module format of the courseware had three lessons and these are as follows: (1) Important terms in transmission genetics, (2) Mendelian Genetics, and (3) Non-Mendelian Genetics. Moreover, the following lessons contain these lessons:

Table 8: Content of the Lessons in the Digital courseware

Lesson 1: Important terms in transmission genetics	**Lesson 2: Mendelian Genetics**	**Lesson 3: Non – Mendelian Genetics**
Genes and Alleles	Law of Segregation	Law of Incomplete Dominance
Dominant and Recessive gene	Law of Independent Assortment	Law of Codominance
Homozygous and Heterozygous genes	Law of Complete Dominance	Multiple Alleles
Genotype and Phenotype	Monohybrid and Dihybrid crossing of traits	Sex-linked traits
Punnett Square		Sex-Influenced traits
		Sex-limited traits

Table 8 shows the distribution of lessons in the digital courseware in transmission genetics. Lesson 1 contained 5 concepts to discuss (genes and alleles, dominant and recessive gene, homozygous and heterozygous gene, genotype and phenotype, and punnett square). Lesson 2 contained 4 concepts to discuss (law of segregation, law of independent assortment, law of complete dominance and monohybrid and dihybrid crossing). Lesson 3 contained 6 concepts to discuss (law of incomplete dominance, law of codominance, multiple alleles, sex-linked traits, sex-influenced traits and sex-limited traits).

Each lesson of the courseware started with the lesson objectives that were distributed in knowledge, skills and attitude domains or otherwise known as cognitive, psychomotor and affective domains. The second part of the module format is the content. It contained the lesson proper and the discussion of the topic. The content of this material was based on Biology textbooks published locally and internationally. The authors of these biology books are Campbell & Reece, Biggs et.al, Raven and Rabago. The definitions, concepts and principles were adapted from the books of the previously cited authors. In terms of sample problems and problem exercises, the researcher constructed those problems in order to organize the level of difficulty and applications of the problems in different field of science (Plant biology, Human Anatomy, Animal Biology etc.). In terms of selection of graphics and illustrations, the researcher downloaded these pictures from the internet (see the discussion of how Mayer's Cognitive Theory of Multimedia Leaning used in the digitization of the courseware in Table 10). The selected pictures and diagrams were used for the activities such as 4-Pics-1-word game. Some downloaded pictures can be found within the module. Lastly, the researcher-made pre and post-tests were preferred by the researcher as written exam to avoid bias to the direct-instruction class. Both groups' achievements were planned to be assessed using the researcher-made pre- and post-tests. This type of test was a multiple choice two-tier test. The first item (A) in a question is related to the second question. Systems of pointing was provided as follows: when item A and B is correct, five (5) points was given to the item. When item A is correct while Item B is incorrect, two (2) points was given. When Item A is incorrect and B is correct, one (1) point was given because the student might probably guessing since the first items are related with the second items.

Table 9: Distributions of questions in the researcher-made pre- and post-tests

Items	Important terms in transmission genetics	Mendelian Genetics
1A	N/A	This item was focused on the application of monohybrid crossing of albinism.
1B	This question elicits explanation about albinism as a recessive trait.	Application of Law of Complete Dominance was observed in this item.
2A	This item described brown-eye trait is dominant.	This question utilized monohybrid crossing of color of the eye as the trait.
2B	This item elicit for the characteristics of the offspring or phenotype.	This item asked for the use of Punnett square for crossing the trait and determine the percentage of having blue-eye offspring.
3A	It applies how genes should be distributed to avoid mutations and aberrations.	This question recalled the student's knowledge about law of segregation.
3B		This question tested the student's comprehension and analysis about the application of law of segregation.
4A	It applies how genes in the gametes are randomly distributed which produces variations.	This question recalled the student's knowledge about law of independent assortment.
4B	N/A	This question tested the student's comprehension and analysis about the application of law of independent assortment

Table 9 discussed the distributions of questions in the researcher-made pre- and post-tests. The questions were delimited up to Mendelian Genetics since the pilot testing were planned to be conducted in Grade 8 since this topic is taught in this grade level.

2.3 Initial validation of the content of the module format with the content-experts

This step was done in order to validate the content of the module format. By this way, errors were minimized prior the digitization of the digital courseware. Content-expert validators were given a printed copy of module format and the content-expert validation tool. Validators were given enough time (two to three weeks) to read, revise and recommend some changes to improve the content of the material. After the initial validation, comments and suggestion were recorded, tallied and organized in a way that every comments were addressed.

2.4 Digitization of the digital courseware in transmission genetics

Before the digitization of the courseware, comments and suggestions of the content-expert validators were organized to improve the content of the materials. Revisions and corrections of answers were also done. Mayer's Cognitive Theory of Multimedia Learning was also reviewed especially its four principles which are all relevant in the development of the courseware. These principles are as follows: (1) *multiple representational principle* which believes that use of words and pictures is more effective in presenting genetics concepts rather than solely in words; (2) *contiguity principle* which believes that explaining genetics concepts using multimedia instruction, simultaneous presentation of words and pictures is better than presenting those separately; (3) *Individual difference principle* which believes that when giving a multimedia explanation, some students can catch genetics concepts easily with visual text but some need pictures to easily get the concept. In this study, visuals and illustrations were highly observed in order to attract the attention of the students; and, *(4) Coherence principle* which believes that students learn better from a coherent summary which highlights the relevant words and pictures than from a longer version of the summary. In the development of the design, the researcher constructed a summary of concepts that are written in simple language and important words are highlighted.

All background pictures of the slides were drawn by the researcher in the Adobe Photoshop. The design of the entire courseware was animated theme in order to catch the attention of the user. In addition, the researcher developed a story about the two boys, named, Matt and Twight, who were classmates and studying transmission genetics. They both went to the library to answer their assignments.

Appendix B discussed the detailed procedure in developing digital courseware on transmission genetics and how these slides were anchored with the principles of Mayer's Cognitive Theory of Multimedia Learning. The components of each slides were discussed such as the definitions, explanations, procedures, animated pictures and hyperlinks that lead the user from one slide to another.

In lesson 1, lesson objectives were shortened in a slide in which the list of words to be encountered in this lesson listed like dominant vs recessive, homozygous vs heterozygous and genotype vs phenotype can be found including the background pictures that give the students cues and ideas about the topic. This arrangement was based on the principle of multiple representation. Contiguity principle was use in the activity in which words and pictures were combined in order to give hints to the students while finding those words. In succeeding slides like the lesson proper, it presented the definition of important terms in transmission genetics together with visuals as suggested in multiple representational principle. Individual difference principle was also considered since there are some students can catch the concepts easily with visual text but some need pictures to easily get the genetics concept. Contiguity principle was also used to present and explain the difference between the concepts of dominant and recessive, homozygous and heterozygous, genotype and phenotype using short-animations or by simultaneous presentation of words and pictures and Coherence principle was used to show the essential parts of the highlighted genetics concepts and its supported illustrations to make it more attractive to the user.

In Lesson 2, the principle of multiple representation was applied in which the pictures of body parts were used together to relate the explanation of law of segregation in terms of the represented letters. Coherence principle was also observed in terms of providing summary of the expected information about the activity. In the slide which contained law of independent assortment, coherence principle was used to provide a summarized concept coherent with the picture which shows the variations among the gametes. In the slide which contained law of complete dominance, multiple representational principle, coherence principle and contiguity principle. Summarized concepts together with animated pictures that work coherently is a better representation of explanation rather of words alone. In terms of problem solving, slides observed the principles of coherence, contiguity and multiple representation. It used multiple representational principle and contiguity principle in the sense that words and pictures were used simultaneously in order to present the concepts of monohybrid crossing of trait such as heights of the plants, colors of the eyes, types of earlobes and skin pigmentation Coherence Principle was used in providing summarized procedure of solving genetics problem and appropriate animation of picture in order to present the method of problem solving coherently.

In lesson 3, it was designed the way how pictures and words are presented in simultaneous manner to deliver the concepts of law of incomplete dominance as suggested by multiple representational principle. Moreover, the summarized definition of this law contain the important information and it is coherently presented with pictures of the flowers' petals which vary in colors. Same designs of slides were used in presenting the concepts of codominance and multiple alleles even the design of these slides were also patterned with the previous way of how sample problems were delivered. It started with the questions, given, genotypes of the parents and its gametes, punnett squares, ratios and finally the short explanation for the final answer. This way of presentation observed the principle of contiguity and coherence.

The slides for sex-linked traits, sex-influenced traits and sex-limited traits used the same templates and background design that were used in different laws under Non-Mendelian Genetics in terms of presenting the concepts and sample problems to be solved. The way of presenting the summarized concepts and pictures are anchored with the multiple representational principle and coherent principle. The summarized concepts contained the essential words that can differentiate these three patterns of inheritance. To further improve the content of these slides, pictures were coherently added to the summarized content. The addition of the pictures aimed to describe the genetic condition of the organisms which possess those traits.

PHASE III: Validation Stage

3.1 Second content validation with the Content-expert validators

After the digitization, the digital courseware was consulted again to the content-expert validators to recheck the revisions made by the researchers. Each of the validators was given the copy of the digitized courseware online. Validators also answer the content-expert validation tool to assess the instructional content of the digital courseware. This time, validators were able to respond in shorter period of time. Their responses were sent through e-mail including the results of their evaluation.

3.2 Validation of the digital courseware with the computer or IT experts

After the digitization and final content validation, it underwent computer-expert validation. The researcher personally demonstrate the digital courseware including its features. Computer experts also operate the digital courseware. Computer experts evaluate the format and design of the courseware including the technical and organizational content using the Computer-Expert validation tool. Furthermore, unstructured interview was done per computer expert to further substantiate the data for validation.

PHASE IV: Revision and Implementation Stage

4.1 Revision Stage

After the entire validations whether content and computer-concerns, all comments and recommendations were considered in order to improve the quality of the digital courseware. Some weaknesses of the digital courseware like way of operation were considered to find solutions while some strengths of the digital courseware were recorded and organized. These points were planned to be used for the discussion of the results.

4.2 Implementation Stage

Prior to the implementation, the researcher prepared visual aids which were needed for the Direct-instructions class (DIC). The researcher prepared hand-outs which contained pictures of different traits in human, plants and animals. These hand-outs and manipulatives served as replacement for the learning tool since the Digital courseware class (DCC) used digital courseware as learning tool.

In pilot-testing stage, it started with briefing the students about the nature of the study such as the competencies to be taken (See Ethical Considerations for further explanation), informing them about their rights and asking their consents if they were willing to participate along the experimentation period. After the briefing, both groups of students were given a pre-test prior to the implementation of the experiment. The pre-test was checked, tallied and recorded. Participants' names were alphabetized and the each pre-test paper was given a code number instead of their actual name. Mean scores of the students in the two groups were determined.

Table 10: Time table for the conduct of research

DAY	Length of time	ACTION(S)
1	20 mins	Briefing of the Students: asking for their assents and distribution of parent's consent.
2	30 mins	Administering of the Pre-test with the Participants of the Study
3 - 5	120 mins	Implementation of the study
6	30 mins	Administering of the Post-test with the Participants of the Study
7	60 mins	Debriefing of the participant (if possible). For those who are interested to know their progress score and its percentage increase.
TOTAL	**260 mins**	

Table 10 summarizes the duration of experiment period. Their science class is similar with Public high school in which it consumed an hour or sixty minutes per session. The entire study consumed two-hundred sixty minutes.

Conduct of the Pilot Testing & its ethical considerations

For the implementation of this material, there were several steps that followed by the researcher and gave emphasis especially the potential ethical issues that this study interfered.

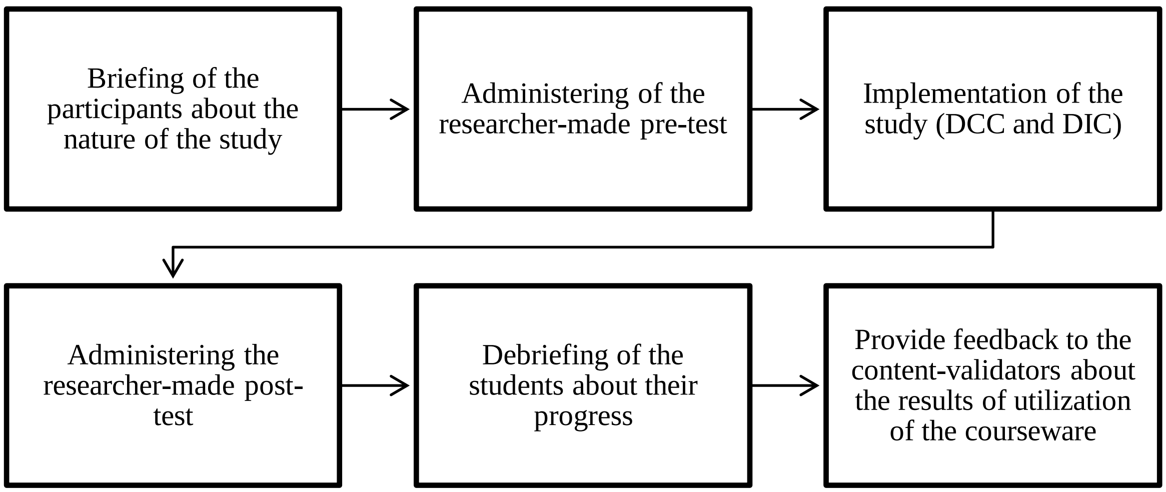

Fig. 4: Conduct of the Pilot Testing & its ethical considerations

Figure 4 shows the conduct of the pilot testing followed by the discussions of the ethical considerations. First, the researcher informed the participants about the objectives of the study which was the utilization of multimedia technology in learning genetics concepts. Students were informed about their rights and asked their consent if they were willing to participate in the study. The term “digital courseware” was not used during briefing of the participants. The students and their guardian(s) has filled out a consent form noting that they agreed to be one of the samples for this study (student part) and letting their child(ren) as a sample for this study (guardian’s part). One grade 8 class was assigned as the Direct-instructions class (DCC) and the other grade 8 class was assigned as the Digital courseware class (DCC). Next, researcher-made pre-test was administered to both groups. Twenty minutes were given in answering the test. After administering the test, it was checked by the researcher using the pointing scale mentioned in the research instruments part. Scores were tallied and recorded. Participants' test papers were alphabetized, tagged and labeled with number codes that served as they identity throughout the implementation. The implementation of the study consumed 7 days or 260 minutes to deliver the lessons 1 and 2. These two lessons only were pilot tested because these topics only are taught in Grade 8 level. The researcher served also as the teacher of the study, primarily, because there was no available teacher who would teach the topics, Mendelian Genetics, since the teachers of the school are physics and chemistry teachers. It is easier for the researcher to deliver the content since the material was originally written by the researcher aside from it is his field of specialization. Similar parts of the competencies were given to both groups of the participants as seen in the lesson plan including problem-solving sets and activities. The Direct-instructions class (DIC) received a hand-out, manipulative materials and activity sheets while the developed digital courseware was utilized by the Digital courseware class (DCC). Congruency of the content of the lessons and its materials were observed to ensure that both groups received equitable and unbiased treatment during implementation. Then, researcher-made post-test was administered a meeting right after the implementation. Again, the test papers were checked and tallied by the researchers. The test papers were alphabetized and paired with their pre-test papers. All checked test papers were properly secured by the researchers until the debriefing stage. Finally, in the debriefing process, students who asked for their progress were asked to prepare a sheet of paper wherein the researchers wrote the following: (1) Pre-test score, (2) Post-test score, (3) Gained-score and (4) Percentage increase of their score. Content validators of the developed digital courseware were also informed about its effectiveness as alternative instructional material.

Statistical Treatment

The following statistical tools were utilized to analyze the data gathered in this study:

Percentage. It is used to determine the distribution of respondents and frequency of responses as part of the whole. It was used in determining the difference in the Pre-Test and Post-test in terms of percentage-increase.

Mean. The mean or average was used as a statistical tool in the interpretation of the Science Teachers/Experts' and IT Experts' evaluation about the Digital Courseware on Transmission Genetics.

Standard Deviation. The standard deviation is used as a statistical tool for interpreting the deviation of scores of Science Teachers/Experts' and IT Experts' evaluation from the mean.

Minimum and Maximum Value. It was used to describe the lowest and the highest scores in the pre-test and post-test.

F-test. It was used to determine if there was a significant difference between the following;

(1) Pre-Test and Post-Test of the Digital courseware class (DCC);

(2) Pre-Test and Post-Test of the Direct-instructions class (DIC); and,

(3) Post-tests of the Digital courseware class (DCC) and Direct-instructions class (DIC).

CHAPTER III
RESULTS and DISCUSSION

Purpose No.1: Develop a digital courseware on transmission genetics.

After the initial content validation of the module format of the digital courseware, several comments and suggestions from the content-experts were collected. Table 11 shows the summary of comments and suggestions of the 3 content-experts validators.

