Implementation and Impact of Integrated Course Design Using Fink's Taxonomy of Significant Learning and Small-group Strategies in a University Undergraduate Biology Curriculum

THESIS

Submitted in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

ASHISH KATYAL

Under the Supervision of

Prof. Pankaj Kumar Sharma

Prof. Manoj Kannan

Dr. L.D. Fink

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

2024

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

CERTIFICATE

This is to certify that the thesis titled **“Implementation and Impact of Integrated Course Design using Fink's Taxonomy of Significant Learning and small-group strategies in a university undergraduate biology curriculum”** submitted by **Ashish Katyal** ID No **2017PHXF0101P** for the award of Ph.D. of the Institute embodies original work done by her under my supervision.

Signature of the Supervisor:

Name in capital letters: **Prof. PANKAJ KUMAR SHARMA**

Designation: Associate Professor, Department of Biological Sciences

Birla Institute of Technology & Science, Pilani

Pilani Campus, Rajasthan, India

Signature of the Co-Supervisor:

Name in capital letters: **Prof. Manoj Kannan**

Designation: Associate Professor, Plaksha University

Sahibzada Ajit Singh Nagar, Punjab 140306

Signature of the Co-Supervisor:

Name in capital letters: **Dr. L. Dee Fink**

Designation: Consultant in Higher Education

Date:

Acknowledgment

I would like to thank God, the almighty who blessed and helped me throughout the journey of my Ph.D. by giving me the determination and strength to fulfill my dream.

First and foremost, I would like to express my sincere gratitude to my Ph.D. supervisor Dr. Pankaj Kumar Sharma, for his continuous support during my Ph.D. Further, I would like to thank him for his patience, motivation, enthusiasm, and immense knowledge and for pushing me farther than I thought I could go. I could not have imagined having a better advisor and mentor for my Ph.D. research. I would also like to thank my co-supervisors, Dr. Manoj Kannan and Dr. L.Dee Fink, for their care and help throughout this journey. This work might not be possible without their support and guidance.

I would like to thank my thesis Doctoral advisory committee (DAC) members, Prof. P.R.Deepa and Dr. Jayashree Mahesh from BITS-Pilani, Pilani campus, for their support, encouragement, and insightful comments. I would like to thank Prof. Shibasish Chowdhury for his valuable support and guidance and for sharing her immense knowledge. I wish to thank him for allowing me to implement pedagogical practices in his tutorial classes in the Introduction to Bioinformatics course. I would like to thank Dr. Bridget Arend for helping and teaching me a certified course related to Integrated Course Design (ICD). I would like to thank all the thesis students of New Science Block (NSB), especially Swarnima, Smita, Harshita, and Sonia and the people of Plaksha University especially Dr. Monika Sharma, Dr. Gittaly Dhingra, Dr. Sachpreet Kaur, Ms. Sonu Kaur, Mr. Santosh Pandey, Dr. Neetu Dillion, and Ms. Megha Gupta for helping and supporting me directly or indirectly in achieving my goals.

I thank the honorable Vice-chancellor, BITS –Pilani, Prof. V. Ramgopal Rao, Director of BITS –Pilani, Prof. Sudhir Kumar Barai, AUGSRD Dean, Prof. Ajit Pratap Singh, and Associate Deans of Pilani campus, Prof. Shamik Chakraborty. I would like to thank all my badminton squad family from the Student Activity Centre (SAC), especially Mrs. Komal Bhagwat, Mrs. Bhargavi Murli, Prof. Sangeeta Sharma, and Prof. Gaurav for their help and support in all my tough times. I would like to thank all my colleagues from BITS, Pilani, and Plaksha University, SAS Nagar, Punjab for their kind assistance. I would like to thank the non-teaching staff for their continuous support. I would like to thank HOD Prof. Rajdeep Chowdhury and other faculty members especially Dr. Sandhya Marathe and Dr. Sudeshna Mukherjee for their support. I am indebted to the BITS, Pilani, and Plaksha University for awarding me the fellowship for carrying out the research work.

I would like to thank wholeheartedly my father, mother, both my sisters, nephew, niece, and friends, especially Zaiba, Neelam, and Akriti for their love and support in pursuing my dream, helping me survive all the stress and never letting me give up.

Thank you all.

ASHISH KATYAL

Abstract

The current pedagogical practices majorly focus on the cognitive domain of students, whether it involves lower order cognitive skills or higher order cognitive skills. There is a need for a transformation from the current content-centered pedagogical practices to a more learning-centered model that not only covers the cognitive and affective domains of students but also goes beyond towards the meta-cognitive domain.

The content-centered pedagogical practices majorly focused on one thing: rote memorization, which mainly leads to remembering and understanding, a major demand of the industrial era. But in the 21st century information era or artificial intelligence era (such as OpenAI's chatGPT or Google's Bard), there is a need for metacognitive skills that can go beyond the lower order cognitive skills of remembering and understanding. These metacognitive skills involve 4C's communication, collaboration, critical thinking, and creativity. The old content-centered approach majorly uses a decade-old, revised Bloom's Taxonomy (L. W. Anderson & Krathwohl, 2001), which is hierarchically arranged and mainly focused on the cognitive and affective domains of learning. For full filling the demands of 21st century learning-centered approach Fink's Taxonomy of Significant Learning (Fink, 2013) is a right solution as it not only integrates cognitive and affective domains of learning but also adds a meta-cognitive component. Also, Fink's Taxonomy of Significant Learning is interactive rather than hierarchical in case of Bloom's Taxonomy that leads to synergistic effect.

As India has announced its new education policy "National Education Policy" in 2020 (NEP-2020 MHRD) (Mhavan et al., 2022) popularly known as NEP-2020 (by keeping in mind the 21st century learner-centered approach) that give major emphasis on holistic, integrated, engaging, experiential learning along with development and enhancement of critical thinking and essential learning among the students. Fink's Integrated Course Design (ICD) provides a practical framework for achieving the desired goals of the National Education Policy 2020, such as a holistic, student-centered approach, deeper learning, and the development of essential 21st-century skills.

Our study not only contributes a practical framework for using ICD to achieve the goals of NEP-2020 but also demonstrates a theoretical framework by utilizing Fink's Integrated Course Design along with the Taxonomy of Significant Learning, popularly known as ICD/SL, to

promote deeper learning, communication, collaboration, and experiential learning among the students.

There are various reasons for choosing ICD/SL, as it shows objective alignment with NEP-2020, encourages interdisciplinary exploration that fosters deeper understanding, promotes skill development (such as critical thinking, creativity, and problem-solving abilities) through hands-on activities, emphasizes active engagement (such as collaborative and interactive learning) of students, and fosters a mindset of lifelong learning by making connections across disciplines.

There is a great need of designing course based upon Disciplinary Based Education Research (DBER) so that students make connections across different disciplines and become lifelong allrounder learners. Biology courses or education is not an exception (Dolan, 2015, 2017). The recent trends of research showed that the curricula based upon Biology Education Research (BER) along with Fink's ICD/SL and small group strategies like Problem and Team-Based Learning are very few across the world and not available in case of India. Also, assessment is mainly based upon cognitive domain of students of biology and student feedback of teachers is very generic and does not capture the learning experience of students.

The Fink's ICD/SL has four major components (such as situational factor, significant learning goals, teaching and learning activities and feedback and assessment) that also shows complete alignment with the Discipline-based approach to design Biology Curricula (i.e., learning outcomes, instructions, and assessment).

Our study demonstrated the designing and implementation of ICD/SL using small group strategies like Problem-Based Learning in the undergraduate third year tutorial course of Introduction to Bioinformatics (BIO F242) at Birla Institute of Technology and Science, Pilani, Pilani campus. The study shows that the implementation has increased the individual class participation and academic score of students along with better student's engagement in the tutorial course. The study also highlights a holistic view of learning that creates a change in the learner's experience to acquire and know more information, but at the same time, it allowed the learner to know about the meaning and use the information and see its effects on themselves and others.

The study also showed the effectiveness of innovative assessment methods in the form of in-class worksheets and out-of-class take-home assignments on student learning and class participation in a third-year undergraduate bioinformatics tutorial course. The results of personal response showed that students found these assessment methods as task engaging, exciting, and challenging. The students also preferred this new mode of assessments to stay connected with the topic and this assessment helped them to think critically about the topic before answering the questions. The findings demonstrated that these activities contributed to students' familiarity with bioinformatics tools, strengthened their concepts, and positively influenced their end-semester reports.

The study also revealed effective implementation active teaching-learning activity in the form of Team-Based Learning in the sophomore-year biology courses of Genetics and Integrated Biology at Birla Institute of Technology and Science, Pilani, Pilani campus and freshman year course of Engines of Life at Plaksha University, SAS Nagar, Punjab. The study showed that teams outperformed the individuals in terms of performance and promoted peer interaction, communication, and critical thinking skills in a collaborative learning environment, resulting in an increase in the acquisition of knowledge and satisfaction among students.

At last study demonstrated development of a customizable student feedback questionnaire to accurately capture student learning outcomes. The questionnaire included Likert scale questions about course content, instructor rapport, overall course experience, and open-ended questions for additional comments or suggestions (Cavalcanti et al., 2020; Gormally et al., 2014; Huxham et al., 2008).

To analyze the subjective feedback received from students, the study utilized sentiment analysis, a popular technique in machine learning and natural language processing. Sentiment analysis was employed to categorize students' opinions into positive, negative, and neutral classes, enabling a deeper understanding of their feedback. The sentiment analysis tool used in the study was called "Pratikriya," which was developed using Python-based libraries. The tool facilitated the classification of students' subjective feedback into different sentiment polarities, such as positive, negative, or neutral. This analysis provided valuable insights into students' perceptions and patterns, enriching the teaching-learning process .The results showed that the sentiment analysis of student subjective feedback was found to be mostly neutral or positive.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AICTE	All India Council for Technical Education
BCPBL	Blended Collaborative Problem Based Learning
BER	Biology Education Research
BITS	Birla Institute of Technology and Science
BLAST	Basic Local Alignment Search Tool
CBA	Competency-Based Assessment
CBME	Competency-Based Medical Education
CDS	Coding Sequence
T-COFFEE	Tree-based Consistency Objective Function for Alignment Evaluation
DBER	Discipline-Based Education Research
DLE	Distance Learning Education
DNA	Deoxyribonucleic acid
EMBL	European Molecular Biology Laboratory
EMBOSS	European Molecular Biology Open Software Suite
FK	Foundational Knowledge
GOR	Garnier–Osguthorpe–Robson
HD	Human Dimension
HOCS	Higher Order Cognitive Skills
ICD	Integrated Course Design
IRAT	Individual Readiness Assurance Test
LHL	Learning How to Learn
LOCS	Lower Order Cognitive Skills
MEGA	Molecular Evolutionary Genetics Analysis
MHRD	Ministry of Human Resource Development
ML	Machine Learning
MT	*Minute Thesis*
NCBI	National Center for Biotechnology Information
NEP	*National Education Policy*
NLP	Natural Language Processing
NLTK	Natural Language Toolkit
NPE	National Policy on Education
NRC	National Research Council
ORF	Open Reading Frame
PBL	Problem-Based Learning
PSIPRED	PSI-blast based secondary structure PREDiction
RAT	Readiness Assurance Test
SAS	Sahibzada Ajit Singh
SDG	Sustainable Development Goal
SL	Significant Learning
STEM	Science, Technology, Engineering and Mathematics
SVM	Support Vector Machine
TBL	Team-Based Learning
TFBS	Transcription Factor Binding Sites
THA	Take-Home Assignments
TRAT	Team Readiness Assurance Test

TSL	Taxonomy of Significant Learning
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
VADER	Valence Aware Dictionary and sEntiment Reasoner
WS	Worksheets

1 Introduction

The field of education is vast and complex, encompassing a multitude of teaching methods, learning styles, and educational philosophies. One area that has received increasing attention in recent years is the role of individual differences, experiential learning, and social-emotional learning in student success. Despite this, there remain significant gaps in pedagogical practices, particularly in the context of Biology Education Research (BER) in India.

Background and Motivation

Traditional teaching methods often adopt a one-size-fits-all approach, neglecting the individual differences among students. Research has shown that students have different learning styles, strengths, and needs, and teaching methods that take these differences into account can be more effective (Kubat, 2018; Pashler et al., 2008; Zapalska & Brozik, 2006). Furthermore, many educational systems rely heavily on lectures and textbooks, lacking emphasis on hands-on, experiential learning. Experiential learning has been shown to be more effective in helping students retain information and develop critical thinking skills (Bradberry & De Maio, 2019; Dimmitt, 2017; Franco Valdez & Valdez Cervantes, 2018; Spanjaard et al., 2018). Lastly, while traditional teaching methods focus mainly on academic skills, research has shown that social and emotional skills, such as empathy, communication, and problem-solving, are also crucial for student success.

Research Problem

The status of BER in India compared to the rest of the world, the lack of curricula based on BER, Taxonomy of Significant Learning, and Problem-Based Learning, the focus of assessment on the cognitive domain rather than the learning domain of students in Biology, and the generic nature of student feedback of teachers are key gaps in existing pedagogy. These gaps highlight the need for a more individualized, experiential, and holistic approach to teaching and learning.

Justification

Addressing these gaps is important as it has the potential to enhance the quality of education, improve student learning outcomes, and contribute to the broader field of educational research.

By designing and implementing an Integrated Course Design (ICD) that encompasses the six aspects of Fink's Taxonomy of Significant Learning (TSL) and small group activities, creating appropriate assessment methods, identifying suitable classroom management platforms and tools, and evolving a student feedback questionnaire, this research aims to address these gaps and contribute to the advancement of pedagogical practices in India.