Table 11: Summary of comments and suggestions of the content-experts validators

Parts of the developed digital courseware	Comments and suggestions
Lesson 1	
Activity	- "Provide answer key for the activity
Definition of Genetics and genes	- "Highlight the word genes in the definition of genetics and the word DNA molecules in the definition of genes to give emphasis on what they are made of."
Alleles	- "specify the traits per body parts."
Dominant and recessive gene	- "Highlight the word ***"masks"*** in the definition of dominant gene and the phrase ***"is masked by"*** in the definition of recessive gene in order to emphasize that recessive gene is not lost. It is just masked by dominant gene and may be expressed once recessive allele pairs with it."
Lesson 2	
Monohybrid and dihybrid cross	- "Countercheck the typographical error. Also, check the answer key. Phenotypes were not edited; this might be copied from the previous answers for the previous problems. Also, place the genotypic and phenotypic ratios beside or below for at least it is placed on a "shape" rather than of words solely."
Lesson 3	
Multiple Alleles	- "Edit the answer key for the color coat of "Himalayan", it might be a typo error upon copying the previous table since the sample problem has the same focus with the previous one."
Sex-limited	- "Separate the phenotypes of the males and females under the genotype. You may also change the color e.g red for male, black for female."
Written Pre- and Post-test	**- "**Please provide answer key. Preferably, you may provide same questionnaire but the answers are in different color"
OVERALL COMMENTS OF THE CONTENT-EXPERT VALIDATORS	

- **“Congratulations Sir Nikko. Thank You for creating this kind of informative material”.**
- **“Job well done. Please give me a copy once it is digitized”**
- **“This material has adequate and accurate information on Transmission Genetics. The organization of the problems from easy to difficult is observed and the procedures of solving genetics problems are really complete and easy to comprehend.”**

The comments and suggestions summarized in table 11 were considered in the development of the digital courseware. In Lesson 1, answer keys were provided on the module format of the digital courseware. Words that were need to be in bold-faced were considered. In Lesson 2, typographical errors were corrected especially on the phenotypes. The genotypic and phenotypic ratios were placed besides the punnett squares. In Lesson 3, typographical errors in the color coat of rabbits were edited. The phenotypes under the genotypes for males and females inside the punnett square were separated as well as the color of the font was changed into red for males and black for females. Separate answer keys with different font color for the answers were added as requested by the validators. These inputs were significant in the digitization of the courseware in transmission genetics.

After the initial revisions of the content of the courseware, comments and suggestions of the content-experts were considered in the digitization of the digital courseware on transmission genetics. The steps in the research procedure summarized in table 10 were strictly followed including the revised content of the module format of the digital courseware. After the digitization, the digitized copy of the courseware was evaluated by the content-expert to see the changes that they have suggested and the way it was digitized.

After the validation with the three content-experts, the digital courseware was administered by the three IT or computer experts. There were recommendations suggested by the computer experts to improve the technical content of the digital courseware. Their suggestions were summarized in table 13.

Table 12: Summary of comments and suggestions of the IT or Computer-experts validators

Components of the developed digital courseware	Comments and suggestions
Animations of the courseware	- improve the speed of the transition of slide from one slide to another or when the user click a button to link to the other parts of the courseware
Operating the courseware	- It should be avoided that when clicking any parts of the courseware, it automatically transferred the user to the other parts of the courseware. This should be addressed. Make sure that only the buttons or menus in the courseware can be clicked to navigate the entire courseware.
***Content of the slide for problem solving**	- Please copy each question of the genetics problems to each slide in which the solutions and explanations are located so the students would not have to go back to the sets of questions.
Pictures	- Comprise the pictures of chromosomes in the slide #26. The pictures were too stretched horizontally.
OVERALL COMMENTS OF THE COMPUTER-EXPERT VALIDATORS	
- "The graphics of the slides including the diagrams and pictures were sketched and edited properly". - "The animations are synchronized with the texts, pictures and shapes". - "The appearance of the courseware is very appealing. It looks like an application operated by flash players."	

Table 12 shows the summary of comments and suggestions of the IT or computer experts who evaluated the digital courseware. These comments and suggestions were considered in the revisions of the digital courseware. The following changes were done as suggested by the computer-experts validators:

(1) the speed of the transitions were increased from 30 seconds into 15 seconds;

(2) the slides were embedded with empty textbox and the buttons to navigate the courseware were placed above the textbox. By this way, only those buttons can be clicked in order to transfer from one part to another;

(3) the questions for the problem exercises were copied and distributed per slide in which those questions had their solutions and explanations; and,

(4) Pictures of chromosomes were compressed horizontally since it was too stretched in the initial consultation.

Purpose No. 2: Validate the developed digital courseware on transmission genetics

After the digitization, the content-experts rechecked the content of the digital courseware and finally evaluated this material using Content-Expert validation tool. The content-experts were given the copy of the revised module format of the courseware and the digitized copy of this. They were given enough time to evaluate the instructional content of the digital courseware.

Table 13: Summary of ratings given by the three Content Experts

Subsets of Instructional Content	Mean	Std.dev	Remarks
a. Objectives	4.00	0.000	Very Appropriate
b. Informational Content	4.00	0.000	Very Appropriate
c. Instructional Events	3.89	0.144	Very Appropriate
d. Learner's Activities	4.00	0.000	Very Appropriate
e. Evaluation	4.00	0.000	Very Appropriate
Mean	**3.98**	**0.115**	Very Appropriate

See Appendix B to see the full detail of the instrument

Table 13 and Figure 5 summarize the ratings of three (3) Content-Experts in terms of instructional content. The material obtained a grand mean of 3.98 which is equivalent to a remark of "very appropriate".

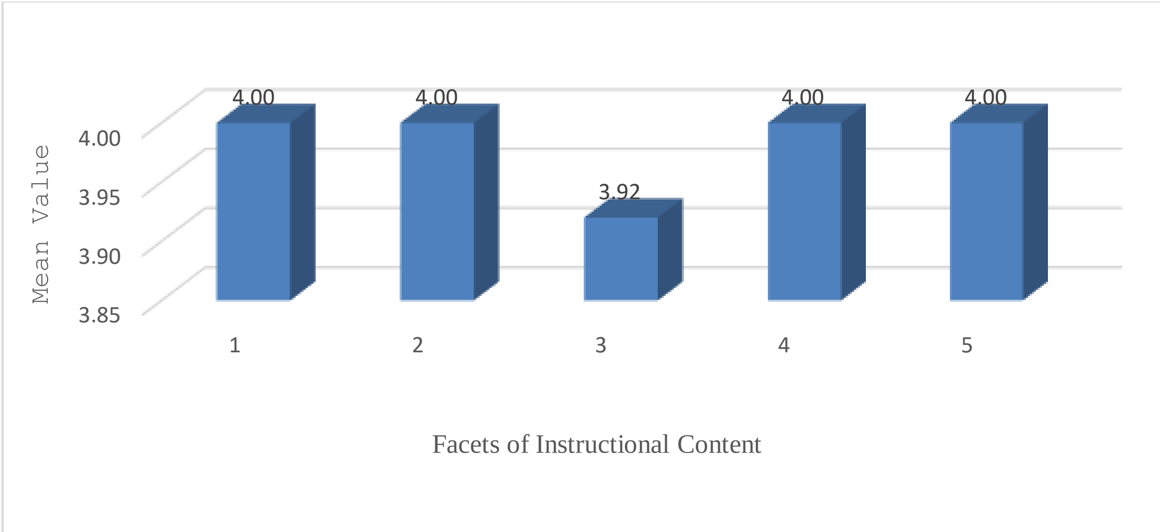

Fig 5: Content-expert validation in terms of instructional content

First in the objective facets, it obtained a mean of 4.00 which has a remark of very appropriate which means the lesson objectives of the courseware are measurable, logically-sequenced, appropriate to the target learners and relevant in delivering the concepts of genetics based on the indicators used in the instrument. The shortened sets of genetics terms together with the background pictures were based on *coherence and multiple representational principles* of Mayer's cognitive theory of multimedia learning and it was found out on the content-expert validation that the shortened sets of genetics terms and pictures were very appropriate in presenting the lesson objectives once they are digitized.

Next, informational content facets also obtained a mean of 4.00 which is equivalent to a remark of very appropriate which means the courseware's informational content were accurate, relevant, sufficient and gradually presented. Next, instructional content facets also obtained a mean of 3.89 and also equivalent to a remark of very appropriate which means the instructions of the courseware were properly and adequately presented, logically arranged, provided a guidance such as cues and hints especially in the concept development from important terms in transmission genetics up to problem solving. These two facets, informational content and instructional events, were based *Contiguity principles and multiple representational principles.* It was shown in the results of the content-expert validation that the summarized genetics concepts were effectively supported by pictures and logically arranged in such a way that it gives cues and hints to simplify the concepts of genetics in different forms such as texts or visuals.

Then, learner's activities facets also obtained a mean of 4.00 which is equivalent to very appropriate which means the learning activities such as exercises, samples and problem solving of the courseware were presented adequately to attain the lesson objectives. The application of coherence principle in presenting the procedures of genetics problem solving was effective since both textual and visual procedures in solving were completely provided. This principle aimed to guide the students along the courseware especially on the problem solving skills. Lastly, evaluation facets also obtained a mean of 4.00 which is equivalent to very appropriate. The Pre-test and Post-test items are very appropriate to diagnose the level of knowledge (Pre-test) and to determine the level of conceptual change (Post-test) of the students. Formative assessment like exercises and problem solving were also very appropriate in concept development which lead to the significant conceptual change of the students from the pre-test to the post-test. Since the evaluation of conceptual change was in the form of paper and pencil test, Mayer's cognitive theory of multimedia was not observed in this part.

To sum up, all facets of instructional content obtained remarks of "very appropriate". It means that this material is suitable as learning tool in teaching transmission genetics as discussed in different facets: lesson objectives, informational content, instructional event, learner's activities and evaluation. Overall, the applications of the principles under Mayer's Cognitive Theory of Multimedia Learning were evident in the developmental stages of this material in terms of instructional content.

To further substantiate this result, the following comments of the validators were also gathered. Based on the validators, the module format of the courseware was already full of adequate information on transmission genetics and the digitized version of this make the concepts more interesting to the user of this learning tool. The way how the genetics problems and its procedural solution presented was excellent. Students may be encouraged to solve the genetics problem exercises because the solutions and explanations were provided in different parts of the courseware to verify if they answers are correct. Moreover, this material can also be used by the students as their reviewer since the courseware was run by Microsoft powerpoint which is accessible in any mobile phone or tablets. Lastly, the background or theme of the courseware was "very eye-catching", the students will not be bored since the colors were "very attracting" at the same time, background audio was "very entertaining".

After the initial consultation with the three computer or IT Experts, revisions were made. After the revision stage, the three computer experts evaluated the digital courseware in terms of its format and design and technical and organizational content. The results of validations are as follows:

Table 14: Summary of ratings given by the three computer or IT Experts

Facets of Instructional Content	Mean	Std.dev	Remarks
a. Format and Design	4.00	0.000	Very Appropriate
b. Technical and Organizational Content	4.00	0.000	Very Appropriate
Mean	**4.00**	**0.000**	Very Appropriate

See Appendix C to see the full detail of the instrument

Table 14 and Figure 6 summarize the ratings of three (3) IT or Computer experts who validated the format & design and technical & organizational content of the digital courseware. It shows that format and design obtained a mean of 4.00 and has a remark of “very appropriate”. In terms of technical and organizational content of the digital courseware, it obtained a mean of 4.0 which has also a remark of very appropriate.

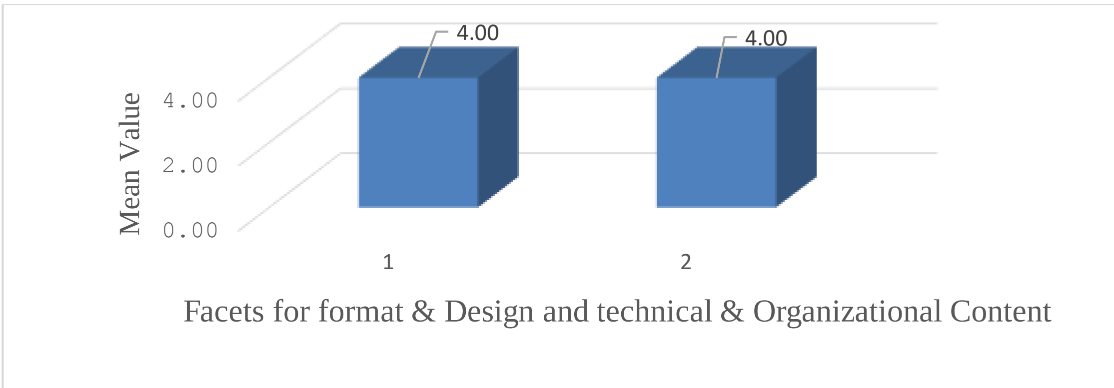

Fig 6: Format & design and technical & Organizational Content

It means that the vocabulary loads or choice of words and its language structure in explaining genetic concepts were suitable for the intended users. Instructions for learner were presented concisely and clearly. Visuals such as illustrations and animations were arranged with the text in synchronized manner as suggested in *coherence principle* especially in presenting the genetics problem, its detailed procedure and explanations for the answers. These visuals are clear and contribute to the enrichment of the subject-matter as suggested in *multiple representational principle* especially in presenting cellular functions such as meiosis, segregation and fertilization of gametes. The evaluation results implied that technical aspect of this material is very appropriate or suitable as an instructional material.

To further support and substantiate the results, comments and suggestions of the computer-experts validators were gathered. The following comments are as follows: The sizes of the pictures were now proportion in terms of length, width and its size for the area on the screen. The genetic problems were placed and distributed each slide the way it was suggested. The timing of the animations were now appropriate and moving in synchronized manner. Moreover, the slides do not move to other parts once click anywhere by the user; it means only the transitional buttons can only be clicked in order to transfer from one part of the courseware to the next. Overall, the format and design of the courseware were “highly impressive and creative” as mentioned by the validators. In terms of organization, the flow of the lessons including its transitions were “smooth and gradually changing” as mentioned by one of the validator.

PURPOSE NO. 3: Try out the validated digital courseware as a learning tool.

After the validation of the digital courseware, it was tried out to the Grade 8 students to test its effectiveness as a learning tool. Prior to the instructions, both groups took the pre-test and right after the implementation, post-test was administered to both groups.

Table 15: Summary of scores in two groups comparing the pre- and post-test scores

		GROUPS			
		Digital courseware class (DCC)	**Remarks**	**Direct-instructions class (DCC)**	**Remarks**
Pre-test scores	Mean score of Lesson 1 (10 points)	2.40	Low	2.39	Low
	Mean Score of Lesson 2 (10 points)	2.98	Low	2.96	Low
	Overall Mean (20 points)	**5.36**	**Low**	**5.39**	**Low**
	Minimum Value	0		0	
	Maximum Value	12		13	
Post-test Scores	Mean score of Lesson 1 (10 points)	6.25	Average	5.43	Average
	Mean score of Lesson 2 (10 points)	6.80	Average	6.38	Average
	Overall Mean (20 points)	**13.00**	**Average**	**11.78**	**Average**
	Minimum Value	7		5	
	Maximum Value	20		17	
Difference		+7.64		+6.39	
Mean gained score		+52.20		+43.77	

**See interpretations in the research instruments*

Table 15 summarizes the results of the implementation (pilot testing) of the digital courseware. Direct-instructions class had a range of 0 - 13 in the pre-test score while 5 - 17 in the post-test score. It also obtained an overall mean of 5.39 in the pre-test while 11.78 in the post-test. The overall mean of the pre-test obtained a remark of *low* and it improved into *average* remark in the overall mean post-test score after the implementation of the direct-instructions. The difference in the scores of this group is +6.39 and had a gained score of +43.77%. The instructions which utilized digital courseware had a range of 0 - 12 in the Pre-Test Score while 7 - 20 in the Post-test Score. It obtained a mean of 5.36 in the Pre-test while 13.00 in the Post-test. The overall mean of the pre-test obtained a remark of *low* and it improved into *average* remark in the overall mean post-test score after the implementation of the digital courseware instructions. The difference in the scores this group is +7.64 and had a gained scores of +52.20%. This result validated that students who underwent digital instructions can also perform the same level of achievement as compare to the students who were instructed using direct-instructions (Lecture Method). Moreover, this result is parallel with the results of Owusu, et. al (2010), wherein they state that the performance of low achievers in Biology within the experimental group improved after they were instructed by the Computer-Assisted Instructions (CAI).

Table 16: Summary of Differences in the mean scores between the groups.

Direct Instructions class (DIC)	X_{min}	X_{max}	Mean	SD	P-value	F-crit	F-comp	REMARK
a. Pre-test **b. Post-test**	0 5	13 17	5.39 11.78	3.72 3.93	0.000	4.02	38.94	Highly Significant
Digital courseware class (DCC)	**X_{min}**	**X_{max}**	**Mean**	**SD**	**P-value**	**F-crit**	**F-comp**	**REMARK**
a. Pre-test **b. Post-test**	0 7	12 20	5.36 13.00	2.38 4.01	0.000	4.02	75.30	Highly Significant
Direct Instructions class (DIC) vs Digital courseware class (DCC)			**Mean**		**P-value**	**F-crit**	**F-comp**	**REMARK**
a. Post-test (DCC) **b. Post-test (DIC)**			**13.00** **11.78**		0.249	4.02	1.35	Not Significant

Table 16 summarizes the differences in the mean scores of the groups using F-test. The Pre-test and Post-test of the Direct-instruction class (DIC) has a remark of highly significant difference because the computed F-value (38.94) is higher than F-critical value (4.02) and aside from that its p-value (0.000) is lower than p=0.01 which served as baseline of this remark. Highly significant remark implied that the scores from the pre-test and post-test of the students in this group have appreciable change after the direct-instructions or the lecture-discussions. The pre-test and post-test of the Digital courseware class has also obtained a remark of highly significant difference because the computed F-value (75.30) is higher than F-critical value (4.02) and aside from that, its p-value (0.000) is lower than p=0.01 which serve as the basis of this remark. Also, highly significant remark implied that the scores from the pre-test and post-test of the students in this group have appreciable change after using the digital courseware for instructions. The computed F-value (1.35) for the comparison of Post-tests of the two groups, Direct-instructions class (DIC) and Digital courseware class (DCC), is lower than F-critical value (4.02) and its p-value (0.24) is higher than p=0.05. These results obtained a remark of “not significant difference”. Meaning, the intervention used in the Digital courseware class, utilization of digital courseware, was as effective as Direct-instructions or lecture method. These results suggest that the digital courseware may be used as a substitute learning tool in teaching transmission genetics. This result was also observable in the study of Ko (2010), stating that the use of Computer-assisted instructional materials (CAIM) has positive effect. It gives quite high cognitive level and decreases 19% level of misconception in a CAI group. This is also implied in the study of Wolf (2012) that many proponent of pedagogical learning emphasizes technology's capacity to personalize learning and improve student's achievement. Utilization of technologically-inclined materials such as computer-assisted instructional materials (CAIM) makes the learning effective and efficient at the same time. It is effective in the sense that it improves the achievement of the students and it is efficient to the side of the teachers because CAI materials may serve as their teaching tool and at the same time can be operated by the students as reviewer for independent study or in distance education.

Since the effect of the digital courseware to the achievement of the students was no significant difference, ten students in the Digital courseware class (DCC) were interviewed informally to further substantiate the results of the pilot testing. They were asked about their learning experiences in using the digital courseware as learning tool. The responses of the students in the short interview were summarized and these are as follows: (1) Operating the digital courseware was fun. It was easier for the students to catch the content since the pictures of the traits were immediately presented, (2) the courseware helped the students to focus on the concepts since hints were provided such as the fonts, animations and pictures, (3) the courseware helped the students to follow directions which buttons to select first, (4) when the students have the copy of the courseware, it will be easy for them to access since it can be operated using mobile phones, and (5) the courseware challenged the students to answer the genetics problems and their answer can be corrected immediately as well as the explanations can provide them an idea why they got wrong answers.

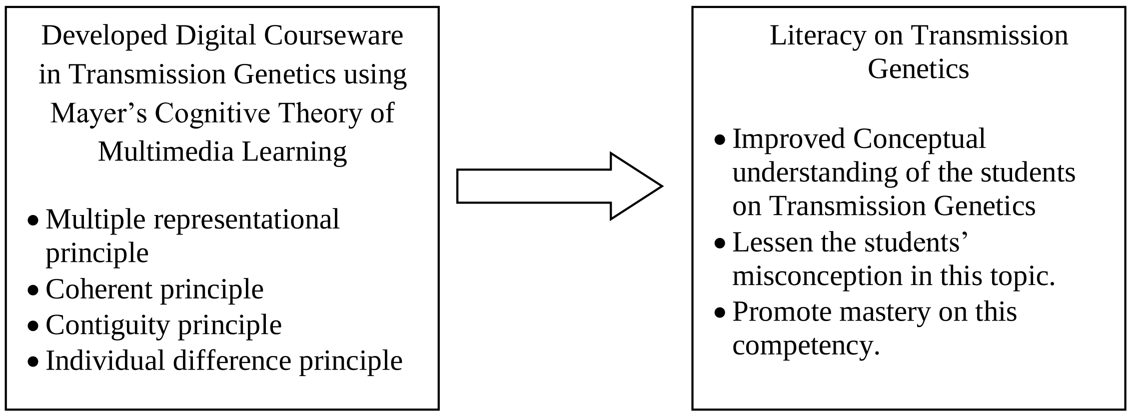

Fig 7: Theoretical contribution of the study

Figure 7 shows the theoretical contribution of this study. The principles used in the development of the digital courseware made a significant contribution in the preparation of the learning tool on transmission genetics which seemed to be one of the least-mastered topics in biology, with low conceptual understanding and has numerous alternative conceptions. Based on the initial results given by the pilot testing (refer to table 16), it was found out that this learning tool was as effective as the lecture-discussion done by the teacher. The mean scores of the students both in Direct instruction class (DCC) and Digital courseware class (DCC) changed positively from low level to average level but did not have significant differences when the means scores of the groups were compared using F-test. It means that this material can be used as an alternative or supplementary learning tools to improve conceptual understanding in transmission genetics and lessen the alternative conceptions since it was found out that digital courseware can attain the same level of achievement in terms of scores. Moreover, this material can be utilized in classroom settings or used by the students as their reviewers in order to attain the goals written in the right box of figure 7.

CHAPTER IV
SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary of the Study

This study aimed to develop a digital courseware in transmission genetics to address the problem in the literature that this topic is considered as least-mastered competency in Biology, has low level of conceptual understanding and has numerous misconceptions. Needs analysis with the in-service biology teachers was conducted in order to contextualize this problem in Philippine settings. The results of the literature review and need analysis served as the purpose of the researcher to develop this learning tool. The development of the digital lessons used the Modified ADDIV model which is composed of these steps: (1) planning stage, (2) design and development stage, (3) validation stage and revision stage. The development of this learning tool was based on the principles of Mayer's Cognitive Theory of Multimedia Learning specifically the way how concepts, pictures, diagrams and other forms of illustration presented in the courseware. The developed digital courseware has underwent validations with content-experts and IT experts to validate its informational content, format & design and technical & organizational content. After the validation, the courseware was pilot tested to the Grade 8 students to test its effectiveness as a learning tool.

Summary of Results

From the analysis of data in, the following results were obtained:

I. **In the developmental stage;**

Needs analysis conducted with in-service biology teachers revealed that transmission genetics (Mendelian and Non-Mendelian Genetics) was one of the topics in

Biology that are least mastered, with low conceptual understanding and with numerous alternative conceptions. The result of this needs analysis, and the problems cited in the literature served as the basis in developing the digital courseware. From these results, the researcher was able to come up with the module format of the digital courseware that underwent initial consultation with the content experts. The comments and suggestions of the content-experts were considered before the digitization of the courseware.

II. In the validation stage; and,

After the digitization, the digital courseware underwent content-expert and computer-expert validation. The instructional content of the developed digital courseware obtained a grand mean of 3.98 or very appropriate learning tool as evaluated by the content-expert validators and in terms of format & design and technical & organizational content, the courseware obtained a grand mean of 4.00 or very appropriate instructional material as evaluated by the IT or computer experts;

III. In the implementation stage;

The Digital courseware class (DCC) obtained mean gained score of +7.64 or +52.20% in the pre- and post-test while in the Direct-instruction class (DIC) obtained a mean gained score of +6.39 or +43.77% in the pre- and post-test. In terms of test of difference, the computed F-value (75.30) of the Digital courseware class (DCC) was higher than F-critical value (4.02) and the p-value (0.000) is lower than p=0.01 which obtained a remark of highly significant; the computed F-value (38.94) of the Direct-instruction class (DCC) was higher than F-critical value (4.02) and the p-value (0.000) is lower than p=0.01

which also obtained a remark of highly significant; and the computed F-value of the Post-tests of Digital courseware class (DCC) and Direct-instruction class (DCC) were 4.02 and it was lower than the F-critical value (1.35). Moreover, the computed p-value (0.24) was higher than p=0.05 and had a remark of significant difference.

Conclusions

Based on the results presented in previous chapter and as stated in the summary, the following conclusions are made:

(1) transmission genetics was contextualized by in-service biology teachers of NCR as one of the topics in Biology that has low conceptual understanding and numerous alternative conceptions as discussed in the needs analysis;

(2) content-expert in Biology and Computer experts positively perceived the components of the digital courseware based on the validation results. Generally, the developed digital courseware in transmission genetics is *very appropriate* learning tool for these topics of grades 8 and 9 of the K to 12 curriculum since it covers the necessary competencies such as definitions, concepts with illustrations, detailed guide or procedure in solving genetics problems and explanations the correct answers; and,

(3) the developed digital courseware was effective in increasing the achievement of the Grade 8 students in Mendelian Genetics.

Limitations

In this study, three sections of the lessons were developed. Only two out of the three lessons were pilot tested since these two lessons are the only ones in the competencies of Grade 8 Science. The third lesson was not pilot tested because it should be taught in the next grade level which is grade 9. Next, based on the conducted needs analysis, transmission genetics occupied the ranks 5 & 6 in terms of low level of conceptual understanding while ranks 4 and 9 in terms of competencies with numerous misconceptions. The competencies which ranked the top were not addressed.

Recommendations

Based on the results of the study, the following recommendations were made:

(1) pilot test the third lesson, non-mendelian genetics, to the Grade 9 Students since this topic is in this grade level competency;

(2) this digital courseware is encouraged to be used by the junior high school science teacher in the Philippines in order to attains its goals such as to improve conceptual understanding, promote mastery and lessen the misconceptions in transmission genetics;

(3) a similar study that utilizes this digital courseware in transmission genetics with other grade 8 respondents to verify and firmly establish its effectiveness and statistical validity; and,

(4) more educators are encouraged to develop other digital courseware that will address the result of conducted needs analysis especially in the competencies like Cellular Respiration, Photosynthesis and Protein

Synthesis in which it occupied the highest ranks in terms of low level of conceptual understanding and least-mastered competency with numerous misconceptions.

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Appendix A

Checklist Inventory for Identifying the Least Mastered Competencies, with Low Conceptual Understanding and Numerous Alternative Conceptions in Biology

Name: __________________________ Number of Years in Teaching: ___ years

Direction: Choose ten (10) competencies in Biology, listed below, which you think are the least mastered competencies by your students and has numerous alternative conceptions. Rank those competencies based on (Rank #1 is the highest while Rank #10 is the lowest). Note: It is important that you choose ten competencies with no repetition of ranks.

Topics in Biology	Least Mastered & Low Conceptual Understanding	With Numerous Misconceptions
Grade 7		
1. Microscopy		
2. Levels of Biological Organization		
3. Animals and Plant cells(Structures and Functions)		
4. Fungi, bacteria and Protists		
5. Sexual and Asexual reproduction		
6. Components of Ecosystems		
7. Ecological Relationships (Symbiotic and non-symbiotic relationship)		
8. Transfer of Energy through trophic levels (Food chain, Food Web, Food Pyramid)		
Grade 8		
9. Digestive System(Structure, Functions, Processes)		
10. Mitosis and Meiosis		
11. Mendelian Genetics (three laws of Inheritance, Monohybrid and hybrid cross, Punnett Square)		
12. Species Diversity; Hierarchial taxonomic system of Classification		
13. Ecological Cycle (Water, Carbon dioxide & Oxygen Cycle, Nitrogen Cycle)		
Grade 9		
14. Respiratory System		
15. Circulatory System		
16. Chromosomes and Locations of genes (Cytogenetics)		
17. Non-Mendelian Genetics(Sex linked, Sex influenced, Sex limited traits and Multiple Alleles, Polygenic Inheritance)		
18. Causes of Species Extinctions (Natural & Anthropogenic)		
19. Photosynthesis		
20. Cellular Respiration		
Grade 10		
21. Reproductive System		
22. Nervous System		
23. Endocrine System		

24.	Protein Synthesis		
25.	DNA Replication		
26.	Chromosomal Abberations and Mutations		
27.	Evolution (fossil records, comparative anatomy, and genetic information provide evidence for evolution)		
28.	Population Growth and Carrying Capacity		

RANK	**Competencies in Biology**			
	With low conceptual understanding and least mastered competency	Mean of Ranks	With numerous alternative conceptions	Mean of Ranks
1	• Cellular respiration	1.68	• Cellular Respiration	1.47
2	• Photosynthesis	1.80	• Protein Synthesis	1.91
3	• Protein Synthesis	3.28	• Mitosis and Meiosis	2.23
4	• DNA Replication	3.80	• Non-Mendelian Genetics	2.56
5	• Non-Mendelian Genetics	6.16	• Photosynthesis	2.68
6	• Mendelian Genetics	7.21	• Circulatory System	6.72
7	• Nervous System	7.35	• Nervous System	7.10
8	• Circulatory System	7.43	• Endocrine System	7.45
9	• Endocrine System	7.50	• Mendelian Genetics	8.20
10	• Mitosis and Meiosis	7.58	• Species Diversity	8.92

APPENDIX B

Detailed procedure in developing digital courseware on transmission genetics and its theoretical applications

Slide No.	Descriptions of the slide	Theoretical applications of Mayer's Cognitive Theory of Multimedia Learning
1	It contained the title of the courseware and the title of this study for the identity of the owner. Title of the study was placed in order to see its references to give credits to the contributors of adapted pictures.	Not applicable
2 - 9	Matt and Twight went to the library to finish their assignments in transmission genetics	Not applicable since it introduced only the topics in the form of story.
10	In the library, there were 3 shelves containing the major parts of transmission genetics. These shelves were the 3 major lessons in the module format that were initially prepared before the initial validations with the content experts. Per shelf has button to click in which the button represents the lesson number.	*Multiple representational principle* – Topics were presented using pictures, buttons that link the user to the other parts of the courseware. Audio was also used in order to attract the user's attention.
11	It contained the objectives of the lesson 1 and the buttons that will lead the lesson activity, lesson proper and lesson index (main menu).	*Coherence principle* – the lesson objectives were shortened. List of words to be encountered in this lesson left like dominant vs recessive, homozygous vs heterozygous, genotype vs phenotype
12	It contained the *Word hunt* activity. The chart may be zoomed into larger image.	*Contiguity principle* – this activity was presented with words and pictures in order to give hints to the students while finding those words.
13	It contained the answer for the *Word hunt* activity	
14	It contained the definition of Genetics, heredity, variations and genes presented with animations. The definitions were shortened yet substantial.	These slides possessed the 4 principles: (1) *multiple representational principle* - words and pictures were used simultaneously to present the definition of important terms in transmission genetics; (2) *contiguity principle* – concepts of dominant vs recessive, homozygous vs heterozygous, genotype vs phenotype were explained using short-animations
15	It contained the definition of alleles. Alleles in the chromosomes were presented in the pictures to show the location of genes in the homologous chromosomes	
16	It contained the definitions of dominant and recessive gene, and the	

	difference between homozygous and heterozygous genes. Hyperlinks were provided to link the users for more examples in slide #17 and #18.	or by simultaneous presentation of words and pictures; (3) *Individual difference principle* this was considered since there are some students can catch the concepts easily with visual text but some need pictures to easily get the genetics concept; and, (4) *Coherence principle* – definitions of terms in transmission genetics were shortened and concepts were summarized. Essential parts of the concepts were highlighted and provided with pictures. Moreover, the researcher constructed a summary of concepts that are written in simple language and important words are highlighted.
17	It contained the examples of dominant vs recessive gene and homozygous gene that can be observed on the height of the plant. Short animations were made to present the concept of dominant and recessive using pairs of alleles.	
18	This slide was resembled to the slide #17 but this time the example is the shape of the seed (rounded or wrinkled).	
19	This slide was resembled to the slide #16 but this slide was focused on the difference between genotype and phenotype	
20	This slide contained the end of the lesson #1. It also contained the hyperlinks that will lead the user to go back to the main menu and the lesson activity if the user wishes to play the activity again	Not applicable since it is a transition slide.
21	This slide contained the beginning of the lesson #2. It also contained the lesson objectives, a button for lesson activity, lesson proper and lesson index (main menu)	*Coherence principle* – the lesson objectives were shortened. List of words to be encountered in this lesson and the pictures that described the lesson were organized to make it more attractive to the user.
22	It contained the lesson activity that has title "*Segregate*", this activity asked the students to form 4 human body with complete body parts. Per body part, it has a letter after it. Example: Black hair (B); brown hair (b). Students should form 4 human body with complete parts. Then, they will answer the guide questions like; 1. What do you think is the use of letters written to every parts? 2. What if those letters are not properly segregated?	Slide #22 - #27 applied the *principle of multiple representation* in which the pictures of body parts were used together to relate the explanation of law of segregation in terms of the represented letters. *Coherence principle* was also observed in terms of providing summary of the expected information about the activity and pictures that are coherent to support the shortened response.

	After this activity, students should be able to explain that letters represent genes and these are EQUALLY distributed.	
23	It contained the answers and explanation for the *"segregate"* activity	
24	It contained the activity about the law of independent assortment. The students are randomly selecting colored paper out of the given box until they were able to follow the patterns of colors. Also, the colored paper has letter that serves as its label. Example: Some pink colored paper has label of upper case "A" or lower case "a". *After this activity, students should be able to explain that letters also represent genes and these are RANDOMLY distributed.* Students also answer this guide question – "Why do you think that there is/are letters written in upper or lower case, what does it imply?"	Slide #22 - #27 applied the *principle of multiple representation* in which the pictures of body parts were used together to relate the explanation of law of segregation in terms of the represented letters. *Coherence principle* was also observed in terms of providing summary of the expected information about the activity and pictures that are coherent to support the shortened response.
25	It contained the answers and explanation for the activity entitled *"Randomly"*.	
26	It contained the activity about the law of complete dominance. This time students are asked to pick two colored papers with letters as label. Students will be asked to write the uppercase letter first in the combination before the lowercase letters, if in case they get two different letter case in two draw lots	
27	It contained the answers and explanation for the activity entitled *"Dominance"*. *Students should be able to realize later why the teacher asked to write the Upper case letter first in combination before the lower case letters.*	

	This slide also contained the buttons that will lead the user to go back to lesson index (main menu) or to proceed to the lesson proper.	
28	This slide contained the three pieces of puzzles representing the three laws of Mendelian pattern of inheritance which are law of segregation, law of independent assortment and law of complete dominance. These are arranged already. The user will just click the piece of the puzzle that is directed by the instructions	Not applicable since it is a transition slide.
29 - 30	This slide contained the definition of the law of segregation. The definition is stated operationally and provided with illustration of a diploid cell. This diploid cell has chromosomes that were labeled with letters to represent the alleles for a gene. This slide has a button which serves to magnify or zoom the diploid cell. Once zoomed, it also discussed the relationship of segregation to Meiosis.	This slides applied the concept of *multiple representational principle and coherent principle*. Summary was provided coherently with the pictures to represent the concepts of alleles.
31	This slide asked the user to restate the law of segregation based on the what they have learned from the previous slide	This time the user is given a chance to restate the law of segregation based on what they have from the previous slide. This slide was anchored with the concept of coherence principle; the use can provide a short summary out of the given pictures.
32	This slide contained the piece of puzzle that link the user to the 2nd law of Mendelian inheritance which is the law of independent assortment	Not applicable since this is a transition slide.
33	This slide contained the definition of law of independent assortment and provide pictures of gametes having different alleles distributed in the chromosomes.	*Coherence principle* was used to provide a summarized concept coherent with the picture which shows the variations among the gametes.
34	This slide contained the piece of puzzle that link the user to th e 3rd law of Mendelian inheritance which is the law of complete dominance	Not applicable since this is a transition slide.