1.1 Integrated Course Design and Taxonomy of Significant Learning

In the last few years, there have been great demands for reforms in biology education, such as focusing bioinformatics programmes on learning, theoretical-practical integration, and small-group or team discussions (Wilson Sayres et al., 2018). Some authors also advocate for a greater focus on data-driven omics scenarios where bioinformatics can be used to incorporate next-generation technology for the students to use technologies that can enhance the learning experience(Amer & Baidoo, 2021). Designing learning activities that utilize all these integrated features would be advantageous. Learning taxonomies, which aid in the proper structuring of a course design, are an appropriate place to start with this work (Uribe Cantalejo & Pardo, 2020). Fink proposed an alternative to Bloom's Taxonomy, pointing out that it places too little focus on aspects of learning that are becoming more popular, such as learning to learn, interpersonal relationships, tolerance, and communication (Fink, 2013) It has been observed by the instructors that students should be provided a set of possibilities to study more actively for themselves, allowing their acquired information to take on personal and professional importance(Darling-Hammond et al., 2020). This goal can be achieved by focusing on skill development rather than course content as part of a learning-focused methodology known as Integrated Course Design (ICD) (Fink, 2013).

The ICD model and Fink's Taxonomy both allow for a holistic approach to course creation. According to this method, a teacher must first identify situational circumstances, learning goals, feedback and assessment activities, and teaching and learning activities that effectively support specific course goals before designing any instruction.

The significant advantage of implementing ICD in designing new courses is that it consists of a new taxonomy of significant learning in contrast to the old Bloom's Taxonomy, which not only covers cognitive skills (i.e., both Lower Order Cognitive Skills (LOCS) and Higher Order Cognitive Skills (HOCS)) but goes beyond it by covering meta-cognitive domains of life-long learning, caring and human-dimension of self and others which is also the requirement of National Education Policy-2020 (NEP-2020 MHRD) (Mhavan et al., 2022). Metacognition, as defined by Flavell, is a process of higher-order thinking that involves "critical analysis of thought" and "knowledge and cognition about a cognitive phenomenon" through monitoring, regulating, and orchestrating cognitive processes and products. It's the ability of individuals to understand and manipulate their own cognitive processes.

On the other hand, Fink's Significant Learning Taxonomy is a holistic approach to learning that includes a metacognitive domain. This domain in Fink's taxonomy aligns with the concept of metacognition by Flavell, as it also emphasizes the importance of students being aware of and taking control of their own learning.The correlation between these two concepts lies in their shared emphasis on the importance of self-awareness and self-regulation in learning. Both recognize that effective learning involves more than just the passive absorption of information; it requires active engagement, reflection, and adjustment based on one's understanding.

However, a direct comparison between metacognition by Pintrich or Flavell and the metacognitive domain in Fink's taxonomy might not yield a one-to-one mapping, as they are conceptual frameworks developed for different purposes. Flavell and Pintrich's work on metacognition is more focused on individual cognitive processes, while Fink's taxonomy is designed as a framework for significant learning in the context of course design.

In Fink's Taxonomy of Significant Learning, the metacognitive domain refers to the level of learning that involves the awareness and understanding of one's own thought processes and learning strategies. Metacognition involves thinking about thinking, which allows learners to monitor, control, and regulate their cognitive processes to become more effective learners. In Fink's framework, the metacognitive domain emphasizes the development of skills such as critical thinking, problem-solving, reflection, and self-assessment. This domain encourages learners to be actively engaged in their learning process, to set goals, to monitor their progress, and to adjust their strategies as needed to achieve those goals.

Metacognitive activities involve tasks such as reflecting on one's learning experiences, evaluating the effectiveness of different learning strategies, identifying areas for improvement, and planning how to approach future learning tasks more effectively. By engaging in metacognitive activities, learners become more self-directed and autonomous in their learning, leading to deeper understanding and long-term retention of knowledge and skills.

ICD is not only focused on designing learning goals, but it also designs and covers three significant aspects, namely- active teaching and learning activities, educative feedback, and assessment and different situational factors (Fink, 2013). The main goal of this study was to see whether redesigning courses using Integrated Course Design (ICD) and small group strategies like Problem-based Learning (PBL) can produce significant learning experiences. The name Integrated Course Design itself involves well-integrated different aspects like situational factors, learning goals/outcomes, teaching and learning, and feedback and assessment (Figure 1-1)

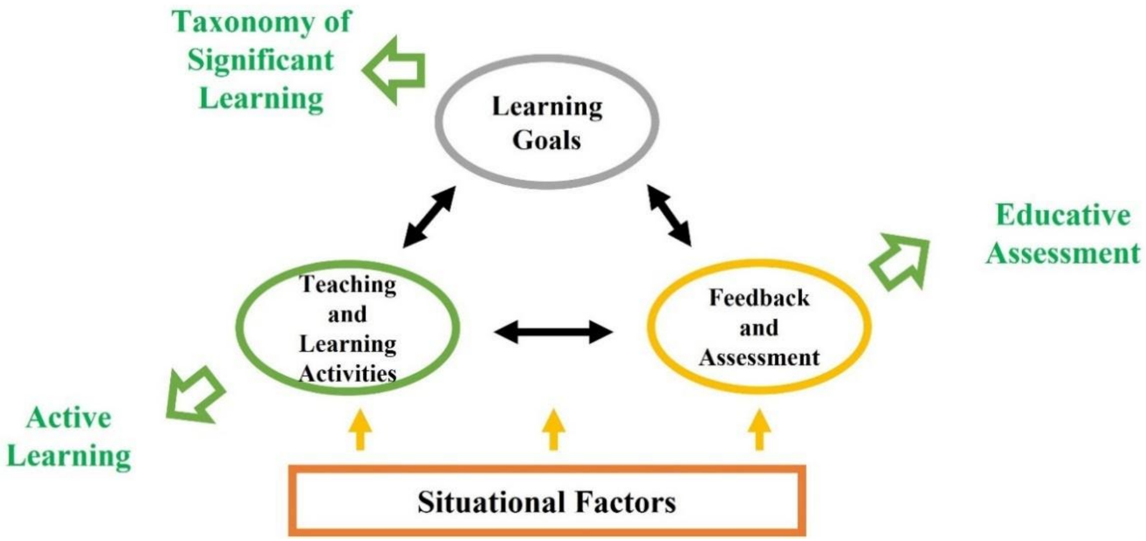


Figure 1-1 Key components of Integrated Course Design (ICD) ***(Fink, 2013)***

While designing each aspect, we must carefully look at various factors that either influence or are required to accomplish that aspect. For instance, in the case of the significant learning goal, we need a taxonomy of significant learning for designing the learning objective of the course that fall into six categories of Foundational Knowledge (FK), Application (A), Integration (I), Human Dimension (HD), Caring (C), Learning How to Learn (LHL) or self-directed life-long learning. The first three categories of Fink's taxonomy of significant learning (i.e., FK, A, and I) cover all six levels of Bloom's taxonomy that can be further divided into Lower Order Cognitive Skills (LOCS) and Higher Order Cognitive Skills (HOCS) (Fink, 2013) (Figure 1-2). There is no denying the importance of what Bloom and his colleagues achieved by developing this taxonomy. Any model that still demands this level of reverence fifty years later is exceptional.

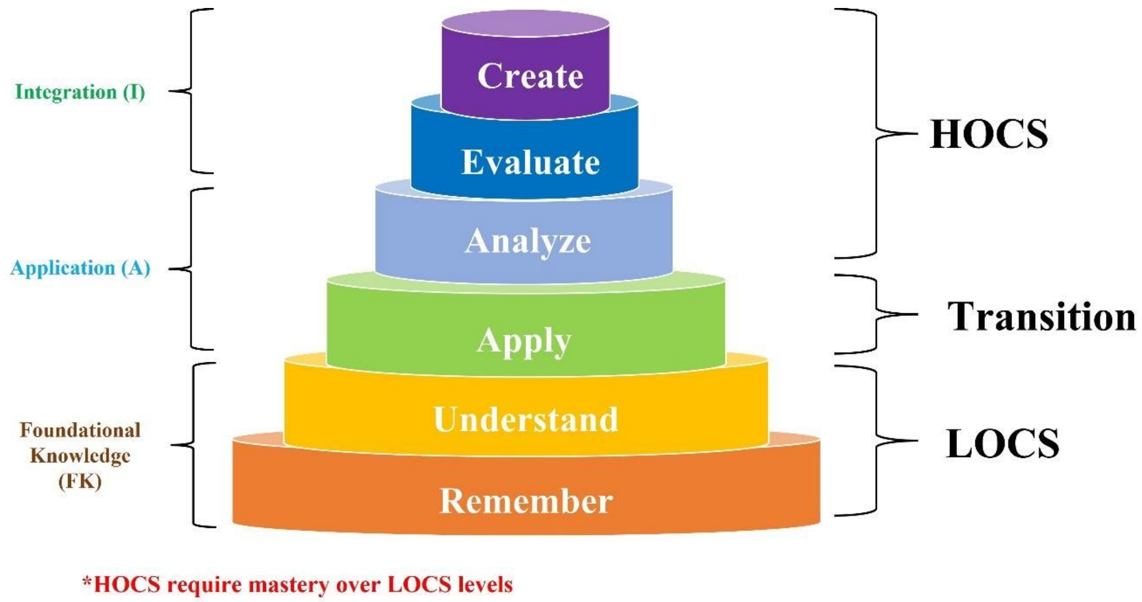


Figure 1-2 Mapping six levels of revised Bloom's Taxonomy with three domains of Fink's Taxonomy of Significant Learning ***(L. W. Anderson & Krathwohl, 2001; Fink, 2013)***

In higher education, there is a need to express essential kinds of learning that do not emerge quickly from the Bloom's taxonomy, for example, learning how to learn, leadership and interpersonal skills, ethics, communication skills, character, tolerance, and the ability to adapt to change, etc.

Fink's taxonomy of significant learning not only covers LOCS and HOCS of revised Bloom's taxonomy, but it goes beyond it by covering both meta-cognitive and affective elements so that assessment can be done not only based on the cognitive domain but with the learning domain of students (Figure 1-3).

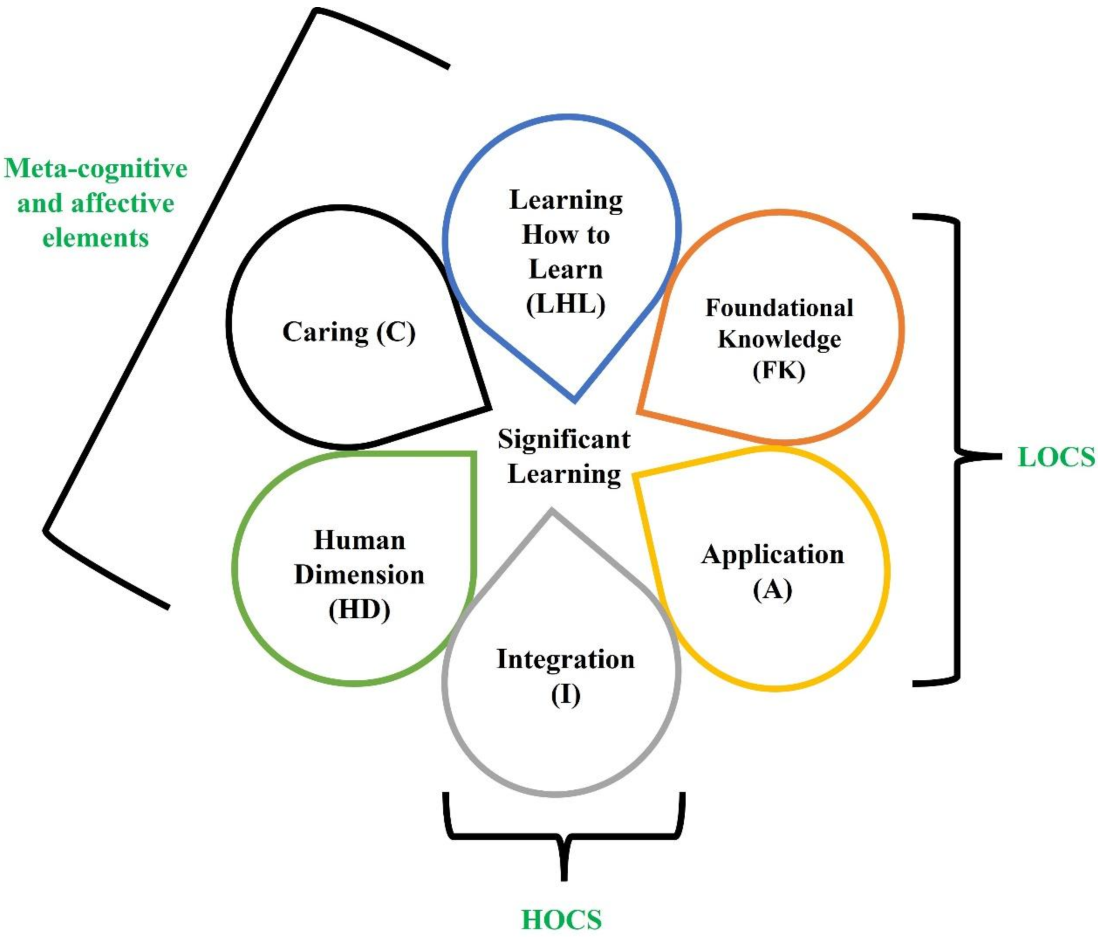


Figure 1-3 Six levels of Fink's taxonomy which are relational, interactive, and synergistic as compared to hierarchical in Bloom's taxonomy *(Fink, 2013)*.

The remaining three domains of Fink's taxonomy of significant learning (i.e., HD, C, and LHL) deal with meta-cognitive and affective skills required for the 21st-century job market. It includes building self-dependent life-long learning, leadership and interpersonal skills, ethics, communication skills, character, tolerance, and the ability to adapt to change, which also aligns with the principles and goals of the National Education Policy-2020 (NEP-2020 MHRD) (Mhavan et al., 2022).

The achievement of these six types of learning through the ICD process assists students by allowing them to progress from essential knowledge acquisition to more meaningful learning. Teachers who commit to adopting the ICD model can create a collection of learning activities that accomplish two goals: knowledge building and learning that adds value to students' lives. According to Fink, good teachers must be skilled in two critical areas of instruction: course design and student engagement (Fink, 2013; Krueger et al., 2011; Purcell, 2020). Competent course design is the most usually absent of these two factors. Some authors in bioinformatics attribute teaching shortcomings to the fact that many teachers lack professional teaching training (Kovarik et al., 2013). However, rather than professional training, their competence as teachers is built on lessons learned via hands-on teaching experience. Teachers must consider Integrated Course Design as a pedagogy (Educational) tool for the understanding of their discipline (Bioinformatics), as well as their use of hands-on practical sessions when considering meaningful learning (Figure 1-1).

This study aimed to see if applying and adapting Fink's ICD and Significant Learning Taxonomy (ICD/SL) enhanced students' class participation and academic performance in the undergraduate course ‘Introduction to Bioinformatics’. This was accomplished by comparing the outcomes of two treatment groups, 2020-21 and 2021-22, with a single control group, 2019-20, which did not employ ICD/SL.

1.2 Assessment methods for Integrated Course Design (ICD)

In formal education setup, teachers have been assessing and evaluating students. Still, recently educators have been figuring out how to include assessment activities as a part of the actual learning process (Fink, 2013). According to Grant Wiggins, "educative assessment" describes how the evaluation process educates students to improve what they can already perform Take-home assignments and worksheets are one of the ways of assessing the students for achieving significant learning goals or objectives of the course. To ensure that assessment activity is truly helping students to understand, take-home assignments and worksheets provide students the freedom to create and take responsibility for their work. To accomplish learning goals in biology-based courses, a student must be able to organize, apply and demonstrate their knowledge and understanding.

Take-home exercises or tasks that students are given by their teachers are one of the popular assessment methodologies to accomplish outside-of-class learning activities. Take-home assignments could include completing a certain amount or amount of reading, writing, or coding, solving questions, building a team project, solving short application-based problems, or practicing other abilities. It is generally considered a continuation or expansion of what students have learned in the tutorial class. Using take-home assignments, students' knowledge can be expanded, their skills will be improved, and they will be better prepared for future courses. Students' understanding will also be extended by being applied to new scenarios (Trenholm & Chinnappan, 2019). Worksheets are another powerful way of assessment that facilitates thinking ability, social interactions, and understanding of specific concepts among students. A typical worksheet cycle majorly involves six phases, namely: analysis, planning, designing, development, implementation, evaluation, and revision(Rahayu et al., 2018).

In addition to that there are numerous other assessment ways to improve student class participation, learning, performance, active participation, and skill development. These methods majorly incorporate active learning engagement strategies, thought-provoking questioning, and developing critical thinking skills using a range of learning resources, self-reflection activities, and feedback (Azer et al., 2013; El-Hashash, 2022). The online method of take-home quizzes in the form of multiple-choice questions is an efficient way of engaging biology students and helps both instructors and students in the long run (Culbert, 2020). Frequent conduction of interactive take-home activities motivates the students to participate in the class (Jones, 1984) (Jones, 1984). Studies have shown that students who regularly participate in weekly engaging activities show better performance, class participation, retrieval of knowledge, and immediate feedback on their performance which is one of the requirements of Fink's Integrated Course Design (ICD) educative assessment (Fink, 2013; Gholami & Moghaddam, 2013; Heise et al., 2020).

Worksheets and take-home assignments are tools that educators use to help students learn and practice new concepts and skills (Buijs & Admiraal, 2013; Choo et al., 2011; Trautwein et al., 2002). Worksheets are typically a set of questions or problems that students are expected to complete on their own in class. They are often used to reinforce material taught in class or to provide additional practice with a particular skill. Worksheets can be used to assess a variety of skills, including Knowledge, Comprehension, Application, and Analysis. Worksheets can be a useful assessment tool, but it is important to remember that they are only one way to assess student learning and understanding.

On the other hand, Take-home assignments are assignments that students are given to complete outside of class, usually as homework (Bengtsson, 2019; Fernández-Alonso et al., 2017; Greenwald & Holdener, 2019). These assignments can be like worksheets in that they may include questions or problems for students to solve, but they may also have other tasks, such as reading assignments, research projects, or writing assignments. Take-home assignments are often used to encourage students to apply the material they have learned in class to real-world situations or to provide opportunities for deeper learning and critical thinking (Gregory & Morón-García, 2009; Latif & Miles, 2020). Both worksheets and take-home assignments can be useful tools for helping students learn and practice new concepts, but educators need to use them effectively and in moderation. It is also important for students to have adequate time and resources to complete the assignments and to seek help if they need it (Joyce et al., 2018; Olufemi, 2014; Trenholm & Chinnappan, 2019). Take-home assignments, also known as homework assignments or project assignments, are a common tool used by employers and educators to assess the skills and abilities of job candidates or students. These assignments are typically given to candidates or students to complete in their own time, outside of a traditional classroom or workplace setting. Additionally, take-home assignments can provide a more comprehensive view of a candidate's or student's abilities, as they typically involve more complex tasks and require a greater level of independence and self-direction (Azer et al., 2013; Culbert, 2020; El-Hashash, 2022). There are also potential drawbacks to using take-home assignments as an assessment tool. One concern is that some candidates or students may have access to more resources or support than others, which could give them an unfair advantage.

Worksheets and take-home assignments are two main assessment methods utilized by instructors in undergraduate programs (Bailey et al., 2018; El Islami et al., 2019; Mahtani et al., 2020; Rahayu et al., 2018; Shorbagi & Ashok, 2016). Both take-home assignments and worksheets have costs associated with them, such as the time instructors spend creating and grading these assessment tools, as well as the time students spend doing take-home assignments or responding to worksheet questions, which could have been used to improve performance.

1.3 Team-Based Learning as an active learning strategy

The role of Biology education is to involve and engage students in understanding biological concepts and using different teaching and learning styles to make the learning more significant (K. L. Anderson, 2016). Lots of work has been done for the engagement of students, for example relating biology to everyday life, incorporating hands-on activities and multimedia or virtual reality, bridging the gap between technology and biology, and utilizing science games and biology-centered field trips to teach biology (Ajaja, 2013; Haspel et al., 2016; Wood & Tanner, 2012). On the other hand, significantly less or marginal work has been done on trying different learning and teaching styles such as fully structured Team-Based Learning (TBL), Problem Based Learning (PBL), Evidence-Based Learning, semi-structured Cooperative Learning, use of clickers, worksheets, and take-home assignments along with discussion, reflective writings, encouraging students to become a self-directed learner and use of peer-teaching method to develop a caring aspect for the subject. Various institutions have embraced pedagogical learning strategies that make use of a variety of teaching techniques to cut down on the number of lectures and encourage active learning.

Team-Based Learning (TBL) is one of the active learning flipped classroom style instructional models that enables students to receive pre-learning materials ahead of time, helps them to comprehend foundational knowledge, and strengthen team-based conversation in class (Bass et al., 2018; Fink, 2013). In this, the pre-assessment serves as the basis for in-class discussion, and class time is devoted to solving application-based case studies, followed by discussions that will support exercises in applied knowledge and deeper learning (Gálvez-Peralta et al., 2018; Krase et al., 2018). The emphasis on student-driven learning and student-centered instruction is strongly emphasized in collaborative learning in the classroom, which fosters team-based discussion and problem-solving (Goolsarran et al., 2018; R. E. Levine et al., 2020; Park et al., 2019).

The peer-to-peer interactions and team-based learning environments enable students to actively participate so that they can learn from one another (Al-Neklawy & Ismail, 2022). During these interactive classroom activities having an educational goal, the function of the instructor is altered from content provider to facilitator and guide. In more and more health professional schools, team-based learning (TBL) is being used as a teaching strategy (DeMasi et al., 2019; James et al., 2019; Keating et al., 2019).

As students participate in active learning and hone their communication abilities, this pedagogical paradigm supports the development of critical thinking and problem-solving skills (Burgess et al., 2018; Chen et al., 2018). Self-preparation, an in-class readiness assurance test (RAT), and application-focused exercises make up the three steps of team-based learning. The educational style places a strong focus on students taking responsibility for their own learning by encouraging them to read the assigned readings in advance in order to engage in team projects and class discussions. A team-based small group approach has been demonstrated to aid students with poor academic performance, and studies have indicated that TBL can lead to better student learning and performance compared to using the standard teaching methods alone (Silva et al., 2022; Volerman & Poeppelman, 2019).

1.4 Questionnaire formation and sentimental analysis of feedback

A student feedback questionnaire is a tool used by educators to gather feedback from students about their learning experiences. It can be used to gather information about a variety of topics, such as the effectiveness of teaching methods, the clarity of course materials, and the overall satisfaction of students with the course (Bijlsma et al., 2022; Kember et al., 2002; Richardson, 2005). A student feedback questionnaire majorly involves questions related to their satisfaction with the quality of the course, the effectiveness of teaching methods, clarity and understandability of course material, clarity in communication about course objectives or goals, relevance, and usefulness of assessments or assignments, rating of instructor and any future improvements in the course (Gormally et al., 2014; Grebennikov & Shah, 2013; Yasmin et al., 2021). Student feedback questionnaires can be administered in a variety of ways, including online surveys, paper surveys, or focus group discussions and it is important to ensure that the questionnaire is designed in a way that is easy for students to understand and complete, and to provides an adequate amount of time for students to respond (Hujala et al., 2020; Irons & Elkington, 2021; Steyn et al., 2019). There is a need to develop a student feedback questionnaire as it will be helpful in gathering information about the effectiveness of the course, able to locate strengths and weaknesses of the course, able to identify ways to improve student engagement and satisfaction, and able to foster a culture of continuous improvement and life-long learning (Bassi, 2019; Cavalcanti et al., 2020; Fink, 2013; Van Doren et al., 2021).

In the era of social networks and technological developments of major companies such as Alphabet, Apple, Meta, Twitter, etc., lots of online applications have come in the past twenty years in different aspects of life, whether it is communication, health, transport, banking, shopping, entertainment, education, etc. So that these platforms can be improved, provide better services, and demonstrate their value or justify their creation, it is crucial to analyse the choices and sentiments of the end users. Students can also be considered end-users in educational setups, where their views or feedback play a vital role in improving courses and designing teaching and learning activities (Fink, 2013; Flodén, 2017; Kanwar & Sanjeeva, 2022; Razinkina et al., 2018).

Also, according to L. Dee Fink, if students are involved in the learning process, then there is a high degree of mental energy associated with it, and the entire process has crucial outcomes or results in the form of a powerful learning experience (Fink, 2013). We can use sentiment analysis (one of the hottest topics and research domains in machine learning and Natural Language Processing) to analyze students' affective or emotional domain by analyzing their feedback in the teaching-learning environment (Cobos et al., 2019; Dolianiti et al., 2019; Kastrati et al., 2021; Okoye et al., 2020; Usart et al., 2023). Sentiment analysis is the most frequently employed technique to analyze subjective feedback in various disciplines, especially student feedback in education (Cabada et al., 2018; Mite-Baidal et al., 2018; Oramas Bustillos et al., 2019). It involves understanding the meaning, tone, content, and intent of students' feedback by analyzing and categorizing students' opinions into positive, negative, and neutral classes.

Feedback data is viewed as a resource that contains important evaluative language, including subject or teaching evaluations, course ratings, and a variety of course and teaching-learning-related ideas. As a result, several research projects based on sentimental analysis tried to make the most of the vast online library of human knowledge (Chakraborty et al., 2020; Mukhopadhyay & Samanta, 2023; Sarkar, 2019).

The significant amount of data of students can be obtained from web forums like Google forms, Learning Management Systems like Moodle, and social networks (Facebook, Twitter, etc.), it has proven to be crucial. Detailed student opinions or feedback are generally subjective and typically unexplored by the institutions or instructors due to the vast amount or less time availability or lots of manual interventions required in evaluation. To extract this considerable number of subjective opinions, new mechanisms of machine techniques can be employed to extract feelings that are embedded inside the subjective feedback of the students. For instance, in various activities, from liking a subject or a way of teaching to problems faced in a specific topic, many institutions or instructors need to look for the opinions of other students before deciding to design or implement a new pedagogical practice.

There are several reasons why sentiment analysis might be used on student feedback. Some of the main reasons include- identifying trends, understanding student needs, informing decision-making, to measure the impact of changes. As described, sentiment analysis includes categorizing a text into several emotions, such as happy or sad, or neutral. Determining the underlying tone, feeling, or sentiment of a document is the goal of sentiment analysis. There are various methods for sentiment classification, out of which lexicon-based and corpus-based methods are commonly used in machine-learning techniques. In a machine-learning approach, a text is typically treated as a set of words, keeping in mind various characteristics for text-preprocessing and tokenization using popular python libraries NLTK or Scikit Learn (Bengfort et al., 2018; Kedia & Rasu, 2020; Richert et al., 2013; Srinivasa-Desikan, 2018). Hence, sentimental analysis is of high relevance and interest in NLP as it gives fast results with minor human intervention.