35	This slide contained the explanation of law of complete dominance and pictures of two cells with different set of alleles. The picture can be zoomed into larger picture	This slide applied the concept of *Multiple representational principle, coherent principle and contiguity principle.* Summarized concepts together with animated pictures that work coherently is a better representation of explanation rather of words alone.
36	This slide contained the larger image of two gametes having different sets of alleles. It has also explanation when these two gametes combined and produce new diploid organism	
37	This slide contained the transition from the concept development to the problem solving. This slide is named as "Library Garden", a garden in which Genetics word problems are solved. It has a "NEXT" button if the user would like proceed to the problem solving.	
38 - 48	These slides contained the sample problem including its solutions and explanation how will you arrive with the answers.	These slides observed the principles of *coherence, contiguity and multiple representation*. It used *multiple representational principle and contiguity principle* in the sense that words and pictures were used simultaneously in order to present the concepts of monohybrid crossing of trait. *Coherence Principle* was used in providing summarized procedure of solving genetics problem and appropriate animation of picture in order to present the method of problem solving coherently.
38	This slide contained the problem that was focused on the height of the plant as a trait. This problem focused on determining the genotypic and phenotypic ratio of the offspring. Animated garden themed was used as the background of the slide and there is a head of rabbit if the user would like to see the answer for this problem.	
39	This slide contained the answer for the problem about crossing of the two plants with different heights. It contained the detail procedure of solving the problem, the punnett square and the tips in writing the genotypes and phenotypes inside the punnett square. The problem and its solution are posted on a panel board while the procedure in solving the problem, posted with animated clouds. Below the solution, there is basket indicating the "next" if the user	

	wishes to proceed to another problem while the “back” menu will link the user to go back to the slide #37.	
40	This slide used the same background designs as used in slide #38 but this time the problem focused on albinism, an example of genetic disease on skin pigmentation. This problem asked the probability of having albino child when a normal person with no history of albinism marries an albino person.	It used *multiple representational principle and contiguity principle* in the sense that words and pictures were used simultaneously in order to present the concepts of monohybrid crossing of trait specifically on the skin pigmentation as a trait. *Coherence Principle* was used in providing summarized procedure of solving genetics problem and appropriate animation of picture in order to present the method of problem solving coherently.
41	This slide used the same design as slide #39 for revealing the answers and its procedure in solving problems about albinism	
43 - 46	This slide also used the same background designs as used in slide #38 but this time the problem focused on the color of the eyes as a trait. The traits are either brown or blue	It used *multiple representational principle and contiguity principle* in the sense that words and pictures were used simultaneously in order to present the concepts of monohybrid crossing of trait specifically on the color of the eyes as a trait. *Coherence Principle* was used in providing summarized procedure of solving genetics problem and appropriate animation of picture in order to present the method of problem solving coherently.
47	This slide also used the template in presenting the problem but his time it focused on the two traits that are crossed which are types of earlobes and color of the eyes.	Same principles were applied but it was focused on dihybrid crossing of traits.
48	This slide also used the template in presenting the solution for the problem about the dihybrid crossing including the detailed procedure like the FOIL Method in determining the gametes. It also contained the transitional button if the user would like to back to the lesson proper or to proceed to the mini-quizzes.	
49	This slide contained the list of seven problem exercise to be solved by the user. The focus of genetics problems	

	is as follows: (1) type of hairlines, (2) polydactyl, (3) length of hair in cats, (4) color of the hair, (5) color of the eye and (6) types of earlobes.	
50	This slide contained the 7 hyperlinks in which the answers and explanations per problems were located. The design of this slide was composed of 7 animated trees in which its leaves were numbered and those numbers represent the link where the user can find the solution and explanation for specific item(s) that they have solved.	Not applicable since it is a transition slide.
51 - 57	These slides contained the solutions for the 7 problem exercises. It started with the given such as the genotypes of the parents and their gametes. Then it was followed by punnett square(s) then end up either with genotypic and phenotypic ratio or with an explanation. It has also "back" button that guides the user to go back to the slide #50 or the slide containing the icons for answer key.	It used *multiple representational principle and contiguity principle* in the sense that words and pictures were used simultaneously in order to present the answers in different genetics problems. *Coherence Principle* was used in providing summarized procedure of solving genetics problems and appropriate animation of picture in order to present the method of problem solving coherently.
58	This slide had also the same template as slides #11 and 21 which contained the objectives of the lesson 3, buttons for lesson proper, lesson activity, lesson's quiz and lesson index (main menu).	Not applicable since it is a transition slide.
59	This slide contained the title of the two activities in this lesson. These are *4PICs* and *WordArrange.* The title of these games can be found below the icon which can be clicked to link the user to the activity where they wish to do before proceeding to the lesson proper. *4PICs* was patterned to the concept of a mobile game, 4-Pics-1-word, which the 4 pictures portray or imply a word to be guessed by the player. There are 6 words to be guessed in this activity and these are: incomplete,	This activity used the concept of *multiple representational principle* to represent the terms in Non-Mendelian genetics in the forms of pictures to be guessed and letters to rearrange to form words that can be found within the lesson.

	intermediate, blood type, limited, linked, color coat. These words can be found within this lesson. The pictures used here were downloaded from internet. (See refences) *WordArrange* is an activity wherein the 15 words that can be found within the lesson are jumbled and the users are asked to rearrange those words to form the words related to Non-Mendelian Genetics.	… This activity used the concept of *multiple representational principle* to represent the terms in Non-Mendelian genetics in the forms of pictures to be guessed and letters to rearrange to form words that can be found within the lesson.
60	It contained the larger image of a logo of 4PICs.	
61-66	These sets of slide contained the 4 pictures per slide and the animated answers for the 4PICs activity	
67	Since Lesson 3 contained the laws of Non-Mendelian Genetics and made up of 6 patterns of inheritance, the design of this slide appeared as library map. There were 6 icons to be clicked and these icons served as the guide of the user to link himself to the lesson proper.	Not applicable since this is a transition slide.
68	This slide contained the definition and conditions of law of incomplete dominance. The definition of this law was defined operationally including the condition in which this pattern of inheritance can be inherited. It has “view diagram” button that links the user to see examples of incomplete dominance trait in plants.	It was designed the way how pictures and words are presented in simultaneous manner to deliver the concepts of law of incomplete dominance as suggested by *multiple representational principle*. Moreover, the summarized definition of this law contain the important information and it is coherently presented with pictures of the flowers’ petals which vary in colors.
69	This slide contained the sample problem about law of incomplete dominance in plants. This slide focused on the red and white color of flower’s petal as a trait. When these flowers are pollinated, it produces pink offspring. This slide started with the given, genotypes and gametes of the two plants. Then it was followed by the punnett square, genotypic and phenotypic ratio of the offspring of this cross. Finally, explanations were provided to differentiate the ratios	

	between the complete dominance and incomplete dominance. It has also "next example" butt	
70	This slide contained another sample problem about colors of the flower's petals. But time it focused on determining the possible offspring when the two pink flowers are pollinated. Same design was used in presenting the sample problems, its detailed procedure and final answer. It has also a "back" button to slide #68	Same principles were applied here as slides #68 to 69.
71	This slide contained the operational definition of law of codominance. It has "View examples" button to links the user to the different examples of codominance in plants and animals.	Same designs of slides and learning principles were applied here as slides #68 to 69 but it focused on the law of codominance.
72	This slide contained the examples of codominance traits in plants and animals like roan, speckled chicken and spotted carnation flower. It has "solve problem" button that links the user to the sample problems.	
73-75	These slides contained the problem solving about the crossing of traits in roan cattle. The first problem asked the possible offspring when roan cows are crossed. Then, the second problem asked the possible offspring when the offspring in the first problem are crossed with white cow. Finally, the last problem asked the possible offspring when the offspring of the second problem crossed again with white cow.	The design of these slides were patterned with the previous way of how sample problems were delivered. It started with the questions, given, genotypes of the parents and its gametes, punnett squares, ratios and finally the short explanation for the final answer. This way of presentation observed the *principle of contiguity and coherence.*
76	This slide discussed the concepts of Multiple alleles with shortened yet operational in definition. It has also a "view example" button that links the user to example like, "blood typing" in Human.	This slide was based on the design used in slide on Law of Incomplete dominance. Also, same principles (*Multiple representational principle* and *Coherent principles)* were applied in presenting the concepts.
77	This slide contained the human blood typing including the possible genotypes for specific phenotype.	This slide was based on the design used in slide on Law of Incomplete dominance. Also, same principles

	It has selection buttons -- “solve problems” and “another example”. “Solve problem” button leads the user to solve problems about blood typing while “another example” button leads the user to another example of trait is inherited through the pattern of multiple alleles. This is advised that the user should click the “solve problem” button first before proceeding to the next example of multiple alleles.	(*Multiple representational principle* and *Coherent principles)* were applied in presenting the concepts.
78 – 81	These slides contained the sample problem solving for blood typing. Same template was used in presenting the problem, procedures and explanation for the final answer.	The design of these slides were patterned with the previous way of how sample problems were delivered. It started with the questions, given, genotypes of the parents and its gametes, punnett squares, ratios and finally the short explanation for the final answer. This way of presentation observed the *principle of contiguity and coherence.*
82	This slide contained the other example of trait that follows inheritance through multiple alleles. The trait is the color coat of rabbits and cats. It contained a table in which the pictures of the different phenotypes of the color coats, the short characteristics or description and its possible genotypes were tabulated.	This slide also observed the *multiple representational principle, coherent principle and contiguity principle*. The pictures and summarized concepts are presented simultaneously in order the students grasp and remember the genetic concept easily.
83-85	This slide also contained the genetic problems about multiple alleles but this time about the color coats of rabbits and cats. Same designed and templates were used to present the problems, procedure in solving and explanation for the final answers. The first problem focused on determining the offspring of the crossing of the two Himalayan cats. The second problem was related with the first problem in which it was asked to determine the offspring of the next generation when the offspring of the two Himalayan cats are mated with albino cats. The last problem focused on determining the offspring of the cross between the Himalayan cat and a chinchilla cat.	The design of these slides were patterned with the previous way of how sample problems were delivered. It started with the questions, given, genotypes of the parents and its gametes, punnett squares, ratios and finally the short explanation for the final answer. This way of presentation observed the *principle of contiguity and coherence.*

86	This slide contained the definition of Sex-linked traits and give examples about the chromosomes of humans. It has also “view example” which leads the user to the example of this pattern of inheritance.	The slides for sex-linked traits, sex-influenced traits and sex-limited traits used the same templates and background design that were used in different laws under Non-Mendelian Genetics in terms of presenting the concepts and sample problems to be solved. The way of presenting the summarized concepts and pictures are anchored with the *multiple representational principle* and *coherent principle*. The summarized concepts contained the essential words that can differentiate these three patterns of inheritance. To further improve the content of these slides, pictures were coherently added to the summarized content. The addition of the pictures aimed to describe the genetic condition of the organisms which possess those traits.
87	This slide contained the example of sex-linked trait which is hemophilia. The discussion about hemophilia, its condition and pattern of inheritance was contained in this slide. Animated punnett squares were provided in order to present the different possible genotypes that may give to hemophilic offspring. This slide also has “more example” button that leads the user to browse the other examples of X-linked traits	
88	This slide contained the examples of other X-linked traits such as colorblindness, Duchene muscle dystrophy and Becker muscle dystrophy. It also contained different examples of Y-Linked traits. It has also “back” button that leads the user to go back to the definitions of sex-linked traits.	
89 - 91	These slides contained the definition and discussion of sex-influenced traits. It differentiated the sex-influenced traits from sex-linked traits in terms of gene location and gene dominance based on the sex of the organisms. Table was provided to see the different genotypes that code for the trait such as baldness. It has also “back” button that leads the user to go back to the definitions of sex-influenced traits, and has “another example” to link the user to the application of this pattern of inheritance in animals	
92	This slide contained the application of sex influenced trait on the plumage of peacocks. It has short explanation why it is considered as sex-influenced	

	trait and how these traits affect sexual behaviors of this bird.	
93 – 95	These slides contained the definition of sex-limited traits including the examples of this pattern of inheritance such as beard in males and production of milk in females after conception of child. Table were also provided to represent the genotypes in male or female that exhibit the traits. Pictures were used in order to show how the traits look like.	
96	This slide contained the practice exercise to be solved by the user. It has six problems distributed to the six laws or patterns of inheritance discussed under Non-Mendelian Genetics.	Pictures of the traits were given in order for the user to imagine the morphology of the organisms that possess or exhibit the traits. Summarized concepts were also used including the definitions and explanations to describe the traits shown in different pictures. These steps are anchored with the concepts of *multiple representational principle, coherent and contiguity principles*. These principles contributed to the design of the slides especially in combining the pictures and words in a slide that it appeared coherently.
97	It contained the shortcuts for the answer keys of practice exercises. There are numbered boxes that correspond to the item number of the problems in slide #96.	
98 - 103	These slides contained the actual answer keys for the practice exercise. It includes the givens of the problem, detailed procedures to solve the problem and explanations for the answers.	
104	It contained the ending part of the courseware in which Matt and Dwight discusses about what they have accomplished in touring the different sections of library about the Transmission Genetics.	

APPENDIX C

VALIDATION TOOL FOR INSTRUCTIONAL CONTENT OF COURSEWARE
(CONTENT-EXPERT VALIDATION)

(Adapted and Modified from: Rivera (2009)

Name____
School Affiliation: ____
Years in Teaching the Subject Area: ___________________________
Highest Attained Degree: _____________________________________

Directions: This form aims to assess your perception of the quality of the courseware given the standard below. Please indicate your assessment by putting a check on one of the following response alternatives opposite each category

4 = Very much 3 = Much 2 = little 1 = None

I. Instructional Content				
A. Objectives	4	3	2	1
1. Are the objectives relevant in delivering the concepts of genetics?				
2. Are the objectives stated in terms of the target users?				
3. Are the objectives observable/measurable?				
4. Are the objectives logically sequenced?				
COMMENTS / SUGGESTIONS:				

1. How accurate or recent are the information in Genetics presented?				
2. How sufficient are the factual information presented to develop a single genetic concept?				
3. How gradual are the factual information on genetics introduced?				
4. Are the factual information relevant to the genetic concept being developed?				
COMMENTS / SUGGESTIONS:				

1. Does the introductory phase adequately set the stage for the instructional process as learning tool?				
2. Does the development phase provide adequate or appropriate instructional content in reasonable order and apply the Principles of Mayer's Cognitive Theory of Multimedia learning?				
3. Does the guidance phase suggest adequate memory schemes, prompts, cues and hint to improve retention as characterized by contiguity principle of Mayer's Cognitive Theory of Multimedia learning?				
4. Does the application phase adequately promote retention and recall by response / practice mechanism (sample problems, reinforcement, question, practice frame)?				
5. Does the performance phase provide adequate opportunities for learners to demonstrate their knowledge/intellectual skills as suggested by Multiple representational principle?				
6. Does the feedback phase provide adequate assistance about the learners' performance as suggested by coherence principle of Mayer's Cognitive Theory of Multimedia learning?				
COMMENTS / SUGGESTIONS:				

1. Are the learners' tasks compatible to the objectives of the courseware?				
2. Are the tasks necessary for the attainment of the objectives as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
3. Are the small tasks sequenced properly within the larger phase as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
4. Are the tasks sufficient for the attainment of the objectives as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
5. Are the tasks adequately complementing or reinforcing one another?				
6. Do the operations in the tasks practice the concepts being developed?				
COMMENTS / SUGGESTIONS:				

1. Does the courseware pre-assess for entry level of intended user?				
2. Does it provide for adequate formative evaluation like exercises?				
3. Does the post-test adequately measure the achievement of the objectives?				
COMMENTS / SUGGESTIONS:				

EVALUATED BY:

____
Printed Name over Signature

APPENDIX D

VALIDATION TOOL FOR FORMAT and DESIGN & TECHNICAL and ORGANIZATIONAL CONTENT OF COURSEWARE (COMPUTER-EXPERT VALIDATION)

(Adapted and Modified from: Rivera (2009)

Name: ____

Company Affiliation: ________________________________

Years in the field of work: ___________________________

Highest Attained Degree: _____________________________

Directions: This form aims to assess your perception of the quality of the courseware given the standard below. Please indicate your assessment by putting a check on one of the following response alternatives opposite each category

4 = Very much 3 = Much 2 = little 1 = None

I. FORMAT and DESIGN				
A. Language & Media Component	4	3	2	1
1. Is the vocabulary load suited to the intended user?				
2. Are the language structure used suited to the intended users?				
3. Are the instructions for the learner stated in concise, clear manner?				
4. Are the visuals' quality clear?				
5. Are the visual presentation integrated with the sequence of the model as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
6. Do the visual contribute adequately to the understanding of the subject-matter as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
7. Do the visuals contribute adequately to the enrichment of the subject-matter content as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
8. Are the visuals appropriately synchronized with the text as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
COMMENTS / SUGGESTIONS:				

II. Technical and Organizational Content				
	4	3	2	1

1. Is the title of the module truly descriptive of the content?				
2. Are the use of graphics, sound and animation appropriate to the learning objectives as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
3. Does the program load consistently without errors?				
4. Are the movements within the program controllable by the user (can exit the program or activity if desired)?				
5. Are the frames (hyperlinks) linked together to ensure optimum learning as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?				
6. Is the length of module sufficient to achieve the objective?				
7. IS the general format and lay outing appealing?				
8. Is the font or typeface used in the module legible?				
COMMENTS / SUGGESTIONS:				

EVALUATED BY:

____

Printed Name over Signature

APPENDIX E

PARENT'S CONSENT & STUDENT'S ASSENT FOR THE PARTICIPATION OF STUDENTS IN THE CONDUCT OF THE EXPERIMENT

PHILIPPINE NORMAL UNIVERSITY
The National Center for Teacher Education
College of Graduate Studies and Teacher Education Research
Science Education Specialization

To the Students:

I am ______________________, Grade 8 student of this university and do agree with the intervention conducted by our Teacher, Mr. Lawsin, in teaching Transmission Genetics using the Digital courseware that he developed. I am properly briefed about the policies of the intervention. I am informed that I should take the Pre-test exam before the intervention and Post-test exam afterwards. Moreover, I was reminded that I have personal access with the result of this intervention especially in my progress report (using the percentage I gained after the intervention).