The raw or unprocessed student subjective feedback datasets involved in sentiment analysis are quite a vital problem in the educational domain. Sentiment analysis can be employed in end-class or end-semester subjective feedback, online reflective writings or articles, personal comments or discussions on a precise subject, and peer feedback in active learning strategies like Team-Based Learning (TBL), Problem-Based Learning (PBL). Online Google forums, communities, and social networks are potential sources for the unprocessed subjective data because most students express their opinions, comments, or discussions on precise subjects. These unprocessed or raw data can be used as a potential starting point for sentimental analysis as it involves a corpus amount of emotional information that can be categorized as positive, negative, and neutral sentiments with quantitative polarities, as shown in Figure 1-4.

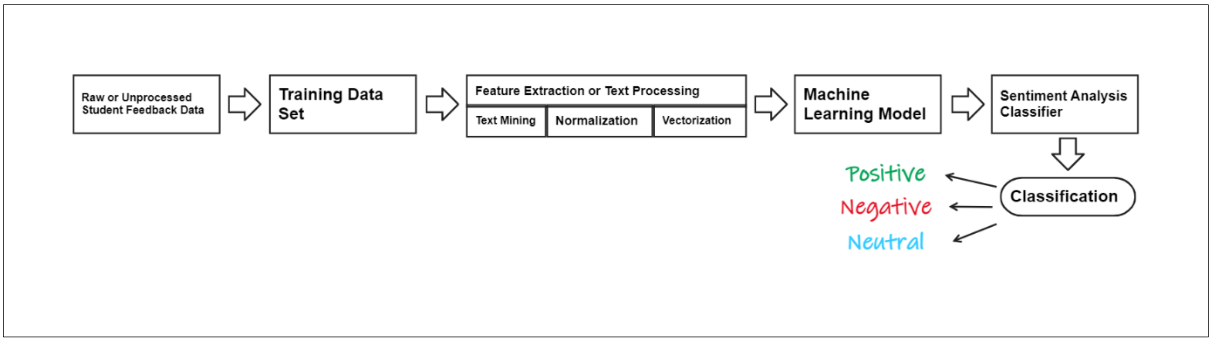


Figure 1-4 Sentiment analysis process using machine learning

In the content of student feedback, sentiment analysis can clarify how students feel about a particular course, instructor, or educational experience. This can be valuable information for educators, as it can help them to identify areas of strength and weakness in their teaching and make improvements based on the feedback they receive. The work of sentiment analysis is challenging since it necessitates unique semantic considerations in addition to syntactic ones.

Evaluating sentiments based on educational resources is an intuitive and natural approach to the challenge of sentiment analysis. The unsupervised creation of linguistic lexicons or manually extracted language rules is at the core of these strategies. The subjective terms and their polarity would be listed in a lexicon (or dictionary). The computer then bases its assessment of subjectivity on the lexicon. Many people tried to create sentiment lexicons that would aid in sentiment analysis. These methods include creating a vocabulary of positive and negative adjectives using a log-linear regression model or a computation of the distance between certain words and a predetermined set of anchor words to predict the polarity of those words (Hatzivassiloglou & McKeown, 1997; Turney, 2002; Wankhade et al., 2022).

Our present study is focused on the development of a student feedback questionnaire that involves a Likert scale or closed questions, questions about the course content, instructor, and their rapport along with the overall course experience of students followed by open-ended questions for an undergraduate third-year course in Introduction to Bioinformatics to determine the polarity of feelings of subjective feedback. The study also focused on the development of a web-based sentiment analysis tool using various open python-based libraries which we named “Pratikriya” to classify the sentiments expressed by students in their respective subjective feedback data.

1.5 Preliminary Work : Personal Rapport fosters better learning – Proof of principle of the Human Dimension of Fink's taxonomy

Rapport is the most commonly used term that denotes positive thoughts and feelings of the closeness of faculty with his/her students, which leads to favourable teaching-learning experiences. The "Human Dimension" of Fink's Taxonomy of Significant Learning places emphasis on student-teacher rapport as well as peer interactions. The "Caring" dimension focusses on how to make the student care for the content that one has to learn. Interventions were made to implement these dimensions in selected groups of a large multidisciplinary student population enrolled in the freshman biology course *BIO F111 General Biology* offered at BITS Pilani to see how it affects learning and performance of this group versus those in which such interventions were not made. The frequency of this class was once a week.

Personal rapport was increased in a structured manner in one tutorial section in 2013-14 and 2014-15 (henceforth referred to as the experimental section) of *BIO F111 General Biology*.

The performance of this experimental section in terms of the Mean Grade Point Value (MGPV) was compared with that of the other sections of the course offered for two consecutive years, viz., 2013-14 and 2014-15. As a control, we compared the MGPV of the tutorial section taken by the same instructor during 2012-13, the MGPV is only 5.63% higher than the average MGPV of the course, in contrast with experimental which was found to be 10.8% higher in 2013-14 and 11.1% higher in 2014-15.

There was a continuous increase in Cohen D's value in consecutive years, i.e., 1.21 in 2012-13, 1.38 in 2013-14, and 1.42 in 2014-15 which shows a significant difference between the experimental section and other sections, as according to Cohen D's Test the average result lying in the considerable difference region (that is, greater than 0.8). The comparative analysis of the Z score of 2014-15 shows that this value lies 2.68 standard deviations above the mean and can, therefore, conceived of as a rather exceptional value. This indicates that if the student joins the experimental section under study, then it is an attractive option for them to learn better and score well. Students of these tutorial sections were also asked to rate the reasons for why their performance was possibly higher. Students rated personal rapport as a strong determinant for enhanced learning, performance, and motivation for studying.

These results, taken together, make a strong case for the systematic implementation of Integrated Course Design, encompassing all the six elements of Fink's Taxonomy of Significant Learning.

1.6 Scope and Need of Integrated Course Design (ICD)

Integrated course design has a wide scope in biology education, offering several benefits for both educators and students. As it has potential to enable an interdisciplinary approach, that can allow students to explore the connections between biology and other disciplines like chemistry, physics, and environmental science. This approach fosters a holistic understanding of biology and promotes the integration of knowledge domains. Also, ICD enhances contextual relevance by incorporating real-world applications into biology courses. Case studies, fieldwork, and laboratory experiments provide students with opportunities to understand how biological concepts are relevant to everyday life and address societal challenges. ICD also facilitates systems thinking in biology education. Biology is a complex field with intricate interactions within living organisms and their environments. By exploring the interdependencies and relationships between various biological processes and entities, students develop a deeper understanding of biology as a whole. Integrated course design addresses the limitations of traditional biology education by moving away from rote memorization and prioritizing critical thinking and concept application. This approach encourages active student engagement, fosters deep learning, and cultivates a profound understanding of biology. Additionally, integrated course design promotes the development of transferable skills such as critical thinking, problem-solving, communication, and collaboration, which are crucial for academic and professional success. Moreover, this approach aligns with the objectives of the National Education Policy 2020, emphasizing multidisciplinary and holistic education. By incorporating interdisciplinary perspectives, integrating knowledge domains, and nurturing holistic development, integrated course design effectively meets the policy's requirements.

Fink's Taxonomy of Significant Learning offers a valuable framework for implementing integrated course design in biology education. It consists of six categories of learning outcomes: foundational knowledge, application and integration, human dimension, caring, and learning how to learn.Foundational knowledge focuses on essential biological principles as the basis for higher-order thinking and concept application. Application and integration involve applying biological concepts to real-world scenarios and integrating knowledge from different disciplines. The human dimension incorporates ethical considerations, social implications, and the impact of biology on human health and society to enhance students' understanding of the broader context. Caring fosters an emotional connection, empathy towards living organisms, and a sense of responsibility for environmental sustainability. Lastly, integrated course design encourages self-directed learning through student engagement, self-reflection, and metacognitive skills. Students are encouraged to explore their interests, take ownership of their learning, and develop lifelong learning strategies.

1.7 Organization of the Thesis

The structure of this thesis follows a systematic organization into five distinct sections. The introductory section serves as the gateway to the research, providing an overview of the study's objectives and significance. Following this, the review of literature delves into existing scholarly works relevant to the topic, offering insights and context to the study's framework.

The subsequent section, material, and methods, outlines the methodologies employed in data collection and analysis, ensuring transparency and reproducibility. The fourth segment, results, and discussion, presents the findings of the research and engages in critical analysis, interpretation, and contextualization of the results within the existing body of knowledge. Lastly, the conclusion and future scope of work section summarizes key findings, discusses implications, and outlines potential avenues for future research, thus concluding the thesis with a forward-looking perspective.

2 Review of Literature

2.1 Introduction and Background to Educational Research and Pedagogy

Pedagogy is the study of teaching and learning. It encompasses a wide range of approaches (i.e., Inquiry-based learning, collaborative learning, flipped classrooms, project-based learning, gamification), theories (i.e., constructivism, cognitive load theory, self-determination theory, and growth mindset), and methods (i.e., lectures, discussions, demonstrations, group work, and problem-based learning) used to facilitate learning. Educational research is studying and investigating educational phenomena to understand and improve teaching and learning processes.

There is always a need for the upgradation of pedagogy from time to time. In the current information era, students have more access to knowledge via the Internet. There is a need for new pedagogical interventions that can motivate students to achieve the learning outcome of the course, but at the same time, provide a high-quality learning experience, and make them lifelong learners.

In educational research, much effort has been made to explore individual differences in learning. Grasha and Riechmann have described six learning styles that are organized into three bipolar dimensions: dependent vs. independent, competitive vs. collaborative, and avoidant vs. participant (Riechmann & Grasha, 1974). Kolb has proposed four learning styles that can be identified as diverging, assimilating, converging, and accommodating. Myers Briggs Type Indicator (MBTI) represents a personality inventory that involves extraversion, introversion, judging, perceiving, sensing & intuition, and Thinking & Feeling (Cassidy *, 2004). Li-fang Zhang has demonstrated that intellectual styles can be modified through socialization and purposeful training based on her critical analyses on the relevant research over the past seven decades (L. Zhang & Sternberg, 2005). Curry proposed a three-layer "onion" model on learning diversity. The outermost layer of the "onion" concerns individuals' instructional preferences, such as "learning skills" or "learning strategies." The innermost layer of the "onion" affects learners' cognitive personality, and the segment between these two is information processing (Curry, 1983). Bloom and his colleagues identified three domains of learning: cognitive, affective, and psychomotor. There has been an updated version of Bloom's taxonomy in the cognitive domain, where the two highest levels were reversed (L. W. Anderson & Krathwohl, 2001). John Biggs and his colleagues found that student intention in learning ranged from getting a degree to looking for deep understanding (J. Biggs, 1979; J. Biggs et al., 2001; J. B. Biggs & Tang, 2011). Deep learning approaches can lead to high-quality learning but not higher scores unless the question is related to higher quality learning (Trigwell & Prosser, 2004). There are three points of the teaching process, namely presage, process, and product, that influence student's learning. John Biggs has proposed a 3P learning model, which describes three-time aspects of teaching and learning, the related factors, and their relationships with each other, where 3 Ps refers to presage, process, and product, respectively (J. Biggs, 1979). Trigwell and Prosser modified the 3-P model and added a new component of students' perceptions of the learning context, indicating the vital effect of student perceptions on their learning (Trigwell & Prosser, 2004). Pascarella also proposed a model that looks at the factors that have an impact on student learning outcomes and cognitive development (Pascarella, 1985). Chickering and Gamson gave seven principles of effective teaching that concentrate on what a teacher can do for the process (Chickering & Gamson, 1989).

In the 21st century, various gaps like personalized learning, assessment, digital literacy, social-emotional and interdisciplinary learning can be visualized in the current pedagogy. Also, there is less satisfaction among the students with the existing way of teaching and learning (Appleton-Knapp & Krentler, 2006; De La Fuente et al., 2020; Douglas et al., 2015; Faize & Nawaz, 2020; Martínez-Caro & Campuzano-Bolarín, 2011). There are multiple reasons behind this lack\lag which involve- weak student-instructor bond or rapport, less emphasis on life-long learning while more focus on factual knowledge and cramming or rote memorization, instructors are themselves not interested in teaching but more focused on their research, and less interested students due to the monotonous way of education as it does not cover the topic in sufficient depth that may not develop spark among students to learn more.

Also, it has been seen that there are specific challenges that an instructor face in his/her class that involves- absenteeism of students, fear/phobia of the subject, lack of prior knowledge among the students, the varied background of students, poor retention of learning among students, students not able to see the value of the course and unable to find connection with other subjects and also students do not complete their assignments on time.

At an educational and organizational level, there are significant challenges, such as students being only grade-centric, they lack motivation for additional learning and self-directed learning, having difficulty seeing the value of what they are learning, and lastly, still, not least poor or low retention rate of learning, i.e., about 10-15 % after the course is over.

2.2 National Education Policy 2020 (NEP-2020)

The National Education Policy 2020 (NEP 2020) is a comprehensive policy document that outlines the vision, goals, and strategies for the development of the education sector in India. It replaces the National Policy on Education (NPE) 1986 and has been developed after extensive consultation with various stakeholders, including educators, policymakers, and the public. The main goals of the NEP 2020 are to: Provide inclusive and equitable access to quality education for all students, regardless of their socio-economic background or location. Promote multilingualism and a strong foundation in the arts, humanities, and sciences. Develop critical thinking, creativity, and problem-solving skills among students. Foster a culture of research and innovation and strengthen the linkages between academia and industry. Enhance the quality and relevance of teacher education and improve the status and working conditions of teachers. Promote flexible and holistic learning opportunities, including vocational education and skill development, and create pathways for students to pursue higher education and employment. Strengthen the governance and financing of the education sector and ensure accountability and transparency at all levels. Overall, the NEP 2020 aims to transform the education system in India and create a dynamic, learner-centric, and globally competitive system that prepares students for the 21st century.

According to National Education Policy (NEP) 2020, pedagogy must evolve to make education more experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centered, discussion-based, flexible, and, enjoyable so that students will be able to develop their critical thing and problem-solving skills. The goal of education must be to build character and enable learners to be ethical, rational, compassionate, and caring while at the same time preparing them for gainful, fulfilling employment. NEP-2020 has a significant emphasis on the development of the creative potential of each learner. It also proposes a revision and revamping of different aspects of the education structure (that also include regulation and governance) to create a new system that completely aligns with the 21st century's aspirational goals of education, including Sustainable Development Goal 4 (SDG4) while building upon India's traditions and value systems. Sustainable Development Goal 4 (SDG4) of 2030 seeks to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.”

The basic principle of NEP-2020 is that the goal of education is not only to develop cognitive capabilities (i.e., both “lower-order” foundational capacities like literacy and numeracy and “higher-order” mental capacities like critical thinking and problem-solving) but also meta-cognitive abilities like social, ethical, and emotional capacities and dispositions (NEP-2020 MHRD) (Mhavan et al., 2022)

After the emergence of epidemics and pandemics of Covid-19, there is a need for collaborative and multidisciplinary learning in the quickly changing employment landscape and global ecosystem where it is critical for the students to not only learn but, more importantly, learn how to learn. So, there is a need for transformation from a traditional content-centered approach to a more learning-centered process.

2.3 Need for transformation

The traditional approach to education has often been focused on delivering content to students, with the assumption that students will learn and retain that content through rote memorization and repetition. This approach can be effective for some students, but it does not always consider the different learning styles and needs of all students. A learning-centered approach, on the other hand, focuses on the needs of the individual learner and seeks to engage students in actively constructing their own knowledge and understanding (Evertson, 2006; Masouleh & Jooneghani, 2012; Singhal, 2017; Smart et al., 2012). There are several reasons why a shift from a traditional, content-centered approach to a more learning-centered approach may be beneficial in education. First, a learning-centered approach can be more effective for promoting long-term retention and understanding of the material. When students are actively engaged in the learning process and can make connections between new information and their prior knowledge, they are more likely to retain that information over time. Second, a learning-centered approach can be more inclusive and equitable, as it considers the diverse learning styles and needs of all students. By providing a range of resources and activities that allow students to learn in ways that are meaningful and relevant to them, educators can better support the learning and success of all students. Finally, a learning-centered approach can better prepare students for the real world, where they will be expected to be lifelong learners who are able to adapt and learn new things throughout their careers. By helping students develop the skills and habits of mind necessary for independent learning, educators can better equip them to succeed in the modern world.

Fink's Integrated Course Design using Taxonomy of Significant Learning, popularly known as ICD\SL, is focused on such transformation, where the goal is to go beyond rote memorization from a content-centric approach toward a more learning-centered paradigm where students will be able to develop Four essential C's, namely Critical thinking, Communication, Collaboration, and Creativity which also aligns with both 21st-century requirements and NEP-2020 (Fink, 2013; Mhavan et al., 2022) (NEP-2020 MHRD) (Figure 2-1). As 21st century is also known as the information or knowledge era as compared to the traditional approach of the industrial age, where the primary focus was on acquiring knowledge which only resulted in remembering and understanding the facts that often led to rote memorization.

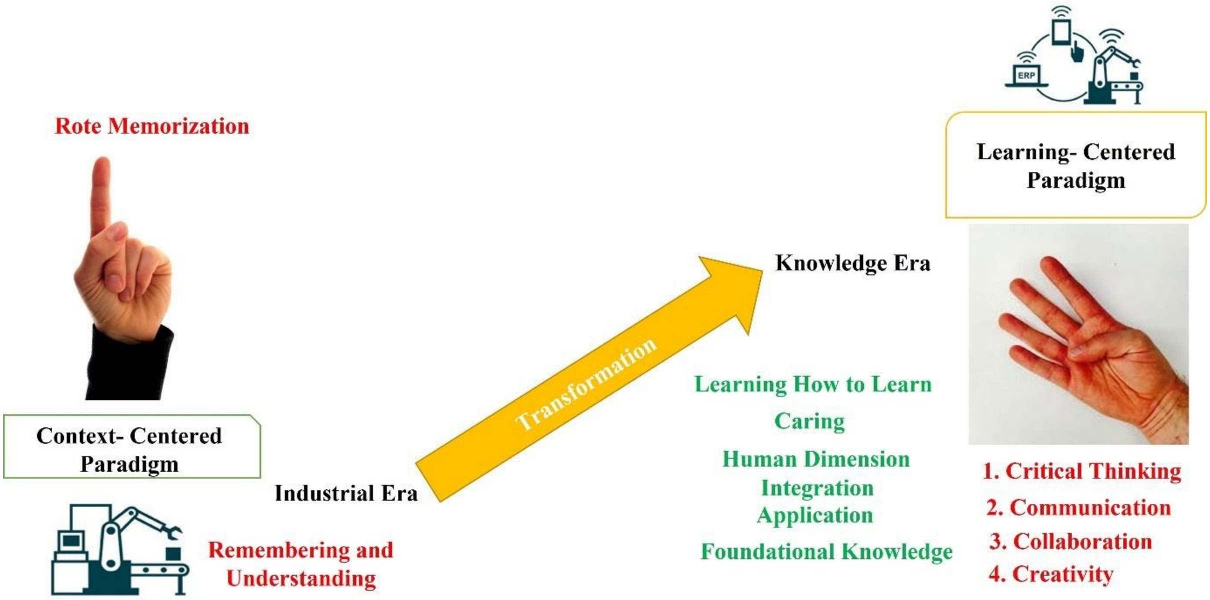


Figure 2-1 The need for a paradigm shift from a traditional content-centered to a more learning-centered approach

2.4 Key Findings from Biology Education Research (BER)

The discipline-based approach to design biology education is a method of teaching biology that is focused on the core concepts and principles of the discipline, rather than just presenting facts and information. This approach emphasizes the use of critical thinking and problem-solving skills to understand and apply biological concepts, and it often involves hands-on activities and real-world applications to make the material more engaging and relevant to students. In this approach, students are encouraged to think like scientists and to develop a deep understanding of the underlying principles of biology. This includes learning about the history of the field, the scientific method, and how to design and conduct experiments to test hypotheses. It also involves learning about key biological concepts such as evolution, genetics, and cellular biology, and how these concepts apply to various areas of biology, such as ecology, physiology, and behavior. Overall, the discipline-based approach to design biology education seeks to provide students with a well-rounded understanding of the discipline and to prepare them for further study or careers in biology or related fields.

It has been observed that student-centered instructional strategies that can positively influence students' learning, achievement, and knowledge retention, as compared with traditional instructional methods (Granitz et al., 2009). It includes asking questions during lecture and having students work in groups to solve problems, make predictions, and explain their thinking to one another. BER (Biology Education Research) has focused on identifying students' conceptual understandings, developing concept inventories that measure students' knowledge of a given concept, and studying the effectiveness of different types of instructional approaches that promote greater student engagement (Wilson & Ryan, 2013). Though Biology Education Research (BER) is making contributions to the understanding of how students learn and gain expertise in biology and more recently than similar efforts in physics, chemistry, or engineering education research (Dolan, 2017). BER includes longitudinal studies, studies that examine similarities and differences among different student groups, research related to the affective domain and the transfer of learning, and the development of assessments to measure student learning. It provides in-depth disciplinary knowledge to questions of teaching and learning in a discipline. BER faces a challenge to identify instructional approaches that can help to overcome the math phobia of many biology students and introduce more quantitative skills into the introductory curriculum, as computational biology and other mathematical methods become more central to the field of biology. In addition to this, biologists have long been concerned about the quality of undergraduate biology education in which broad questions about science learning, such as whether collaborative or individual learning was more effective or how to balance the value of conceptualization over rote memorization (Schinske et al., 2017). To overcome the above challenges, Biology faculty members, and biology education researchers use specific instructional strategies such as bridging analogies, active learning, classroom-based assessments and focused surveys through quantitative and qualitative methods. Biology Education Research is a subfield of discipline-based education research (DBER) that has begun to study increasingly sophisticated questions about teaching and learning. DBER has in-depth disciplinary knowledge of what constitutes expertise and expert-like understanding in a discipline. This knowledge has the potential to guide research focused on the essential concepts in the subject. It offers a framework for interpreting the findings of students' learning and understanding in the discipline of Biology (Figure 2-2). DBER investigates teaching and learning in a given discipline; it is informed by and complementary to extensive research on human learning and cognition (Schinske et al., 2017). There are several challenges that undergraduate students face in learning science and engineering. Indeed, these challenges can pose serious barriers to learning and acquiring expertise in a discipline, and they have significant implications for instruction, especially if instructors are not aware of them. Another challenge is with respect to accurate conceptual understanding, i.e., students have false ideas and beliefs about concepts fundamental to the discipline (Koba & Tweed, 2009). Students' incorrect knowledge poses a challenge to learning, because it comes in many forms, ranging from a single idea to a flawed mental model based on erroneous understandings of several interrelated concepts. Developing expertise in a discipline includes becoming familiar with representations unique to that discipline, such as evolutionary trees in biology, depictions of molecular structures in chemistry, and topographic maps in the geosciences (Singer et al., 2013). Specific instructional strategies can improve students' learning and understanding. For example, the use of "bridging analogies" can help students bring incorrect beliefs more in line with accepted scientific explanations (D. E. Brown & Clement, 1989). Bridging analogies, instructors provide a series of links between a student's correct understanding and the situation about which he or she harbours an erroneous perception. Also, interactive lecture demonstrations—in which students predict the result of an event, discuss their predictions with their peers, watch the presentation, and compare their predictions with the actual result (Sokoloff & Thornton, 1997).

Biology Education Research (BER) is a field of research that focuses on the study of how people learn biology and the effectiveness of different approaches to teaching biology. It encompasses a wide range of topics, including the use of technology in biology education, the role of inquiry-based learning, and the development of assessment tools for biology.

Researchers in this field may also study the impact of social and cultural factors on biology learning and the effectiveness of various instructional strategies and interventions. BER research often involves collecting data from biology classrooms and studying the factors that influence student learning, such as the use of different teaching methods or the impact of certain classroom environments. Researchers may also conduct studies to evaluate the effectiveness of different biology education materials and resources, such as textbooks or online learning platforms. The goal of BER is to improve the quality of biology education and to better understand how students learn and retain knowledge in this subject. This research can inform the development of new teaching strategies and materials and help educators to design effective and engaging biology lessons that meet the needs of diverse learners.

The generation of biology education research (BER), or BER 2.0, involves the selection and use of the right kind of tools to study physiological systems, to model ecological processes, and to analyze metabolic networks under teaching and learning (Dolan, 2015). Biology Education Research works differently from STEM education as it deals with overlapping domains of knowledge such as understanding of the self and responsible behavior, maintaining health and well-being, and environmental citizenship (Page & Reiss, 2010). Biology Education Research is a part of discipline-based education research (DBER) to study affective domain, differences among student groups, and assessments of student learning (Singer et al., 2013). BER has an enormous potential in identifying and nurturing the innovation for the benefit of student learning (Schinske et al., 2017). BER can actively enhance the interest of the student in learning Biology by developing positive feelings between an individual and a physical object, activity, or topic of focus (Rowland et al., 2019). Biology Education is an interactive way of teaching vital skills of Biology through a visual process (Subramaniam, 2014).