____
Name and Signature of the students

To the Parents/Guardians:

This is to ask your consent to allow your child(ren) to be one of the respondents in the research that I am conducting, ***"Development of Digital Courseware in Transmission Genetics".*** In this study, the respondents will undergo a Pre-Test, Intervention and Post-test about transmission genetics to test the effectiveness of the digital courseware developed by the researcher.

The said intervention will be conducted on the month of March this 2017. Any information or data gathered will be treated with utmost confidentiality. I am hoping for your consideration!

Mr. Nikko Lorenz P. Lawsin
Science Teacher / Researcher

______ Yes, I allow my child(ren) to participate the intervention of digital courseware in transmission genetics.
______ No, I refuse to allow my child to participate on the intervention of digital courseware in transmission genetics.

____
Parent's/Guardian's Signature
(Signature over printed name)

APPENDIX F

LETTER TO THE EXPERTS FOR VALIDATION

PHILIPPINE NORMAL UNIVERSITY
The National Center for Teacher Education
College of Graduate Studies and Teacher Education Research
Science Education Specialization
(Biology)

January 23, 2017

____
Master Teacher I
Las Pinas Science High School
Las Pinas City, NCR

To Mr. ______________________

Good day!

I am conducting my research study entitled ***"Development of Digital Courseware in Transmission Genetics"*** as a fulfilment in completing my degree (Master of Arts in Science Education major in Biology). As part of this, I am requesting you to be one of my Content-Expert Validators who will evaluate the digital courseware in transmission genetics that I developed as a product of this study.

The main objective of this material is to address the low conceptual understanding in transmission genetics, the numerous alternative conceptions, and as least mastered competencies in Biology thru courseware in line with the 21st Century Learning and Pedagogy.

I am looking forward for your positive response!

Mr. Nikko Lorenz P. Lawsin
MASEd Biology Candidate
Researcher
****
Note: Please see the envelope containing the "Content" to be validated, the validation tool and the actual developed digital courseware in Transmission Genetics.

PHILIPPINE NORMAL UNIVERSITY
The National Center for Teacher Education
College of Graduate Studies and Teacher Education Research
Science Education Specialization
(Biology)

January 23, 2017

____
Researcher & Project-Manager
Department of Science & Technology
DOST – ITDI, Taguig, NCR

To ______________________________:

Good day!

I am conducting my research study entitled ***"Development of Digital Courseware in Transmission Genetics"*** as a fulfilment in completing my degree (Master of Arts in Science Education major in Biology). As part of this, I am requesting you to be one of my Content-Expert Validators who will evaluate the digital courseware in transmission genetics that I developed as a product of this study.

The main objective of this material is to address the low conceptual understanding in transmission genetics, the numerous alternative conceptions, and as least mastered competencies in Biology thru courseware in line with the 21st Century Learning and Pedagogy.

I am looking forward for your positive response!

Mr. Nikko Lorenz P. Lawsin
MASEd Biology Candidate
Researcher
****
Note: Please see the envelope containing the "Content" to be validated, the validation tool and the actual developed digital courseware in Transmission Genetics.

PHILIPPINE NORMAL UNIVERSITY
The National Center for Teacher Education
College of Graduate Studies and Teacher Education Research
Science Education Specialization
(Biology)

January 23, 2017

____
FACULTY, University of Santo Tomas
High School (USTHS)
Manila City, NCR

To ______________________________:

Good day!

I am conducting my research study entitled ***"Development of Digital Courseware in Transmission Genetics"*** as a fulfilment in completing my degree (Master of Arts in Science Education major in Biology). As part of this, I am requesting you to be one of my Content-Expert Validators who will evaluate the digital courseware in transmission genetics that I developed as a product of this study.

The main objective of this material is to address the low conceptual understanding in transmission genetics, the numerous alternative conceptions, and as least mastered competencies in Biology thru courseware in line with the 21st Century Learning and Pedagogy.

I am looking forward for your positive response!

Mr. Nikko Lorenz P. Lawsin
MASEd Biology Candidate
Researcher
****
Note: Please see the envelope containing the "Content" to be validated, the validation tool and the actual developed digital courseware in Transmission Genetics.

Appendix G

Results of Content-Expert Evaluation

Facets	EXP1	EXP2	EXP3	Mean	SD	REMARKS
OBJECTIVES						
1. Are the Objectives relevant in delivering the concepts of genetics?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Are the objectives stated in terms of the target users?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. Are the objectives observable/measurable?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
4. Are the objectives logically sequenced?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
MEAN PER EXPERT	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
INFORMATIONAL CONTENT						
1. How Accurate/recent are the information in Genetics presented?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. How Sufficient are the factual information presented to develop a single genetic concept?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. How gradual are the factual information introduced?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
4. Are the factual information relevant to the genetic concept being developed?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
MEAN PER EXPERT	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
Instructional Events						
1. Does the development phase provide adequate or appropriate instructional content in reasonable order and apply the Principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Does the guidance phase suggest adequate memory schemes, prompts, cues and hint to improve retention as characterized by contiguity principle of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate

3. Does the application phase adequately promote retention and recall by response / practice mechanism (sample problems, reinforcement, question, practice frame)?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
4. Does the performance phase provide adequate opportunities for learners to demonstrate their knowledge/intellectual skills as suggested by Multiple representational principle?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
5. Does the feedback phase provide adequate assistance about the learners' performance as suggested by coherence principle of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
6. Does the development phase provide adequate or appropriate instructional content in reasonable order and apply the Principles of Mayer's Cognitive Theory of Multimedia learning?	4.0	3.0	4.0	**3.67**	0.577	Very Appropriate
MEAN PER EXPERT	4.0	3.89	4.0	**3.96**	0.144	Very Appropriate
Learner's Activities						
1. Are the learners' tasks compatible to the objectives of the courseware?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Are the tasks necessary for the attainment of the objectives as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. Are the small tasks sequenced properly within the larger phase as suggested in the principles	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate

of Mayer's Cognitive Theory of Multimedia learning?						
4. Are the tasks sufficient for the attainment of the objectives as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
5. Are the tasks adequately complementing or reinforcing one another?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
6. Do the operations in the tasks practice the concepts being developed?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
MEAN PER EXPERT	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
Evaluation						
1. Does the courseware pre-assess for entry level of intended user?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Does it provide for adequate formative evaluation like exercises?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. Does the post-test adequately measure the achievement of the objectives?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
Mean Per Expert	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate

Appendix H

Computer or IT-Expert Evaluation

Facets	**EXP 1**	**EXP2**	**EXP3**	**Mean**	**SD**	**REMARKS**
Format & Design						
1. Is the vocabulary load suited to the intended user?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Are the language structure used suited to the intended users?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. Are the instructions for the learner stated in concise, clear manner?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
4. Are the visuals' quality clear?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
5. Are the visual presentation integrated with the sequence of the model as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
6. Do the visual contribute adequately to the understanding of the subject-matter as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
7. Do the visuals contribute adequately to the enrichment of the subject-matter content as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
8. Are the visuals appropriately synchronized with the text as suggested in the principles of Mayer's Cognitive Theory of Multimedia learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
MEAN PER EXPERT	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
TECHNICAL and ORGANIZATIONAL CONTENT						

1. Is the title of the module truly descriptive of the content?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
2. Are the use of graphics, sound and animation appropriate to the learning objectives?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
3. Does the program load consistently without errors?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
4. Are the movements within the program controllable by the user (can exit the program or activity if desired)?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
5. Are the frames (hyperlinks) linked together to ensure optimum learning?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
6. Is the length of module sufficient to achieve the objective?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
7. Is the general format and lay outing appealing?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
8. Is the font or typeface used in the module legible?	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate
MEAN PER EXPERT	4.00	4.00	4.00	**4.00**	0.000	Very Appropriate

Appendix I

Pre- and Post-test Scores of Digital Instructions Class and Direct Instructions Class (RAW DATA)

	Direct Instructions Class (DIC)						Digital courseware class (DCC)					Post-Test	
#	Pre-Tes	Post-Tes	Gained Score	% Gained		#	Pre-Test	Post-Tes	Gained Scores	% Gained		EXP	CTRL
1	6	7	1	7.14%		**1**	12	20	8	100.0%		20	7
2	13	13	0	0.00%		**3**	10	17	7	70.0%		17	13
3	0	12	12	60.00%		**4**	5	15	10	66.7%		15	12
4	8	17	9	75.00%		**5**	5	8	3	20.0%		8	17
5	6	16	10	71.43%		**7**	4	10	6	37.5%		10	16
6	2	11	9	50.00%		**8**	5	20	15	100.0%		20	11
7	5	8	3	20.00%		**9**	5	12	7	46.7%		12	8
8	0	8	8	40.00%		**10**	5	7	2	13.3%		7	8
9	10	10	0	0.00%		**11**	7	12	5	38.5%		12	10
10	7	7	0	0.00%		**12**	5	11	6	40.0%		11	7
11	12	17	5	62.50%		**13**	4	14	10	62.5%		14	17
12	3	5	2	11.76%		**14**	4	11	7	43.8%		11	5
13	4	17	13	81.25%		**15**	5	8	3	20.0%		8	17
15	4	7	3	18.75%		**16**	5	14	9	60.0%		14	7
16	10	17	7	70.00%		**17**	4	15	11	68.8%		15	17
17	8	17	9	75.00%		**18**	8	11	3	25.0%		11	17
18	2	13	11	61.11%		**19**	5	14	9	60.0%		14	13
19	8	17	9	75.00%		**20**	6	9	3	21.4%		9	17
20	5	9	4	26.67%		**21**	7	7	0	0.0%		7	9
21	9	9	0	0.00%		**22**	2	9	7	38.9%		9	9
22	9	13	4	36.36%		**23**	7	20	13	100.0%		20	13
23	3	11	8	47.06%		**24**	2	8	6	33.3%		8	11
24	8	14	6	50.00%		**25**	3	13	10	58.8%		13	14
25	0	14	14	70.00%		**26**	0	14	14	70.0%		14	14
26	3	15	12	70.59%		**27**	5	17	12	80.0%		17	15
27	0	5	5	25.00%		**28**	7	13	6	46.2%		13	5
28	4	10	6	37.50%		**29**	7	17	10	76.9%		17	10
29	2	11	9	50.00%		**30**	6	18	12	85.7%		18	11
												13	
X	5.3929	11.786	6.3928571	43.77%		16	5.3571	13	7.64285714	52.2%		13	11.786
SD	3.7252	3.938					2.376	4.0092				4.0092	3.938

Analysis of Variance (F-test) Pre-test and Post-test of Control Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	28	151	5.392857	13.87698413
Column 2	28	330	11.78571	15.50793651

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	572.161	1	572.1607	38.9424	7.003E-08	4.019
Within Groups	793.393	54	14.69246			
Total	1365.55	55				

Analysis of Variance (F-test) Pre-test and Post-test of Experimental Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	28	150	5.357143	5.645503
Column 2	28	364	13	16.07407

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	817.7857	1	817.7857	75.304	8.07E-12	4.0195
Within Groups	586.4286	54	10.85979			
Total	1404.214	55				

Analysis of Variance (F-test) Pre-test and Post-test of Experimental Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	29	377	13	15.5
Column 2	28	330	11.78571	15.50794

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21.00501	1	21.00501	1.354822	0.249461	4.0161
Within Groups	852.7143	55	15.5039			
Total	873.7193	56				

PHOTO DOCUMENTATION

Pre-Test of Control Group

Pre-Test of Experimental Group



Implementation of the Study (Control Group)



Implementation of the Study (Experimental Group)

Post-Test of Control Group

Post-Test of Experimental Group

Lesson 1: Important Terms in Transmission Genetics

I. OBJECTIVES:

After this section, students should be able to:

1. define the following; Genetics, heredity, variation, genes and alleles,
2. differentiate the following;
    a. dominant trait and recessive trait
    b. homozygous and heterozygous genes
    c. genotype and phenotype

3. describe the use of Punnett square in determining possible ratio of offspring.

II. CONTENT:

Activity

Direction: Search and shade the following words listed at word bank below

Words to search

Alleles	Variation	Homozygous	Phenotype	Segregate
Genes	Dominant	Heterozygous	Chromosomes	Assortment
Heredity	Recessive	Genotype	Trait	Offspring

Q	W	E	R	T	Y	U	I	O	P	P	A	S	D	D	C	F	G	H	J	K	L	Z	X	C	V	B	N	N	M	Q	H	A
M	Q	W	D	F	V	G	A	R	H	E	T	E	R	O	Z	Y	G	O	U	S	A	U	L	A	A	S	A	I	T	S	O	Z
L	A	D	F	A	D	S	S	E	E	T	A	S	D	M	S	A	D	F	I	E	L	D	S	U	P	A	S	I	L	I	M	X
P	D	S	H	S	S	D	G	E	N	E	S	S	D	I	A	A	A	D	R	G	O	V	E	Y	A	U	L	D	A	R	O	S
O	D	C	R	S	D	S	A	E	O	F	D	S	F	N	S	S	E	V	A	R	I	A	T	I	O	N	A	N	O	H	Z	W
I	C	H	R	O	S	T	A	N	T	P	A	X	E	A	D	P	E	F	R	E	E	S	D	F	F	S	P	S	V	C	Y	D
O	C	H	E	R	E	D	I	T	Y	R	U	C	R	N	Y	F	T	F	F	G	L	W	O	F	F	S	P	R	I	N	G	F
I	L	R	I	T	D	A	A	D	P	A	U	V	D	T	D	G	F	C	P	A	L	L	E	L	E	S	A	S	E	A	O	C
U	U	I	S	M	R	D	A	D	E	D	L	V	O	E	S	J	D	C	C	T	A	C	A	P	C	V	D	E	Y	E	U	F
Y	S	S	T	E	C	A	D	D	A	A	C	N	D	E	D	K	R	E	C	E	S	S	I	V	E	S	S	D	O	D	S	V
H	A	T	I	N	A	P	I	A	U	L	E	C	F	X	C	V	B	D	A	F	L	U	A	B	S	A	E	D	U	R	E	E
G	P	I	A	T	N	P	A	T	U	G	R	D	E	N	A	P	A	U	C	H	R	O	M	O	S	O	M	E	S	L	C	R

Answer:

Q	W	E	R	T	Y	U	I	O	**P**	P	A	S	D	**D**	C	F	G	H	J	K	L	Z	X	C	V	B	N	N	M	Q	**H**	A
M	Q	W	D	F	V	G	A	R	**H**	**E**	**T**	**E**	**R**	**O**	**Z**	**Y**	**G**	**O**	**U**	**S**	A	U	L	A	A	S	A	I	T	S	**O**	Z
L	A	D	F	**A**	D	S	S	E	**E**	T	A	S	D	**M**	S	A	D	F	I	**E**	L	D	S	U	P	A	S	I	L	I	**M**	X
P	D	S	H	**S**	S	D	**G**	**E**	**N**	**E**	**S**	S	D	**I**	A	A	A	D		**G**	O	V	E	Y	A	U	L	D	A	R	**O**	S
O	D	C	R	**S**	D	S	A	E	**O**	F	D	S	F	**N**	S	S	**E**	**V**	**A**	**R**	**I**	**A**	**T**	**I**	**O**	**N**	A	N	O	H	**Z**	W
I	C	H	R	**O**	S	T	A	N	**T**	P	A	X	E	**A**	D	**P**	E	F	R	**E**	E	S	D	F	F	S	P	S	V	C	**Y**	D
O	C	**H**	**E**	**R**	**E**	**D**	**I**	**T**	**Y**	R	U	C	R	**N**	**Y**	F	T	F	F	**G**	L	W	**O**	**F**	**F**	**S**	**P**	**R**	**I**	**N**	**G**	F
I	L	R	I	**T**	D	A	A	D	**P**	A	U	V	D	**T**	D	G	F	C	P	**A**	**L**	**L**	**E**	**L**	**E**	**S**	A	S	E	A	**O**	C
U	U	I	S	**M**	**R**	D	A	D	**E**	D	L	V	**O**	E	S	J	D	C	C	**T**	A	C	A	P	C	V	D	E	Y	E	**U**	F
Y	S	C	T	**E**	C	**A**	D	D	A	A	C	**N**	D	E	D	K	**R**	**E**	**C**	**E**	**S**	**S**	**I**	**V**	**E**	S	S	D	O	D	**S**	V
H	A	T	I	**N**	A	P	**I**	A	U	L	**E**	C	F	X	C	V	B	D	A	F	L	U	A	B	S	A	E	D	U	R	E	E
G	P	I	A	**T**	N	P	A	**T**	U	**G**	R	D	E	N	A	P	A	U	**C**	**H**	**R**	**O**	**M**	**O**	**S**	**O**	**M**	**E**	**S**	L	C	R

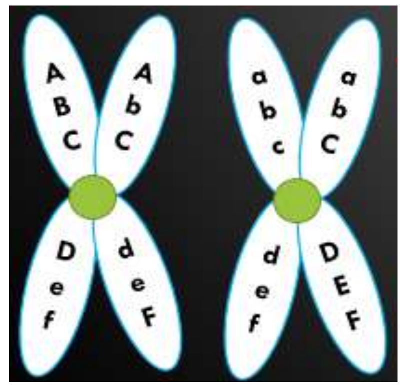
Genetics is a science of **heredity** and **variation**

- Heredity is the transmission of **genes** from one generation to another.
- Variations are the differences in living organisms of their own kind.
- Genes are sequences of **DNA Molecules** that determine the characteristics of organisms.

➢ **<u>Alleles</u>**

- One member of a pair or series of genes that occupy a specific position or locus on a specific chromosome determining a specific trait.