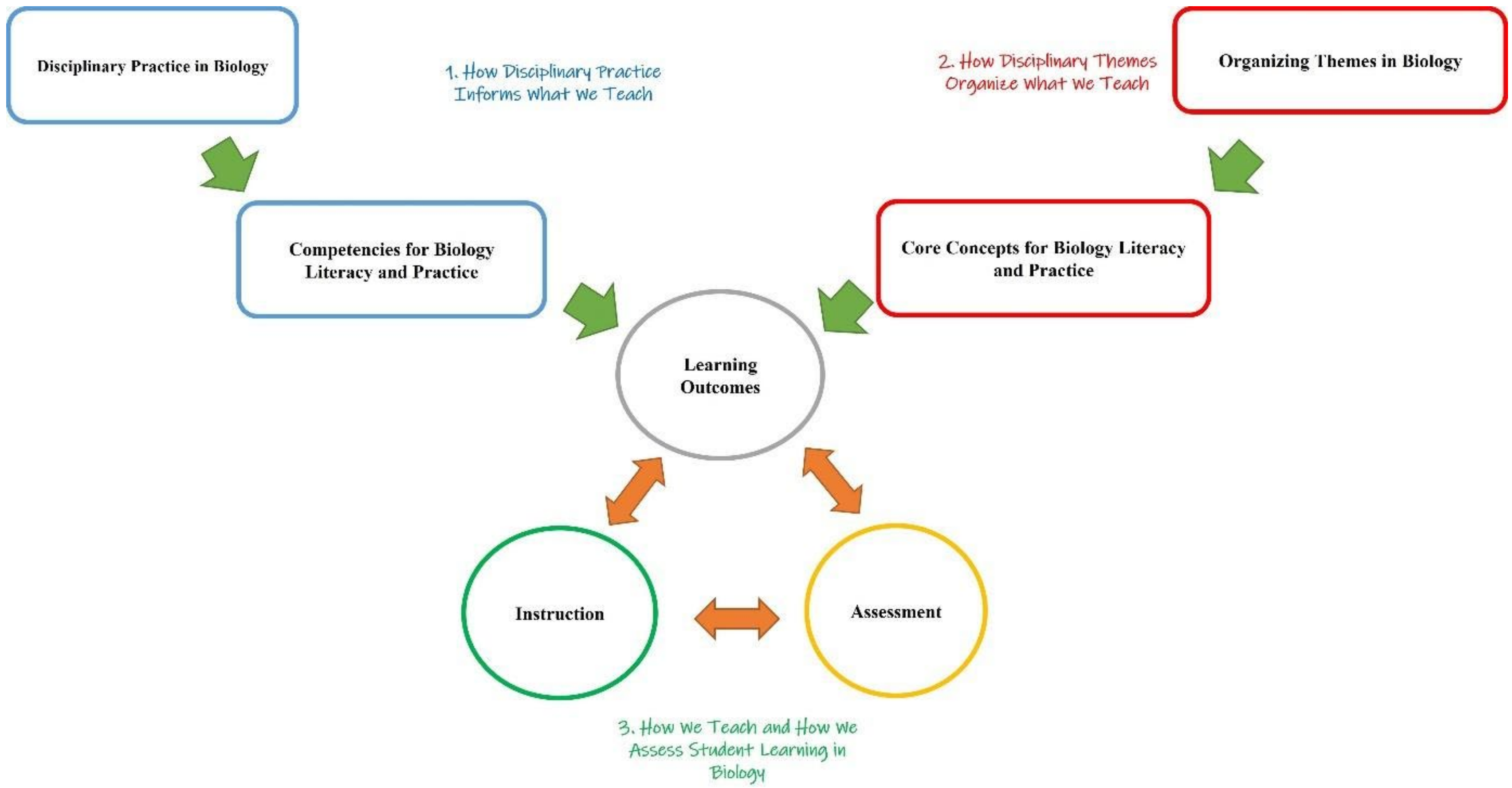


Figure 2-2 Discipline-based approach to designing Biology Curricula

2.5 Bloom's Taxonomy

Bloom and his colleagues identified three domains of learning: cognitive, affective, and psychomotor. The Psychomotor domain defines the learning that deals with physical movement, coordination, and the use of motor skills. According to one of the researchers in the field, Dave, there are five major categories in this domain. Imitation is the most basic level, which involves simply observing and copying the action of someone else. Manipulation is the second level, involving reproducing activity from instruction or memory. So it is a step forward from imitation. The third level is precision, referring to the ability to execute skill smoothly, accurately, and independently. The fourth level is articulation, which means being able to adapt or integrate expertise to satisfy a new context. It is a much-advanced level. The highest level is naturalization, referring to an instinctive mastery of activity and related skills at a strategic level (L. W. Anderson & Krathwohl, 2001; Burwash et al., 2016). The affective domain describes the emotional aspects of learning. It includes changes in interest, belief, attitude, value, and motivation. Researchers identified five major categories in this domain, which range from the simplest to the most complex.

The first category is receiving, which refers to the awareness of an attitude, behavior, or value and the willingness to hear or receiving information. The second category is responding. It goes beyond the willingness to receive information passively to active attention to stimuli, willingness to participate, or showing enjoyment. The third category is valuing, referring to the value a person attaches to a particular object, phenomenon, or behavior. It involves an acceptance of a value, preference for value, or a commitment to a particular stance or action. The fourth category is the organization. It involves conceptualizing different values, resolving the conflicts between them, and developing a personal value system. The fifth category is characterization or internalization. At this level, a student already has a consistent value system established. He or she behaves consistently as per the values he or she has internalized.

The cognitive domain is perhaps the domain where most of the work in curriculum development has been undertaken. It involves the recognition of knowledge and the development of intellectual abilities and skills. Under this domain, six levels were identified and ordered from the simplest to the most complex. Knowledge is the simplest level, which focuses on memorization, recognition, and recall of information. For example, define technical terms by giving their attributes and properties. Comprehension is the second level, which focuses on translation, understanding the meaning, and interpretation of information, e.g., explaining some concepts using one's own simpler words. Application is the third level, which focuses on using or implementing learned materials or concepts in a new context. For example, predict the effect of a change in a factor in a unique situation. The fourth level is analysis, which focuses on separating materials or concepts into parts and distinguishing between facts and inferences in order to find the underlying structure. For example, recognize the causal relationships, or identify the important and unimportant details in a historical account. The fifth level is synthesis, which focuses on combining diverse elements together to build a new structure or create something new. For example, formulate hypotheses based upon some analysis. The highest level is evaluation, which focuses on making judgments on the value of ideas or materials (O'Neill & Murphy, 2010). For example, critically review the major theories in a field. More recently, there has been an updated version of this taxonomy in the cognitive domain known as "Revised Bloom's Taxonomy", where the two highest levels synthesis and evaluation were reversed and replaced by evaluate and create (Figure 2-3) (L. W. Anderson & Krathwohl, 2001) .

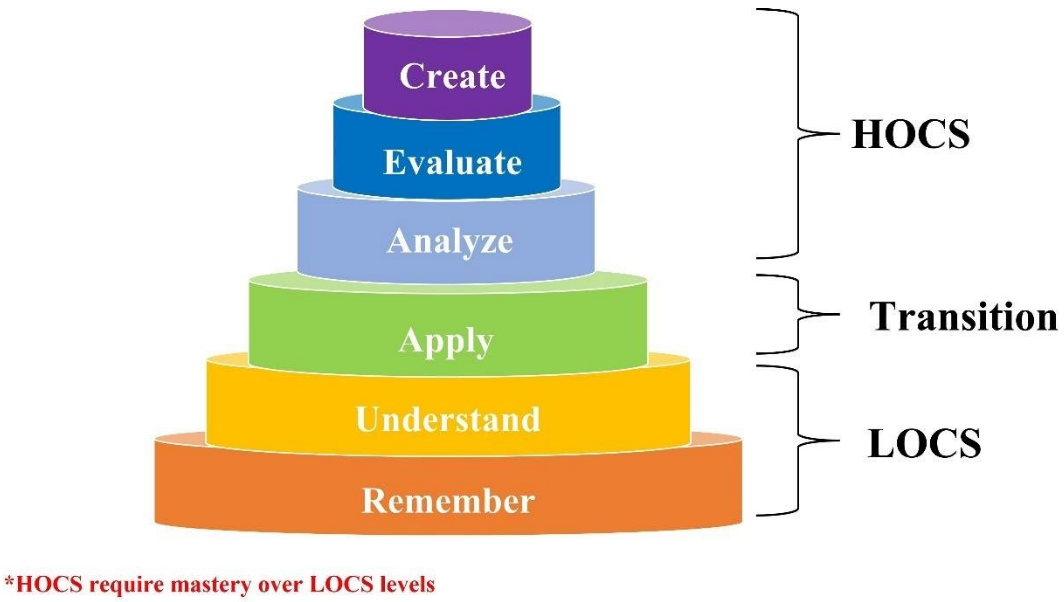


Figure 2-3 Levels of revised Bloom's Taxonomy- There are total six levels of Bloom's Taxonomy which can classify into two categories namely LOCS (Lower Order Cognitive Skills) and HOCS (Higher-Order Cognitive Skills) (adapted from (L. W. Anderson & Krathwohl, 2001 and Fink, 2013)

2.6 Fink's Taxonomy of Significant Learning as a foundation for Integrated Course Design (ICD/SL)

As mentioned earlier in section 1.1 the time may have arrived when we need a new and broader taxonomy of significant learning. Various situational factors influence the assessment procedure, e.g., the specific context of the situation, expectations of others, nature of the subject, and characteristics of the learner, and teacher. Taxonomy of significant learning is quite helpful in assessing the long-term and short-term learning goals of students in which short-term goals involve lower and higher-order cognitive skills. In contrast, long-term goals include lifelong self-directed learning, caring for the subject, and its influence on society and social interaction with teachers and fellow students. So, L. Dee Fink has attempted the task of creating a new taxonomy (Fink, 2013); in the process of constructing this taxonomy, there has to be some kind of change in the learner. No change, no learning (Uribe Cantalejo & Pardo, 2020). Significant learning requires that there be some kind of lasting change that is important in terms of the learner's Life.

As mentioned in section 1.1 Dr. Fink has created a taxonomy based on the six domains of significant learning (Figure 2-4). Foundational knowledge provides the basic understanding that is necessary for other kinds of learning. Application learning allows other kinds of learning to become useful. Integration is an act of making new connections and gives learners a new form of power, especially intellectual power. Integration is an act of making new connections and gives learners a new form of power, especially intellectual power. Human dimension informs students about the human significance of what they are learning. Caring refers to the student’s need to learn more about the subject and make it a part of their lives. Without caring for learning, nothing significant happens. Learning how to learn enables students to continue learning in the future and to do so with greater effectiveness.

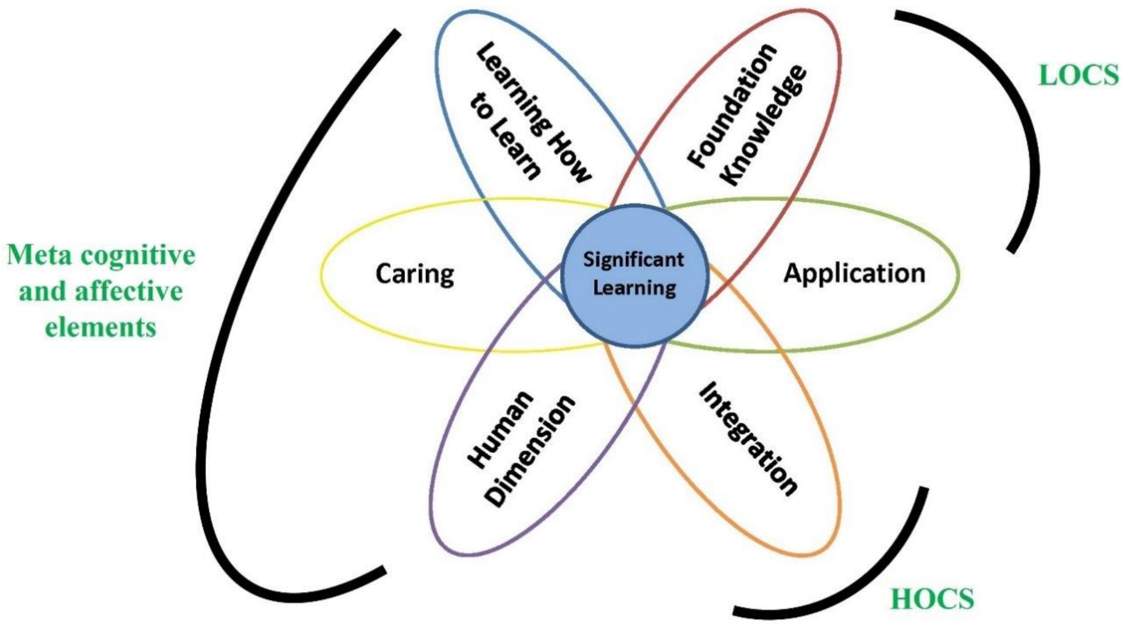


Figure 2-4 Taxonomy of Significant Learning- There are six different modules of Fink's Taxonomy of Significant Learning that are relational, interactive, and synergistic compared to those in Bloom's taxonomy (adapted from Fink, 2013).

An intervention of integrated Fink's taxonomy helped the students to integrate their learning and appreciate the value of their expertise in supporting those experiencing mental illness (Keating et al., 2019). Crawford has designed a learner centred course based upon Fink's Taxonomy for Significant Learning that shows gains in student knowledge, perceived skills, and confidence via formative and summative assessments of student-reported outcomes (Crawford, 2012). An evaluation of student performance based upon Fink's Model of Integrated Course Design (ICD) conducted by Uribe Cantalejo and Pardo in Basics of Dental Anatomy course showed better academic performance of the treatment groups as compared to control groups (Uribe Cantalejo & Pardo, 2020). The thematic analysis of Fink's Taxonomy of Significant Learning study on e-book chapter showed an increase in teamwork, more faculty guidance, and technical support. An emotional behavior study was conducted based on Fink's Taxonomy and showed an increase in the awareness and responsibility of students in the learning process (Cadorin et al., 2017). A study based on The Taxonomy of Significant Learning on medical education showed an assessment of critical thinking, reflection, empathy, and self-directed learning. The results showed these aspects were not assessed via Competency-

Based Medical Education (CBME) and competency-based assessment (CBA) approaches (Branzetti et al., 2019). A qualitative study addressing the importance of health promotion at the individual level conducted via the Taxonomy of Significant Learning showed interactive teaching and learning has also benefited the students as well as the children and families (Samawi et al., 2012).

The significant advantage of implementing ICD has been already mentioned in section 1.1.

The goal of redesigning the course using Integrated Course Design (ICD) using small group strategies has been mentioned in section 1.1 along with the Figures 1.1 and 1.2 respectively.

2.7 Active Learning

In the case of the significant teaching and learning module of Integrated Course Design (ICD), we can incorporate various active learning strategies like Problem-Based Learning (PBL), collaborative learning, and Team-Based Learning (TBL) to achieve our significant learning goals. Active learning plays a vital role in students learning as they learn more and retain their learning long-term compared to acquisition via passive manner (Bavishi et al., 2022; McCarthy & Anderson, 1999; Michel et al., 2009; Wolff et al., 2015). In other words, the primary goal of active learning is to involve the students in "doing things" and thinking about what they are doing. The "doing things" involves debates or intra-team discussions, simulation, hands-on experience, in-class activities, guided design, small group problem-solving activities, problem-centric case studies, etc. We can use individual or a combination of active learning strategies for achieving effective teaching and learning goals. For instance, we can use a problem-based collaborative learning strategy as an active learning method in which students learn and then work independently by gaining hands-on experience and then collaborate with their fellow groupmates to achieve the desired objective. This kind of activity covers three important aspects of active learning, namely- Information and ideas, experience, and reflective dialogue that are required for achieving significant learning (Figure 2-9).