In these homologous chromosomes,



A is for the genes for the color of the eyes
B is for the genes for the shape of the nose
C is for the genes for the color of hair
D is for the genes for the types of earlobes
E is for the genes for the skin pigmentation
F is for the genes for the movement of tongue

Per gene (A,B,C,D,E or F) has 4 alleles in the pair of homologous chromosomes

➢ **<u>Dominant Gene</u>**
- this is the gene or factor that **<u>masks</u>** another gene. (e.g. tall and short gene, the tall gene masks the short gene thus the trait results to the tall trait.) The resulting trait is called the *dominant trait*.

➢ **<u>Recessive Gene</u>**
- this is the gene or factor that **<u>is masked</u>** by the dominant gene.

<u>A</u> is dominant gene ; **<u>a</u>** is for recessive gene

➢ **<u>Homozygous Gene</u>**
- genes that are morphologically alike or have the same alleles.

➢ **<u>Heterozygous Gene</u>**
- genes that are morphologically different. One allele is dominant and the other is recessive allele.

<u>AA</u> and **<u>aa</u>** is homozygous gene ; **<u>Aa</u>** is for heterozygous gene

Height of the plant is a common example in which it can be tall or short.

1.) A tall plant is crossed with another tall plant. Tallness is a dominant gene.			
 A	 A	=	 AA
Expected offspring should be tall			
2.) A tall plant is crossed with a short plant			
 A	 a	=	 Aa
Expected offspring is also tall since **dominant gene masks the recessive gene.**			
3.) A short plant is also crossed with another short plant.			
 a	 a	=	 aa
Expected offspring is now short since **all alleles code for short gene.**			

Another set of Examples is the seed of pea plants in which it is either round or wrinkled.

1.) A Rounded-seed plant is crossed with another rounded-seed plant. Rounded seed is a dominant gene.			
 A	 A	=	 AA

Expected offspring should be rounded-seed.

2.) A Rounded-seed plant is crossed with a wrinkled-seed plant.

 A	 a	=	 Aa

Expected offspring is also rounded-seed since **dominant gene masks the recessive gene**

3.) A wrinkled-seed plant is crossed with another wrinkled-seed plant.

 a	 a	=	 aa

Expected offspring are all wrinkled seed. **Both recessive alleles are now expressed.**

- **<u>Genotype</u>**

- this is the genetic make-up or genetic composition for a particular trait.

Ex. AA (Homozygous) or Aa (Heterozygous) is the genotype for the tall trait while aa is the genotype for the short trait.

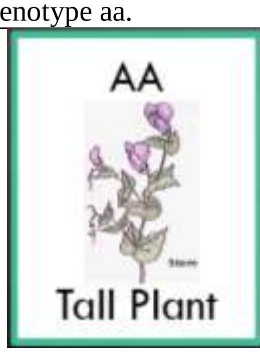
- **<u>Phenotype</u>**

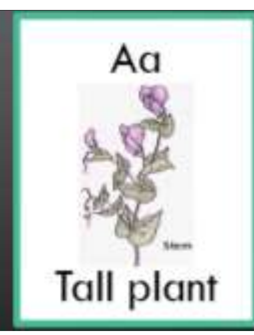
- the appearance or characteristic of the organism or the trait that is expressed as determined by the genotype.

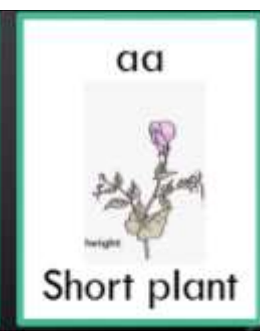
Ex: The tall trait as determined by the genotype AA or Aa. The short trait as determined by the genotype aa.

GENOTYPE

PHENOTYPE







➢ **<u>Punnett Square</u>**

- It is a diagram that is used to predict the outcome of a particular cross or breeding experiment. It is named after Reginald C. Punnett.

Genotype of Parent 2

Genotype of Parent 1

	A	**a**
A	AA Tall	Aa Tall
a	Aa Tall	aa short

Lesson 2: MENDELIAN GENETICS

I. OBJECTIVES:

After this section, students should be able to:

1. discuss the three laws of Mendelian Genetics,
2. solve Monohybrid and dihybrid cross problems under Mendelian Genetics, and;
3. appreciate other biological principles that are related with this topic such as meiosis, mutations, anatomy, and physiology.

II. CONTENT:

Activity:

#1: Segregate!

- In this activity, students will assemble four (4) human body. Each part has coded letters that are written in upper and lower case. *After this activity, students should be able to explain that letters represent genes and these are EQUALLY distributed*

Hair (H)	Hair (h)	Hair (H)	Hair (h)
Nose (n)	Nose (n)	Nose (N)	Nose (N)
Eyes (E)	Eyes (e)	Eyes (e)	Eyes (E)
Ears (F)	Ears (F)	Ears (F)	Ears (F)
Lips (l)	Lips (L)	Lips (L)	Lips (L)
Skin (s)	Skin (S)	Skin (S)	Skin(s)
Legs (M)	Legs(m)	Legs(m)	Legs(M)
Arms (A)	Arms (A)	Arms (a)	Arms (A)

Guide Questions:

1. Were you able to form four human body with complete parts out of the given materials?
2. What is the relevance of having complete parts of the body?
3. What do you think is the use of letters written to every parts?
4. What if those letters are not properly segregated?

#2: ASSORTED

In this activity, students will assemble four (4) chains or sets of colors with labels written also in upper and lower case letters. *After this activity, students should be able to explain that letters also represent genes and these are RANDOMLY distributed*

Pink (A)	Pink (a)	Pink (a)	Pink (A)
Green (G)	Green (G)	Green (g)	Green (G)
Red (r)	Red (R)	Red (r)	Red (r)
Blue (B)	Blue (B)	Blue (b)	Blue (b)
Orange (N)	Orange (n)	Orange (n)	Orange (N)
Yellow (D)	Yellow (d)	Yellow (d)	Yellow (d)
White (H)	White (h)	White (H)	White (H)
Brown (r)	Brown (R)	Brown (r)	Brown (r)

Guide Questions:

1. Were you able to form four chains of colors out of the given materials? What do you think is the use of letters written to every parts?
2. Why do you think that there is/are letters written in upper or lower case, what does it imply?

 # 3: DOMINANCE

In this activity, the students will get two colored-papers following the given chain of colors below. Each colored paper contains letter written in upper or lower cases. Students will be asked to write the upper case letter first in the combination before the lower case letters, if in case they get two different letter case in two draw lots. *Students should be able to realize later why the teacher asked to write the Upper case letter first in combination before the lower case letters.*

Given chain:

Blue	Green	Orange	Yellow	White

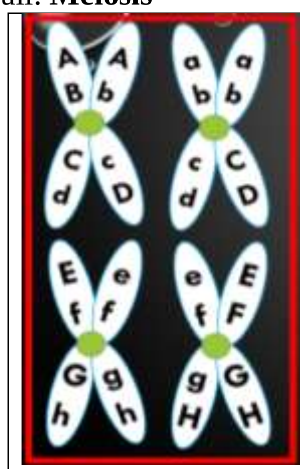
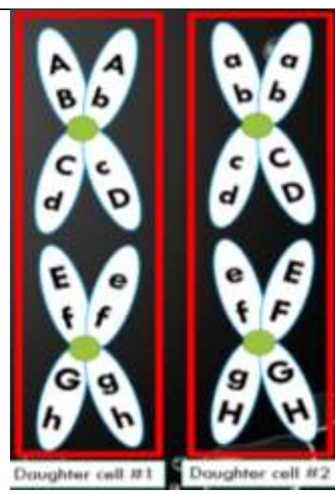
Guide Questions:

1. Write the combination of the entire chain.
2. Why do you think it is asked you to write the upper case first before the lower case?
3. Based on the three (3) Learning stations, what do you think is the main topic for today?

Mendelian Genetics: Three Laws of Inheritance

1. **Law of Segregation**
   - This law states that all the genes for all the traits of an organism are equally divided and are equally distributed in all the resulting gametes after meiosis. This principle states that each individual carries two hereditary alleles, affecting any given character or trait.

Recall: **Meiosis**

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>In a cell which is composed of 4 chromosomes, it contains genes A to H which code for specific trait.</td><td colspan="2">After, Meiosis I or otherwise known as reduction stage, it forms two daughter cells with half chromosomal number as compare to the parent cell.
Meiosis II is also known as division stage, it forms four (4) haploid daughter cells which come from the two (2) daughter cells of Meiosis I.</td></tr>
</table>

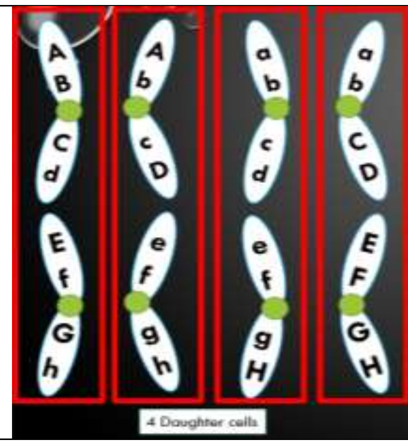
<table>
<tr><td>Student Drill:
Now, Restate the 1st Law of Mendelian Genetics
____
____
____</td><td>This is for immediate feedback to check students' concept retention</td></tr>
<tr><td colspan="2">*Check the answer above*</td></tr>
</table>

2. **Law of Independent Assortment**

➢ This law states that alleles of different genes are distributed randomly to the gametes and fertilization occurs at random

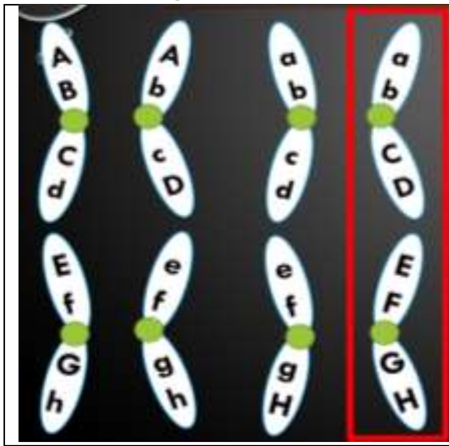
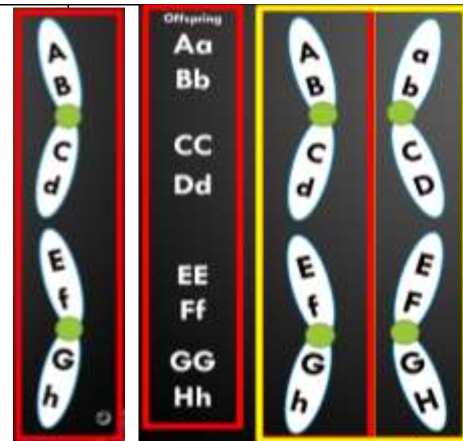
<table>
<tr><td>4 daughter cells/gametes contain different sets of alleles (dominant or recessive) that are randomly distributed. It favors variations since fertilization occurs also in random.

If these gametes become sperm cells, these four (4) cells will become four (4) mature sperm cells.

While if these gametes become egg or ovum, only one of the four will become mature egg and the remaining three will become polar bodies.</td><td>
</td></tr>
</table>

3. **Law of Complete Dominance**

- This principle states that a cross between homozygous dominant genes and homozygous recessive genes will result to a progeny of heterozygous genes determining all dominant traits.

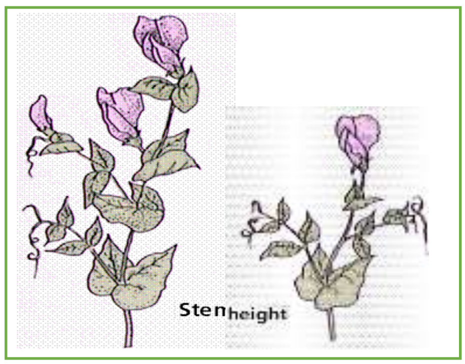
	
If this gamete becomes an ovum or egg then is fertilized by a sperm which has this set of chromosomes	Dominant gene masks the recessive gene producing heterozygous sets of genotype

SAMPLE PROBLEM SOLVING

#1. A tall plant, which came from three generations of tall plant, is crossed with a short plant. Determine the genotypic and phenotypic ratio of the offspring of this cross.

Procedure in Solving Genetics Problems.

- Determine first the genotype of the parents that has phenotypes that code for tall and short.
- You already know that tall is dominant than short plant. So A – is for tall and a – is for short.
- The phrase "which come from the three generations of tall plants" implies that this tall plant in the cross is homozygous tall (AA)



Solution:

Parents' Genotypes: AA x aa

Gametes: (A) (A) x (a) (a)

	A	**A**
a	Aa Tall	Aa Tall
a	Aa Tall	Aa Tall

Genotypic Ratio: (4:0) or 1:0 (Lowest Term)
Or 100% Aa
Phenotypic Ratio: (4:0) or 1:0 (Lowest Term)
Or 100% Tall

Please remind the students that they should place the phenotype under the genotype so it will be easy for them to count if you ask for genotypic and phenotypic ratio.

#2 Albinism is a recessive genetic disease in which the patients become non-pigmented. A normal man with no history of albinism is married with an albino woman. What is the probability that they could have (an) albino child/ren?

Procedure in Solving Genetics Problems.

- Determine first the genotype of the parents that has phenotypes that code for normal and albino
- You already know that normal pigmentation is dominant than albinism. So A – is for normal and a – is for albino as stated in the problem
- Find keyword(s) that will help you solve the problem
- The term "with no history of albinism" implies that this parent in the cross is homozygous dominant (AA) – normal

Solution:

Parents' Genotypes: AA x aa

Gametes: (A) (A) x (a) (a)

	A	**A**
a	Aa Normal	Aa Normal
a	Aa Normal	Aa Normal

Genotypic Ratio: (4:0) or 1:0 (Lowest Term) or 100% Aa

Phenotypic Ratio: (4:0) or 1:0 (Lowest Term) Or 100% Normal Pigmentation

Please remind the students that they should place the phenotype under the genotype so it will be easy for them to count if you ask for genotypic and phenotypic ratio.

#3 Brown-eye is more observable in humans. A person with blue eyes is married with brown-eyes and all of their offspring have brown eyes. Assign the phenotype of the following genotype.

Answer:

BB – brown; Bb – brown; bb – blue

Since "brown eyes" is dominant than "blue eyes", it masks the gene for the blue eyes in accordance with the Law of Complete Dominance.

#4 Donna is a brown-eyed woman who has a father with blue eyes. She married an American man with blue eyes. What is the probability that they could have blue-eyed offspring?

Procedure in solving Genetics Problems

TIPS!!!

- You already know that "brown eyes" is dominant than blue eyes as stated in the previous problem.
- Determine the genotype of the parents
- Find keyword(s) that will help you solve the problem
- The term "who has a father with blue eyes" implied that Donna has heterozygous genotype; her father has blue-eyes while her mother is has brown eyes where she inherited that phenotype.

Solution:

Donna's Genotype and his husband: Bb x bb

Gametes: (B) (b) x (b) (b)

	B	**b**
b	Bb Brown	bb Blue
b	Bb Brown	bb Blue

Genotypic Ratio: (2:2) or 1:1 (Lowest Term)
Or 50% bb
Phenotypic Ratio: (2:2) or 1:1 (Lowest Term)
Or 50% blue

#5 Arthur has brown eyes (BB) and attached earlobes (ee). He married Magdalene who has green eyes (bb) and unattached earlobes (Ee). What is the genotypic and phenotypic ratio of offspring of this couple.

Procedure

- Based on the problem, it is stated that brown eyes and unattached earlobes are dominant trait while green and attached earlobes are recessive.
  - B = brown eyes, b = green eyes; E = unattached earlobes, e = attached earlobes
- Determine the complete genotype of the parents
  - Arthur's and Magdalene's Genotype = BBee x bbEe
- Identify the gametes of the Parents using FOIL METHOD (First, Outer, Inner & Last)
  - (Be) (Be) (Be) (Be) x (bE) (be) (bE) (be)

Arthur's Gametes		Magdalene's Gametes			
		bE	be	bE	be
	Be	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes
	Be	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes
	Be	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes
	Be	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes	BbEe Brown eyes & Unattached Earlobes	Bbee Brown eyes & attached Earlobes

Genotypic Ratio: 8 : 8 (BbEe : Bbee) or (1 : 1 Lowest Term)
Phenotypic Ratio: 8 : 8 (Brown eyes & Unattached Earlobes : Brown eyes & Attached Earlobes) or (1 : 1 Lowest Term)

Practice Exercise

Direction: Solve the following problems by utilizing Punette square.

1. Widow's peak is a dominant trait in human hairline. Mario is a widow's peak (AA) man who is married with Teresa who has straight hairline. What is the probability that they could have offspring with straight hairline? Justify your answer.
2. Marian has a widow's peak hairline but his father has straight hairline. Marian is married with Pedro who has straight hairline. Determine the genotypic and phenotypic ratio of their offspring.
3. Polydactyl, or having six (6) fingers or toes on each limb, is a dominant trait. Jose has normal number of digits while his wife, Tricia, was born as polydactyl. One of Tricia's Parents has also normal number of digits. What is the probability that they could have polydactyl children?
4. In domestic cats, long hair is recessive to short hair. A true-breeding (homozygous) short-haired male is mated to a long-haired female. Will this cross produce long-haired kittens? Why?
5. Two cats are mated. One of the parent cats is long-haired (recessive allele). The litters which result are two short-haired and three long-haired kittens. What does the second parent look like, and what is its genotype?
6. Domeng has brown eyes (Bb) and unattached earlobes (EE). He marries Angeline who has green eyes (bb) and attached earlobes (ee). What is the probability that they could have children with **brown eyes and attached earlobes?**
7. Harry, a blue-eyed (bb) and black hair (HH) man, has children with Katrina, a brown-eyed woman (Bb) with blonde hair (hh). What is the probability of having blue-eyed black haired offspring?

*** See Answers on the next page ***

Answer:

1. A = widow's peak hairline; a = straight hairline
Mario's genotype & Teresa's genotype = AA x aa
Gametes of the parents = (A) (A) x (a) (a)

<table>
<tr><td></td><td>A</td><td>A</td><td rowspan="3">Genotypic Ratio = 4:0 or 1:0 (Aa)
Phenotypic Ratio = 4:0 or 1:0
(Widow's Peak Hairline)
Justification: Because Widow's Peak, as dominant gene, masks the recessive gene which is the straight hairline.</td></tr>
<tr><td>a</td><td>Aa
Widow's Peak</td><td>Aa
Widow's Peak</td></tr>
<tr><td>a</td><td>Aa
Widow's Peak</td><td>Aa
Widow's Peak</td></tr>
</table>

2. A = widow's peak hairline; a = straight hairline
Marian's genotype & Pedro's genotype = Aa x aa
Gametes of the parents = (A) (a) x (a) (a)

<table>
<tr><td></td><td>A</td><td>a</td><td rowspan="3">Genotypic Ratio
2:2 or 1:1 (Aa & aa)
Phenotypic Ratio
2:2 or 1:1
(Widow's Peak & Straight Hairline)</td></tr>
<tr><td>a</td><td>Aa
Widow's Peak</td><td>aa
Straight hairline</td></tr>
<tr><td>a</td><td>Aa
Widow's Peak</td><td>aa
Straight hairline</td></tr>
</table>

3. D = Polydactyl; d = normal number of digits
Jose's genotype & Tricia's genotype = dd x Dd
Gametes of the parents = (D) (d) x (d) (d)

<table>
<tr><td></td><td>d</td><td>d</td><td rowspan="3">Genotypic Ratio
2:2 or 1:1 (Dd & dd)
Phenotypic Ratio
2:2 or 1:1
(50% Polydactyl)</td></tr>
<tr><td>D</td><td>Dd
Polydactyl</td><td>Dd
Polydactyl</td></tr>
<tr><td>d</td><td>dd
normal</td><td>dd
normal</td></tr>
</table>

4. H = short-haired; h = Long-haired
Male cat's genotype & Female cat's genotype = HH x hh
Gametes of the parents = (H) (H) x (h) (h)

<table>
<tr><td></td><td>H</td><td>H</td><td rowspan="3">Genotypic Ratio = 4:0 or 1:0 (Hh)
Phenotypic Ratio = 4:0 or 1:0
(short-haired)
Justification: Because short-haired, as dominant gene, masks the recessive gene which is long-haired.</td></tr>
<tr><td>h</td><td>Hh
short-haired</td><td>Hh
short-haired</td></tr>
<tr><td>h</td><td>Hh
short-haired</td><td>Hh
short-haired</td></tr>
</table>

5. H = short-haired; h = Long-haired
Parent 1's genotype & Parent 2's genotype = hh x Hh
Gametes of the parents = (H) (H) x (h) (h)

<table>
<tr><td></td><td>H</td><td>h</td><td rowspan="3">Genotypic Ratio = 2:2 or 1:1
Phenotypic Ratio = 2:2 or 1:1
(Short-haired: Long-haired)
Justification: Second Parent should be Heterozygous (Hh) in order to have long-haired offspring because if it is dominant (HH), no long-haired offspring will be produced.</td></tr>
<tr><td>h</td><td>Hh
Short-haired</td><td>hh
Long-haired</td></tr>
<tr><td>h</td><td>Hh
Short-haired</td><td>hh
Long-haired</td></tr>
</table>

6. B = brown eyes, b = green eyes; E = unattached earlobes, e = attached earlobes
Domeng's and Angeline's Genotype = BbEE x bbee
Gametes of the Parents: Use FOIL METHOD (BE) (BE) (bE) (bE) x (be) (be) (be) (be)

		Angeline's Gamates			
		be	be	be	be
Domeng's Gametes	BE	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes
	BE	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes	BbEe Brown eyes & Unattached Earlobes
	bE	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes
	bE	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes	bbEe green eyes & Unattached Earlobes

Based on the phenotypic results, there is no probability that they could have offspring with brown eyes & attached earlobes (BBee/Bbee).

7. B = brown eyes, b = blue eyes; H = black hair, h = blonde hair
Harry's and's Genotype = bbHH x Bbhh
Gametes of the Parents: Use FOIL METHOD (bH) (bH) (bH) (bH) x (Bh) (Bh) (bh) (bh)

		Katrina's Gamates			
		bH	bH	bH	bH
Harry's Gametes	Bh	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair
	Bh	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair	BbHh Brown eyes & Black hair
	bh	bbHh blue eyes & black hair	bbHh blue eyes & black hair	bbHh blue eyes & black hair	bbHh blue eyes & black hair
	bh	bbHh blue eyes & black hair	bbHh blue eyes & black hair	bbHh blue eyes & black hair	bbHh blue eyes & black hair

Based on the phenotypic results, there is 50% probability that they could have offspring with blue-eyes and black-hair (bbHh)

Lesson 3: NON-MENDELIAN GENETICS

I. OBJECTIVES:

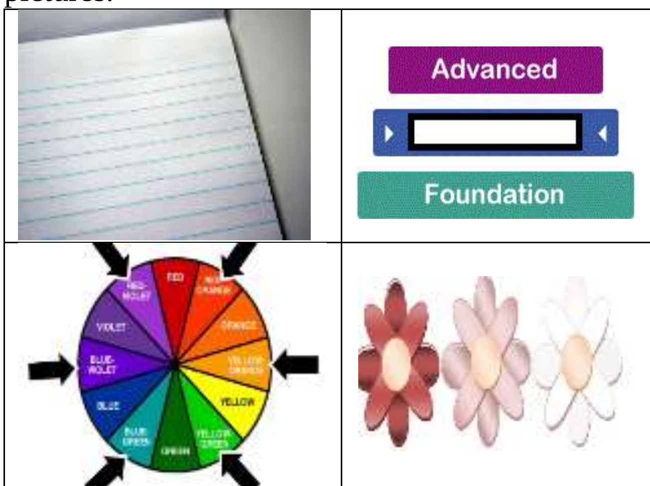
After this section, students should be able to:

1. differentiate incomplete and codominance from complete dominance,
2. determine the pattern of inheritance in multiple alleles in blood typing, color coats of cats and rabbits.
3. differentiate sex-linked, sex-influenced and sex-limited Trait

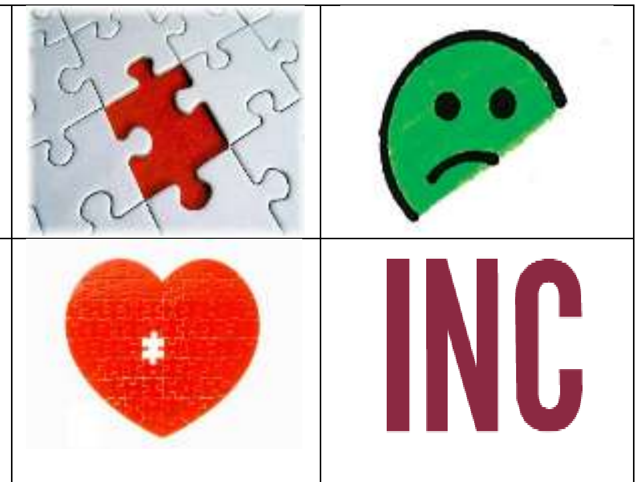
II. CONTENT:

Non – Mendelian Genetics: Incomplete Dominance, Co-dominance, Multiple Alleles, Sex – linked, Sex – influenced and sex – limited gene.

Activity 1 (4-Pics-1-word): Guess the word using the hints portrayed by the four (4) pictures.



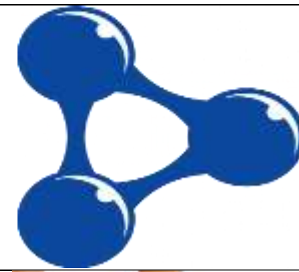
I	N	T	E	R	M	E	D	I	A	T	E



I	N	C	O	M	P	L	E	T	E

C	O	L	O	R	C	O	A	T

B	L	O	O	D	T	Y	P	E

				
				
L I M I T E D			**L I N K E D**	

Activity 2: Rearrange the jumbled letters to form words. These words will be encountered in succeeding parts of the lessons.

	Jumbled Letters	Answers
1	POINTMEELC CAMEINNOD	Incomplete Dominance
2	DIETAEMINERT	Intermediate
3	DACOINNCOME	Codominance
4	ARON	Roan
5	MUTELIPL LESALEL	Multiple Alleles
6	DOBOL PYTING	Blood Typing
7	TIOUGA	Agouti
8	NICHALLICH	Chinchilla
9	AIMHAYLAN	Himalayan
10	BOILAN	Albino
11	XES KILNED	Sex linked
12	PHILIMOAHE	Hemophilia
13	EXS ENFLUENCID	Sex Influenced
14	SADLEBNS	Baldness
15	SXE TIMEDLI	Sex Limited

These patterns of inheritance do not follow the rules established by Gregor Mendel

1. **Law of Incomplete Dominance -** This principle states that a cross between homozygous dominant and recessive genes will result to a progeny of heterozygous genes determining an **<u>intermediate</u>** trait between the dominant trait and recessive trait. Both alleles exert an effect and jointly produce an intermediate phenotype. The diagram shows the cross using color of flower.

Red flower (AA) is crossed with white flower (aa). Determine the genotypic and phenotypic ratio of this cross.

Procedure:

1. Assign a legend for the traits

A – Red;
a – White; Aa - Pink

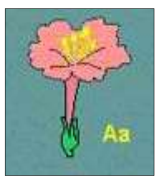
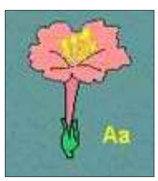
2. Determine the genotype of both parents

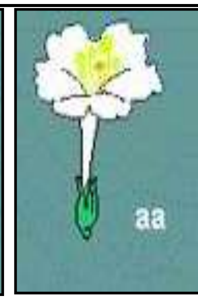
AA x aa

3. Determine the gametes of the Parents

(A) (A) x (a) (a)

4. Place the gametes in the punnett square.

	A	A
a	Aa Pink 	Aa Pink 
a	Aa Pink 	Aa Pink 



Genotypic ratio
4:0 or 1:0 (Lowest term)
100% Aa

Phenotypic ratio
4:0 or 1:0 (Lowest Term)
100% Pink

In Law of Complete Dominance, heterozygous (Aa) results to a progeny of red flower since it is dominant gene while in law of incomplete dominance, heterozygous (Aa) results to a progeny of pink flower. The dominant gene DOES NOT COMPLETELY masks the recessive gene that is why intermediate trait (Pink) appears.

Two Pink Flowers (Aa) from second generation are crossed. Determine the genotypic and phenotypic ratio of this cross.

Procedure:

1. Assign a legend for the traits

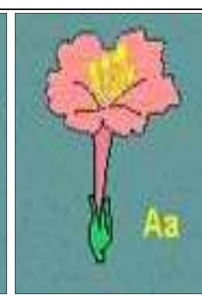
A – Red;
a – White
Aa - Pink

2. Determine the genotype of both parents

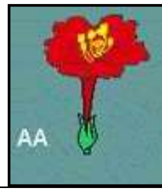
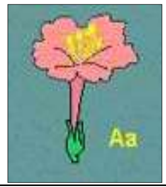
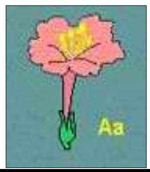
Aa x Aa

3. Determine the gametes of the Parents

(A) (a) x (A) (a)



Genotypic ratio
1:2:1(AA, Aa, aa)
Phenotypic ratio
1:2:1 (Red, Pink & White)

Place the gametes in the punnette square.		
	A	a
A	AA Red 	Aa Pink 
a	Aa Pink 	aa White 

Genotypic ratio (both in Law of Complete Dominance and Incomplete Dominance) is the same 1:2:1 (AA,Aa,aa).

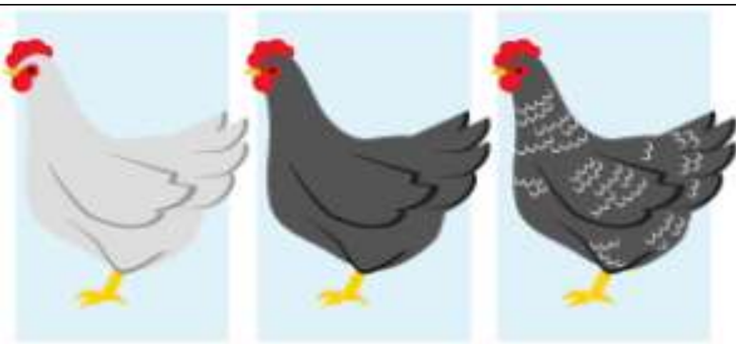
But in Phenotypic ratio following the law of complete dominance, the ratio is 3:1. (3) Red and (1) White While in Law of Incomplete Dominance, it is 1:2:1. (1) Red, (2) Pink and (1) white.

2. **Law of Codominance** - This principle states that a cross between homozygous dominant genes and recessive genes will result to a progeny of heterozygous genes determining a phenotype where both the dominant trait and recessive trait are expressed. Common examples of codominance are the following;

   a. <u>Roan</u> - color coat of animals where both phenotypes appear.

A red coat cow is mated with white coat cow. The offspring of this cross produced roan, animals where both red and white appear as color coat of animals.		
		
AA Red Coat	aa White coat	Aa Roan
The allele (A) is for Red; (a) for White and Aa is for Roan		

   b. <u>Speckled Chicken.</u> A chicken in which the color of the feathers are mixture of white and black that both appear. It happens when a white chicken is crossed with a black chicken,



aa	AA	Aa
White	Black	Speckled

c. Spotted Carnation flower. This happens when a carnation plant with pink flower is crossed with carnation plant with white flower. Both phenotypes appear resulting to spotted flower.

		
AA (Pink)	aa (White)	Aa (Spotted)

#1. Two roan cows are crossed. What is the expected genotypic ratio and phenotypic ratio of this cross?

Procedure:

1. Assign a legend for the traits

A – Red;
a – White; Aa – Roan

2. Determine the genotype of both parents

Aa x Aa

3. Determine the gametes of the Parents

(A) (a) x (A) (a)

4. Place the gametes in the punnette square.

	A	a
A	AA Red 	Aa Roan 
a	Aa Roan 	Aa White 

Genotypic Ratio = 1:2:1 (AA,Aa,aa)
Phenotypic Ratio = 1:2:1 (Red, Roan & White)

#2 White cow is crossed with a roan cow. Determine the genotypic and phenotypic ratio of this cross. What will be the genotypic and phenotypic ratio if the offspring of this cross is mated with another white cow?

Procedure:

1. Assign a legend for the traits

A – Red;

a – White; Aa - Roan

2. Determine the genotype of both parents

White (aa) x Roan (Aa)

3. Determine the gametes of the Parents

(a) (a) x (A) (a)

4. Place the gametes in the punnette square.

	A	a
a	Aa Roan 	aa White 
a	Aa Roan 	aa White 

Genotypic Ratio = 2:2 or 1:1 (Lowest term) (Aa & aa)
Phenotypic Ratio = 2:2 or 1:1 (Lowest term) (Roan & White)

The offspring of this cross are ***roan and white***. Based on the problem, these probable offspring will be crossed again to white cow.

If the offspring is Roan mated with white cow…
(Aa) x (aa)

	A	a
a	Aa Roan 	aa White 
a	Aa Roan 	aa White 

Genotypic Ratio = 2:2 or 1:1 (Lowest term) (Aa & aa)
Phenotypic Ratio = 2:2 or 1:1 (Lowest term) (Roan & White)

The genotype and phenotype is maintained as observed in first generation.

If the offspring is white and mated with another white cow…
(aa) x (aa)

	a	a
a	aa White 	aa White 
a	aa White 	aa White 

Genotypic Ratio = 4:0 or 1:0 (Lowest term) (aa)
Phenotypic Ratio = 4:0 or 1:0 (Lowest term) (All White)

All of the offspring of this cross are white.

3. **Multiple Alleles** - One gene has several possible alleles for its chromosomal locus. Inheritance by multiple alleles often results in more than two possible genotypes for a particular trait.

E.g. Human Blood Types

Human Blood Typing has four (4) Phenotypes which are Type A, Type B, Type AB and Type O.

Blood Type (Phenotype)	**Pattern of Inheritance**	**Genotype(s)**
Type A	Dominant	AA, AO
Type B	Dominant	BB, BO
Type AB	Codominance	AB
Type O	Recessive	OO

Examples:

#1. A couple with three children having blood type A, B and AB. What are the genotypes of the parents? What is the probability of having an O-child?

Explanation: In this type of problem, you need to do a "Trial-and-error" in identifying the genotypes of the parents since it is the easiest way to answer this problem.

You already know that Type A can have genotypes of AA or AO, and Type B can have BB or BO & lastly, Type AB has only a genotype of AB.

These are the following cross that you might try; (AA x BB), (AO x BB), (AA x BO) and (AO x BO). Let's try it all.

Cross: AA x BB

	A	A
B	AB Type AB	AB Type AB
B	AB Type AB	AB Type AB

In this cross, all of the offspring are Type AB, these are not the parents of the offspring in Problem #1.

Cross: AO x BB

	A	O
B	AB Type AB	BO Type B
B	AB Type AB	BO Type B

In this cross, the offspring are Type AB and Type O only, these are not the parents of the offspring in Problem #1 since Type A offspring did not appear.

Cross: AA x BO

	A	A
B	AB Type AB	AB Type AB
O	AO Type A	AO Type A

In this cross, the offspring are Type AB and Type A only, these are not the parents of the offspring in Problem #1 since Type B did not appear

Cross: AO x BO

	A	O
B	AB Type AB	BO Type B
O	AO Type A	OO Type O

In this cross, all blood types appear. These are the genotypes of the parents in Problem #1. Moreover, there is 25% chances that this cross could have offspring with blood type O.