Active learning is a teaching method that involves students in the learning process through activities and interactions with the material, rather than passively receiving information from a teacher or a textbook. In active learning, students are more actively engaged in their own learning and are given the opportunity to explore, discover, and apply new knowledge and skills. There are many different approaches to active learning, but some common examples include: Problem-based learning: This approach involves students in solving real-world problems or simulations that require them to apply their knowledge and skills. Inquiry-based learning: This approach encourages students to ask questions and explore topics of interest, with the teacher serving as a facilitator rather than a traditional lecturer. Collaborative or Team-Based Learning: This approach involves students working together in groups to solve problems or complete projects, which can help them learn from one another and develop teamwork skills. Experiential learning: This approach involves hands-on activities and real-life experiences that allow students to apply their knowledge and skills in a practical setting. Overall, active learning can be an effective way to engage students and promote deeper understanding of course material. It can also help students develop critical thinking skills, problem-solving skills, and teamwork skills, which are valuable in both academic and professional settings.

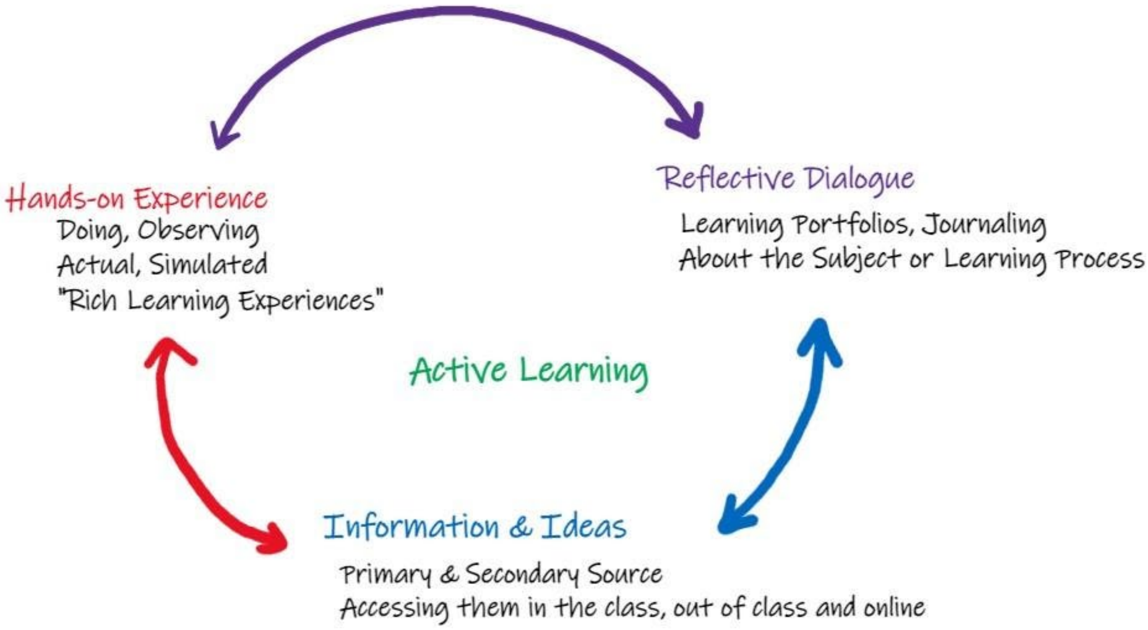


Figure 2-9 The components of active learning that involve both information and ideas and hands-on experience along with reflective dialogues

2.7.1 Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is one of the active learning small group methods that are well integrated with hands-on experience, which can help achieve effective teaching and learning (Figure 2-10).

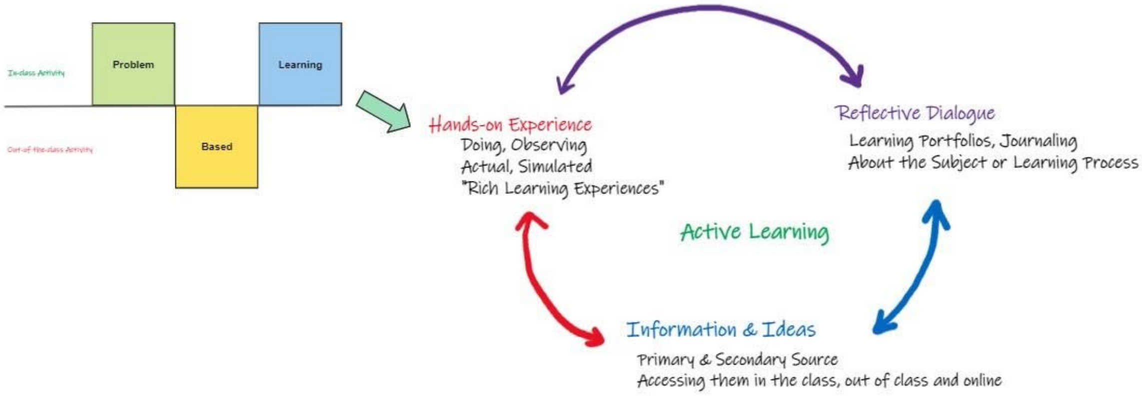


Figure 2-10 The integration of problem-based learning with the holistic active learning approach

PBL was pioneered first in the medical program at McMaster University in Canada in the 1960s. The use of PBL has then expanded from health sciences to many other disciplines and other levels of education as well. PBL is a student-centred instructional approach that uses 21st-century competencies (Allen et al., 2011; Hmelo-Silver, 2004). It engages the student in the in-depth inquiry of the problem for addressing the driving or real-world questions of the society, PBL also helps students in relevant and authentic learning that covers four aspects namely- communication, collaboration, critical thinking and learning academic content. Five steps are involved in PBL (Figure 2-11). PBL exercises students' choice and voice, where they can critique and revise one's work. It also allows students to present their work to the community.

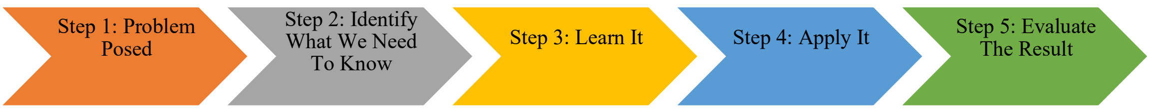


Figure 2-11 Steps involved in Problem-Based Learning

PBL has been an essential instructional strategy, especially in medical education since the 1970-the 80s, and in other aligned professional fields like biology, bioinformatics, chemistry, chemical engineering, etc. In PBL, the problem comes first, i.e., the students are not given much information about the subject; instead, a real-world problem is provided to them as a case study. This real-world problem will help students in their future to deal with related issues both in their personal and professional work.

Problem-based learning (PBL) is a teaching approach in which students learn by actively solving authentic and complex problems. In PBL, the teacher serves as a facilitator, providing support and guidance as students work together to identify and solve a problem. PBL is a student-centered approach that emphasizes critical thinking, problem-solving, and collaboration skills. PBL typically follows a set of steps, such as: Introducing a problem or scenario to the students Facilitating small group discussions and brainstorming sessions to encourage students to identify and define the problem, Assisting students in researching and gathering information to help solve the problem, Encouraging students to develop and present potential solutions to the problem, Reflecting on the process of solving the problem and the learning that took place. PBL can be used in a variety of subjects and can be an effective way to engage students and promote deep learning. It can also help students develop important 21st-century skills such as critical thinking, collaboration, and communication.

This kind of learning is just a role reversal or flipped method compared to the traditional learning method in which students only study content information during their entire semester and wait till the end of the semester to start working on the kind of problems they learned earlier (Chang et al., 2022; Hu et al., 2019; Kardipah & Wibawa, 2020; Paristiowati et al., 2019; A. Wang et al., 2022). This PBL approach of active learning, usually done in the same groups or with collaborative effort, is required for achieving meaningful learning goals. In other words, the PBL helps identify what, why, and how about the subject by the students on their own, which helps make them self-directed lifelong learners. The critical questions encountered and answered by the students are- What kind of topics are involved in the problem, What can they do about these problems, What do they not know about the topic or problem as a group, How can an individual can learn about the topic or subtopic or can use his/her understanding so that he/she is able to contribute to his/her team to learn the topic as a whole, What appropriate solution as a team they can offer at last.

A semi-quantitative analysis, for Bioinformatics laboratory-based research projects, was conducted using pre- and post-module quizzes, which incorporated process and content-specific questions that showed an increase in students' engagement, practical bioinformatics skills, and process-specific knowledge (J. A. L. Brown, 2016). An Integrated group-centred problem-based learning (PBL) conducted for master students by providing a flipped style of teaching access. The study, based upon semi-structured interviews, showed the effectiveness and likeliness of the PBL style of teaching among the students, as compared to traditional learning, which leads to the formation of communities of practice (CoPs) or strong networks (Davies et al., 2019). An application centred project-based learning conducted for the bioinformatics training course, for finding out engagement, active thinking, interaction, and discussion among the students showed an increase in participation, higher satisfaction, and greater awareness of Bioinformatics resources (Emery & Morgan, 2017).

The problem-based learning activities involve a sequence of in and out-of-class activities to help students develop essential practical thinking abilities. The castle top diagram can easily represent both in and out of the class activities engaged in problem-based learning (Figure 2-12).

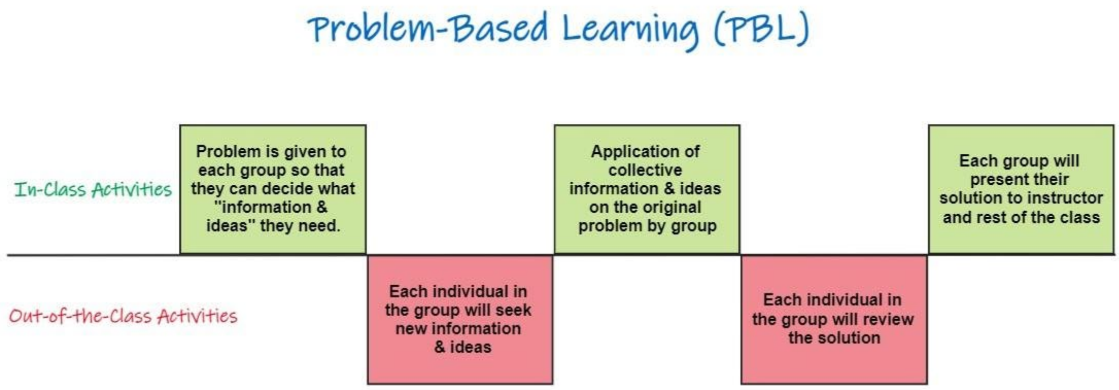


Figure 2-12 The castle-top diagram of problem-based learning representing various in and out-of-class activities

These PBL activities can help students achieve five different aspects, namely focus, technical skills, innovation, and creativity, ability to work on their own, and life skills. Also, it has been found that these five aspects of PBL align with Fink's taxonomy of significant learning for achieving learning goals or objectives (Figure 2-13).

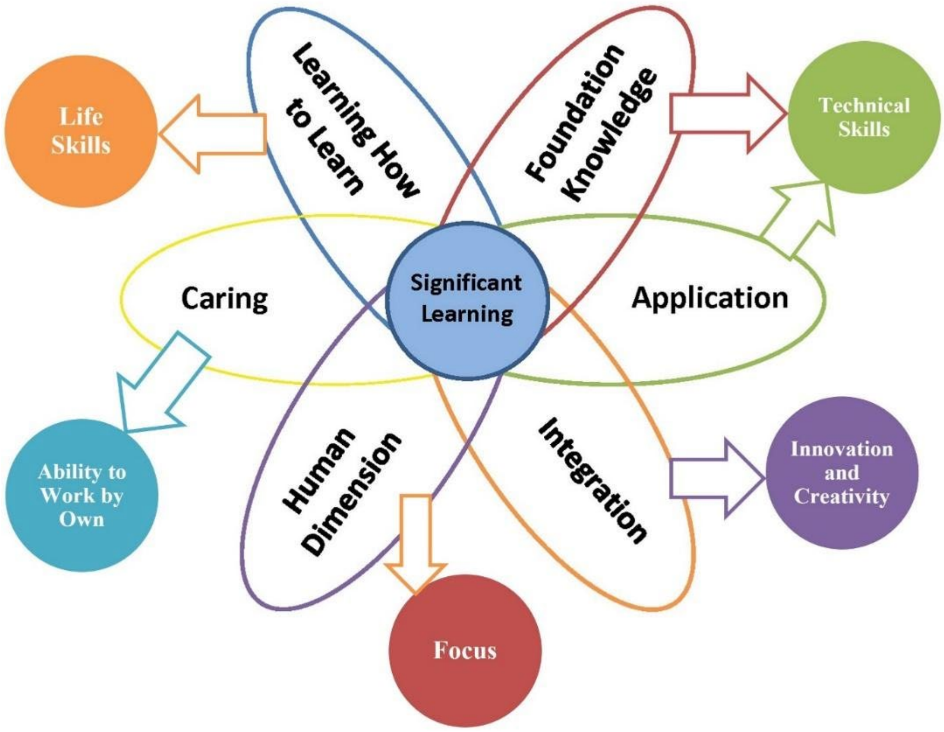


Figure 2-13 The mapping of five aspects of problem-based learning with Fink's taxonomy of significant learning

2.7.2 Team-Based Learning (TBL)

One another small-group active learning strategy is Team-Based Learning (TBL) by forming a permanent group for high performance in contrast to temporary groups of cooperative learning (James et al., 2019; R. E. Levine et al., 2020). TBL is also considered one of the highly structured small group active learning methods that have been widely used since the 1990s (Figure 2-14).