#2 Ana is a Type AB woman and she married Peter, a Type O man. What are the possible genotype and phenotype which their offspring could have?

Solution:
Ana's Genotype : AB Gametes: (A) (B)
Peter's Genotype : OO Gametes: (O) (O)

	A	B	
O	AO Type A	BO Type B	The genotypes of their offspring are AO and BO. Their offspring can be Type A or Type B.
O	AO Type A	BO Type B	

#3 The couple, who are both type-AB, has a child. Will this couple produce all Type-AB children?

Solution:
Parent 1 Genotype : AB Gametes: (A) (B)
Parent 2 Genotype : AB Gametes: (A) (B)

	A	B	
A	AA Type A	AB Type AB	There is only 50% probability that they could have Type AB children
B	AB Type AB	BB Type B	

Another examples of multiple alleles are the color coats of cats and rabbits. The phenotypes are Agouti, chinchilla, Himalayan and albino.

Color Coat (Phenotypes)	Pattern of inheritance	Genotypes
Agouti (I^A) - In color coat of rabbit, it is dark brown while in cat, it is only black.	Most dominant 	**$I^A I^A$, $I^A I^{ch}$, $I^A I^H$, $I^A I^a$** The first allele (I^A) is the most dominant among the alleles, so agouti will appear no matter what second allele will be paired with it.
Chinchilla (I^{ch}) - This phenotype has gray color in rabbits. While in Cats contains of three color combinations of Black, Orange and White	More dominant 	**$I^{ch} I^{ch}$, $I^{ch} I^H$, $I^{ch} I^a$** The first allele (I^{ch}) must only pair with second alleles (I^{ch}, I^H, I^a) in order for the phenotype -- chinchilla to appear.
Himalayan (I^H) - This phenotype is a combination of black and white color. Sometimes the entire body is white but the leg parts, paws areas and tail are black, or sometimes the entire	Dominant 	**$I^H I^H$, $I^H I^a$** The first allele (I^H) must only pair with second alleles (I^H, I^a) in order for the phenotype -- Himalayan to appear.

body is black but has ventral (belly) part and leg parts are white.		
Albino(I^a) - This phenotype is white in color. Albinism, in lower animals like cat, is normal. Unlike in Human, albinism is a genetic disease.	Recessive 	**I^a I^a** This phenotype has only one genotype since it is the recessive.

Examples:

#4 Pure breed Himalayan cat is mated with another Himalayan cat but its father is an albino. What is the genotypic and phenotypic ratio of this cross? What will be the phenotypes if the offspring of this cross is/are mated with another albino cat?

Solution:
Cat 1's Genotype : I^H I^H (Hint: Pure breed means homozygous genotype
Cat 2's Genotype : I^H I^a (Hint: "Himalayan but the father is an albino" means heterozygous Himalayan.

	I^H	I^H	**Genotypic Ratio** 2 : 2 or 1:1(Lowest term)(I^H I^H : I^H I^a)
I^H	I^H I^H Himalayan	I^H I^H Himalayan	
I^a	I^H I^a Himalayan	I^H I^a Himalayan	**Phenotypic Ratio** 4 : 0 or 1:0(Lowest Term) or 100% Himalayan

Based on the problem, the offspring of initial cross is mated again with an albino cat.
Since there are two different genotypes, we will cross them separately and determine the phenotypes as it is asked in the problem

Cross: I^H I^H x I^a I^a

	I^H	I^H
I^a	I^H I^a Himalayan	I^H I^a Himalayan
I^a	I^H I^a Himalayan	I^H I^a Himalayan

All offspring of this cross have still Himalayan color coat.

Cross: I^H I^a x I^a I^a

	I^H	I^a
I^a	I^H I^a Himalayan	I^a I^a Albino
I^a	I^H I^a Himalayan	I^a I^a Albino

There is 50-50% possibility that this cross may produce Himalayan or albino cat.

#5 Jennilyn's Cat is an agouti but one of its parent is an albino. Anjo has a chinchilla cat but one of its parent is a Himalayan cat. What are the color coat they should expect?

Solution:
Jennilyn's Cat : I^A I^a Gametes: (I^A) (I^a)
Anjo's Cat : I^{ch} I^H Gametes: (I^{ch}) (I^H)

	I^A	I^a	This cross may yield to offspring with phenotypes of Agouti, Chinchilla and Himalayan
I^{ch}	$I^A I^{ch}$ Agouti	$I^{ch} I^a$ Chinchilla	
I^H	$I^A I^H$ Agouti	$I^H I^a$ Himalayan	

4. **Sex-Linked Traits –** The condition in which a gene responsible for a specific trait is located on a sex chromosome, resulting in sexually dependent inheritance of the trait.

Human have X or Y Chromosomes. Females have XX chromosomes while males have XY chromosomes in the 23^{rd} pair.

Examples of X-linked traits are the following;

1. Hemophilia is a recessive genetic disease which is caused by lacking of Factor VIII Protein resulting to inability of blood clotting after scratch, cut or laceration.

You all know that Male has XY and Female has XX in the 23^{rd} pair of chromosomes. Now what will happen if ….

… Your father has hemophilia and your mother has no history of hemophilia,

X^H = normal ; X^h = with hemophilia
Male = X^hY Female = $X^H X^H$

	X^h	Y
X^H	$X^H X^h$ Normal	X^H Y Normal
X^H	$X^H X^h$ Normal	X^H Y Normal

All offspring of this cross either male or female are normal, but the female are carrier $X^H X^h$.

… Your father is normal and your mother is a carrier of hemophilia,

X^H = normal ; X^h = with hemophilia
Male = X^HY Female = $X^H X^h$

	X^H	Y
X^H	$X^H X^H$ Normal	X^H Y Normal
X^h	$X^H X^h$ Normal	X^h Y hemophilic

In female, all are normal but one is a carrier but in male, there is 50% that it could have hemophilic son.

Now you try this. What if the father is normal and the mother is hemophilic.

X^H = normal ; X^h = with hemophilia
Male = X^HY Female = $X^h X^h$

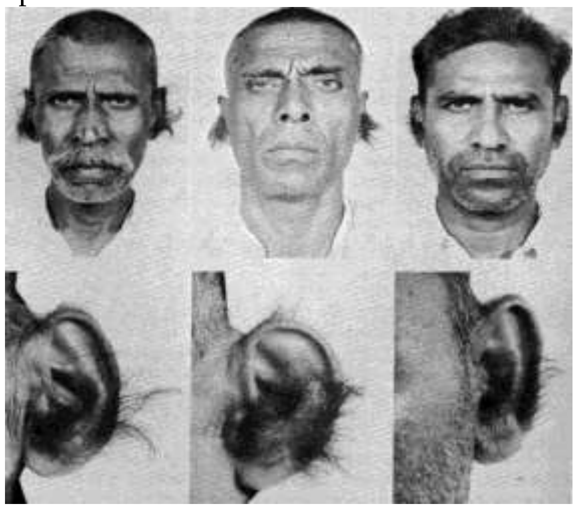
	X^H	Y	In this cross, females are all normal but the males are all hemophilic. This is the reason why hemophilia is common to male than female even though it is X-linked trait.
X^h	$X^H X^h$ Normal	X^h Y hemophilic	
X^h	$X^H X^h$ Normal	X^h Y hemophilic	

These patterns of inheritance follow once the gene is recessive in nature. You may also try it in other recessive genes like color blindness and Duchenne's muscle dystrophy

2. Color – blindness is a recessive genetic disease in which the person has inability to distinguish red and green color;
3. Duchenne's Muscular Dystrophy is a recessive genetic condition that causes muscle degeneration; and,
4. Becker's muscular dystrophy is a milder form of Duchenne, which causes slowly progressive muscle weakness of the legs and pelvis.

Example of Y-linked traits or holandric inheritance;

1. Trichocyst is a recessive genetic condition in which there is rare hairy structures surrounding the pinnae of the ear.



2. Testis-specific Y-encoded protein 1 (TSPY 1) is a protein that in humans is encoded by the TSPY1-gene

5. **Sex-Influenced Traits** – These are traits controlled by the genes that are affected by the gender of the organism. The gender that is more affected shows the gene dominance.

E.g., Baldness. There are more bald males than females. Thus in males BB and Bb are for bald phenotype and bb is for non-bald. But in females BB is for bald and Bb and bb are for non-bald phenotype. Note: Genes are **not** linked anymore to sex chromosomes.

Genotype	Phenotypes in Male	Phenotypes in Female
BB	Bald	Bald
Bb	Bald	Non – bald
bb	Non - bald	Non-bald

Another example is the plumage (tail) of peacock. The peacock has more colorful tail than peahen. This structure for male favors their mating behaviour because the more colorful their plumage is, the easier for them to attract female.	 Peacock in the left and peahen in the right side

6. **Sex Limited Traits** – these are traits controlled by genes that are limited to one gender only. Common example is the presence of beared in male and milk production which is only exclusive in female after conceptions.

The table shows that no matter what is the genotype of the female, it always yield to non-bearded offspring since beardedness is only exclusive to male.

Genotype	Phenotypes in Male	Phenotypes in Female
BB	Non-bearded	Non-bearded
Bb	Non-bearded	Non-bearded
bb	Bearded	Non-bearded

Practice Exercise

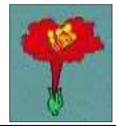
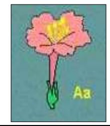
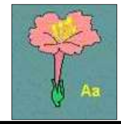
Direction: Solve the following problems by utilizing Punnett square.

1. A Pink flower is crossed with Red flower. Following the law of incomplete dominance, determine the genotypic and phenotypic ratio of this cross. The offspring of this cross is pollinated with a plant with white flower. Will it produce a plant with white flower in this generation? Account for your answer.
2. A hen with speckled (Both white and black) feather is mated with white rooster. Determine the genotypic and phenotypic ratio of this cross.
3. Mrs. Cruz is a Type-A woman while his husband, Mr. Cruz, is a type B man. Their first and second children is a type A and type B, respectively, while their third child is a type-O child. Can the third child be considered as their children? How?
4. A cat produced a litter of six (6) kittens; 3 were agouti, 2 Chinchilla and 1Himalayan. Determine the possible genotypes of the parents.
5. Hannah is a colorblind woman. She married Dante with normal color vision. What is the probability that they could have a colorblind son?
6. Jose is a bearded man. He married Joana who has a bearded-father. What is the probability that they could have a bearded-son?

Answer:

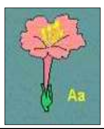
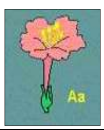
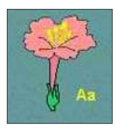
1. Solution:
R = Red; r = white; Rr = Pink
Plant 1 (Pink Flower) = Rr
Plant 2 (Red Flower) = RR

The Genotypic and Phenotypic ratio of the 1st cross is 1:1 (RR & Rr) and 1:1 (Red & Pink) respectively. Based on the problem, the offspring of this cross is pollinated again with the plant with white flower.

	R	r
R	RR Red 	Rr Pink 
R	RR Red 	Rr Pink 

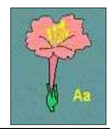
Offspring 1: RED pollinated with white

Genotypes: RR x rr
Gametes: (R) (R) x (r) (r)

	R	R
r	Rr Pink 	Rr Pink 
r	Rr Pink 	Rr Pink 

All of the offspring of this cross will yield to a plant with pink flower

Offspring 2: PINK pollinated again with white
Genotypes: Rr x rr
Gametes: (R) (r) x (r) (r)

	R	r
r	Rr Pink 	rr White 
r	Rr Pink 	rr White 

This cross may yield to a 50-50% Pink and White Offspring

2. Solution
A = Black-feathered a = white-feathered Aa = Speckled feather
Parent 1 (Speckled) = Aa Gametes = (A) (a)
Parent 2 (White) = aa Gametes = (a) (a)

	A	a
a	Aa Speckled 	aa White 
a	Aa Speckled 	aa White 

Genotypic Ratio
2 : 2 or 1 : 1(Lowest term)(Aa & aa)

Phenotypic Ratio
2 : 2 or 1 : 1 (Lowest Term) or 50% Speckled & 50% White

3. The third child of Family Cruz might be their children if the Genotype of Mr & Mrs Cruz is AO and BO, respectively.

	A	O
B	AB Type AB	BO Type B
O	AO Type A	OO Type O

This punnet square may support the claim that the 3rd child is still their children. Moreover, it shows also the phenotypes of the 1st and 2nd children (Types A & B)

4. In this problem, YOU SHOULD NOT CREATE a punnett square with 6 boxes. That is the common mistakes done by students because in the given that there are six (6) kittens. You should only use the 4-squares punnet square. The point is, there should be higher chance for agouti since it is numerous in the number of kittens aside from it is the dominant. The three possible genotypes of the parents are the following;

	I^A	I^a
I^{ch}	$I^A I^{ch}$ Agouti	$I^{ch} I^a$ Chinchilla
I^H	$I^A I^H$ Agouti	$I^H I^a$ Himalayan

	I^A	I^H
I^{ch}	$I^A I^{ch}$ Agouti	$I^{ch} I^H$ Chinchilla
I^a	$I^A I^a$ Agouti	$I^H I^a$ Himalayan

	I^A	I^H
I^{ch}	$I^A I^{ch}$ Agouti	$I^{ch} I^H$ Chinchilla
I^H	$I^A I^H$ Agouti	$I^H I^H$ Himalayan

There are 50% chance to produce an agouti while both 25% for Himalayan and Chinchilla

5. X^C = normal ; X^c = color blind

Male (normal vision) = X^CY Female (color blind) = $X^c X^c$

	X^C	Y
X^c	$X^C X^c$ Normal	X^c Y Color blind
X^c	$X^C X^c$ Normal	X^c Y Color blind

There is 100% possibility that the male offspring of this cross is color blind

6. Jose is bearded (bb). In the case of Joana, we do not know her genotype because she is female and beard does not appear in her gender. But in the problem, it was mentioned that her father is also bearded, so, she is either Bb or bb. Either she got “B or b” allele from her mother because the other “b-allele” absolutely comes from her bearded father. Your answer might be one of these.

Solution

Jose’s Genotype : bb Gametes : (b) (b)

Joana’s Genotype : Bb or bb Gametes : (B) (b) or (b) (b)

	B	**b**
b	**Bb** **M=Non-bearded** **F = Non-bearded**	**bb** **M = Bearded** **F = Non - bearded**
b	**Bb** **M=Non-bearded** **F = Non-bearded**	**bb** **M = Bearded** **F = Non-bearded**

There is 50% Probability that they could have bearded son.

If Joana’s genotype is (bb),

	b	b
b	**bb** **M = bearded** **F = Non-bearded**	**bb** **M = Bearded** **F = Non - bearded**
b	**bb** **M = bearded** **F = Non-bearded**	**bb** **M = Bearded** **F = Non-bearded**

There is 100% Probability that they could have bearded son.

PRE-TEST & POST-TEST FOR PILOT TESTING
COVERAGE: LESSON 1 & 2 (GRADE 8 STUDENTS)

PHILIPPINE NORMAL UNIVERSITY – MANILA
The National Centre for Teacher Education (NCTE)
College of Graduate Studies and Teacher Education Research (CGSTER)

Name: ______________________________ Date: __________ Score: ___________
Year and Sec: ________________________ Time Schedule: ________________________
Directions: Answer the following question by ***utilizing Punnett Square***

1A. An albino man marries a normally pigmented woman who had an albino mother. What types of children could this couple expect?
  a. All are albino
  b. Some are albino but some are normal
  c. All are normal
  d. Data are insufficient

1B. If their children will marry a normally pigmented individuals with no history of albinism, will they produce albino offspring? Why?
____
____
____
____

2A. A brown-eye man who has a mother with blue-eyes, marries a blue-eye woman. Determine the possible genotype(s) of their offspring if brown-eye (B/b) is common to human races
  a. Bb and bb
  b. Bb only
  c. bb only
  d. BB and Bb

2B. What is the probability that they could have a blue-eyes son/daughter?
  a. 25%
  b. 50%
  c. 75%
  d. 100%

3A. Genes for all the traits are equally divided after Meiosis II. This statement is anchored with what Law of Mendelian Genetics?
  a. Law of Segregation
  b. Law of Independent Assortment
  c. Law of Complete Dominance
  d. Law of Complete Assortment

3B. If the genes for all the traits are not equally divided, which of the following will ***NOT*** be the effect to the offspring?
  a. Aberrations
  b. Mutations
  c. Abnormalities
  d. Development

4A. Variations among the offspring such as Physical appearance are anchored with the concept of _____?
  a. Law of Segregation
  b. Law of Independent Assortment
  c. Law of Complete Dominance
  d. Law of Complete Assortment

4B. Which of the following ***does not*** follow the Law of Independent assortment?
  a. Anna and Donna have similar features that are inherited from her mother.
  b. Leo has similar characteristics with his siblings.
  c. Albinism is observable throughout generations in Mike's Family
  d. Mary's fraternal twin has features that are different from each other yet has similarities that make them as siblings

ANSWER KEY

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b. Some are albino but some are normal
c. All are normal
d. Data are insufficient

1B. If their children will marry a normally pigmented individuals with no history of albinism, will they produce albino offspring? Why?
This couple should not expect an offspring which is albino. Since normal pigmentation is dominant, it can mask the recessive gene - - albino.

2A. A brown-eye man who has a mother with blue-eyes, marries a blue-eye woman. Determine the possible genotype(s) of their offspring if brown-eye (B/b) is common to human races
a. Bb and bb
b. Bb only
c. bb only
d. BB and Bb

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4B. Which of the following ***does not*** follow the Law of Independent assortment?
a. Anna and Donna have similar features that are inherited from her mother.
b. Leo has similar characteristics with his siblings.
c. Albinism is observable throughout generations in Mike's Family **(Complete dominance)**
d. Mary's fraternal twin has features that are different from each other yet has similarities that make them as siblings