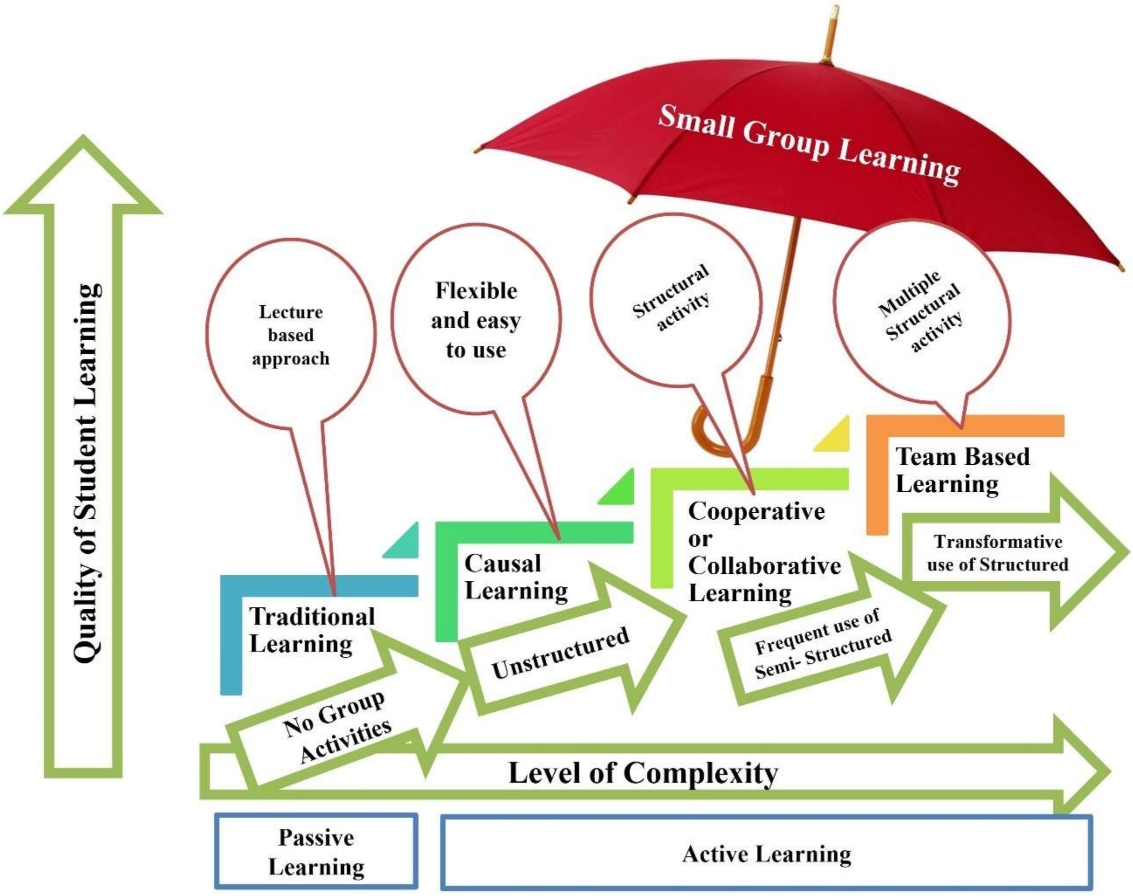


Figure 2-14 Hierarchy in Small Groups Learning in which traditional learning or lecturing is simple but has a minor quality of learning. In contrast, team-based learning is highly structured and has the maximum rate of student learning.

Team-based learning (TBL) is a teaching strategy that involves organizing students into small, heterogeneous teams and using a variety of learning activities to facilitate the acquisition and application of knowledge (Haspel et al., 2019; Volerman & Poeppelman, 2019). TBL is often used in higher education settings, particularly in courses that involve complex material that requires students to apply their knowledge to real-world situations. In TBL, students work together in teams to complete a variety of activities, such as problem-solving exercises, case studies, simulations, and group presentations. These activities are designed to help students learn and apply the material in a collaborative and interactive way. TBL typically involves both in-class and out-of-class work, and students may be required to complete readings, assignments, and other preparatory work before coming to class. TBL has been shown to be an effective teaching strategy for a number of reasons. For one, it encourages active learning, which has been shown to be more effective than passive learning (e.g., listening to lectures). TBL also promotes higher-order thinking skills, such as analysis, synthesis, and evaluation, which are important for success in many fields (DeMasi et al., 2019; Park et al., 2019). Additionally, TBL can foster teamwork and collaboration skills, which are increasingly important in today's work environment. Overall, TBL can be a powerful tool for teaching and learning, particularly in courses that involve complex material that requires students to apply their knowledge in real-world situations (Hurst-Kennedy, 2018; Krase et al., 2018).

It is also considered one of the easiest ways to incorporate active learning into the course, which can result in a dramatic difference in the quality of the learning experience. The team-based learning distinguishes itself from other small group strategies as it is based upon instructional strategy rather than technique. Also, it involves a series of connected small-group strategies rather than independent activities. TBL involves a high level of individual commitment and trust for the welfare of group members (Fink, 2013; Nguyen et al., 2016; Whittaker, 2015).

There are three phases of team-based learning- preparation, application, and assessment. (Figure 2-15).

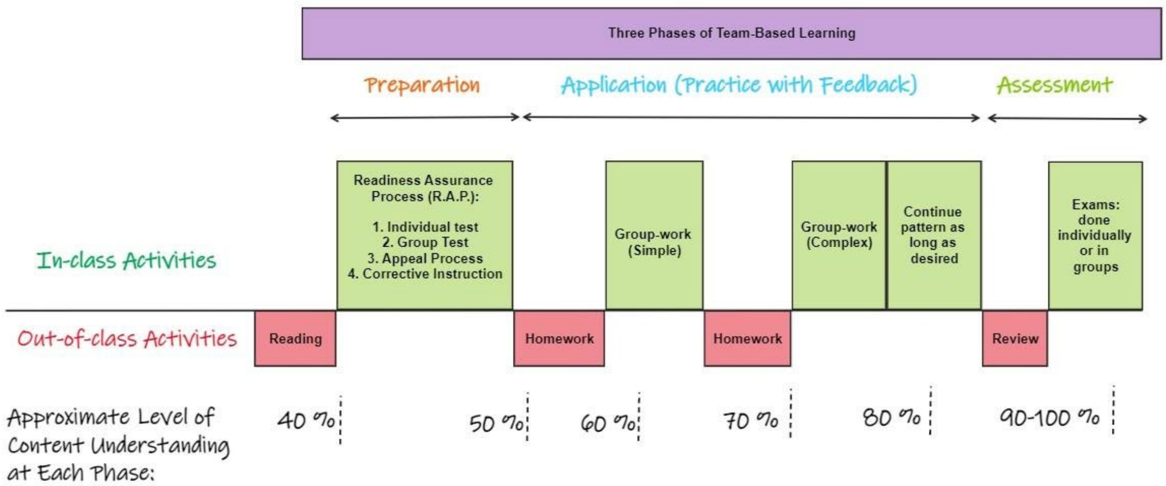


Figure 2-15 A castle-top diagram represents a series of in and out-of-class activities in team-based learning that involves three phases- preparation, application, and assessment.

These series of in and out-class activities are helpful in the transformation of small groups into teams which further can extract the extraordinary capabilities of teams to accomplish a higher level of content and application learning. This flipped style teaching strategy of the "Readiness Assurance Test (RAT)" (in which students read the content material on their own before coming to class and then undergo a test on that material both individually and in the group) quickly and effectively brings nearly all the students to a moderate level of content understanding (Figure 2-16).

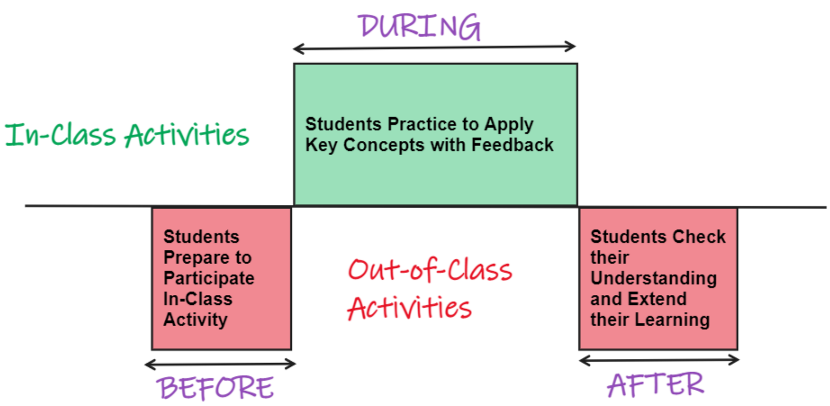


Figure 2-16 A castle-top diagram representing the flipped style of team-based learning in which students "prepare" themselves before class and participate in individual and team-based Readiness Assurance Test (RAT)

Through the intervention of the Readiness Assurance Test (RAT), students can spend a significant amount of time working in a small group by learning how to apply the content through a series of practice application exercises.

As in problem-based learning, team-based learning is also well integrated with one of the components of active learning. In out-of-class activities, students acquire information and ideas before coming to the class in the readiness assurance process. This process allows students to get hands-on experience in case studies or real-world problems hence resulting in active learning (Figure 2-17).

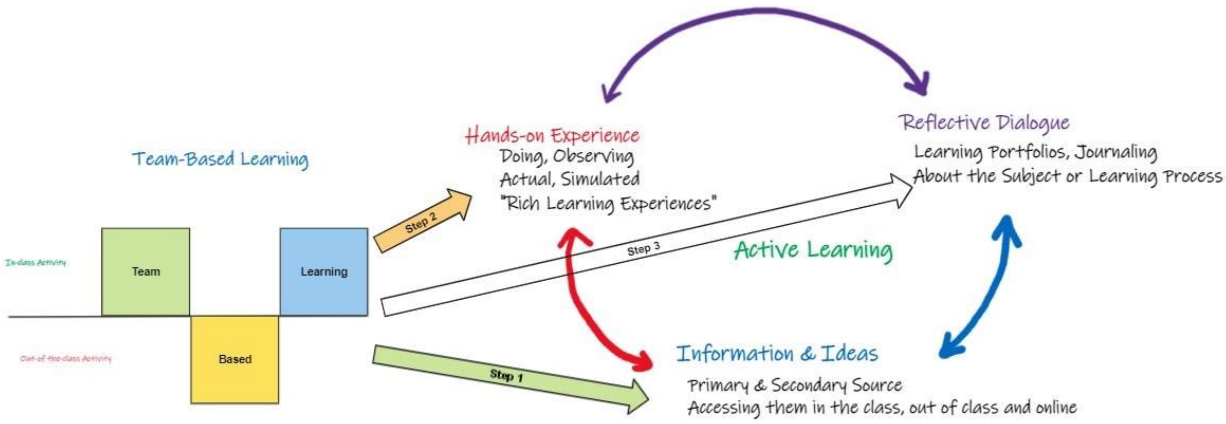


Figure 2-17 The three sequences of events in team-based learning with active learning components

Team-Based Learning has certain advantages over the traditional learning process as it gives more emphasis on applying the concepts inside the class and learning the concepts before coming to class and analysis of learning by readiness assurance test before applying the concepts in contrast to more emphasis on understanding the concepts inside the class and less emphasis on applying the concepts outside the class (Figure 2-18).

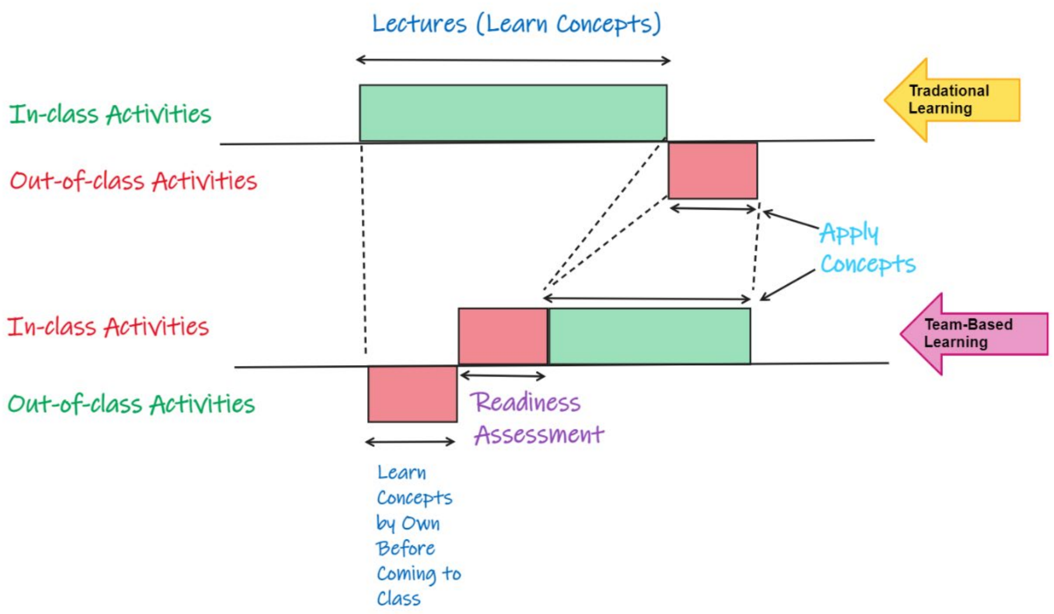


Figure 2-18 A comparative analysis of the castle-top diagram of both traditional and team-based learning in which greater emphasis is given to applying the concepts rather than learning the concepts inside the class

2.8 Assessment and Feedback

The Integrated Course Design focuses on feed-forward educative feedback or assessment rather than auditive assessment (Figure 2-19).

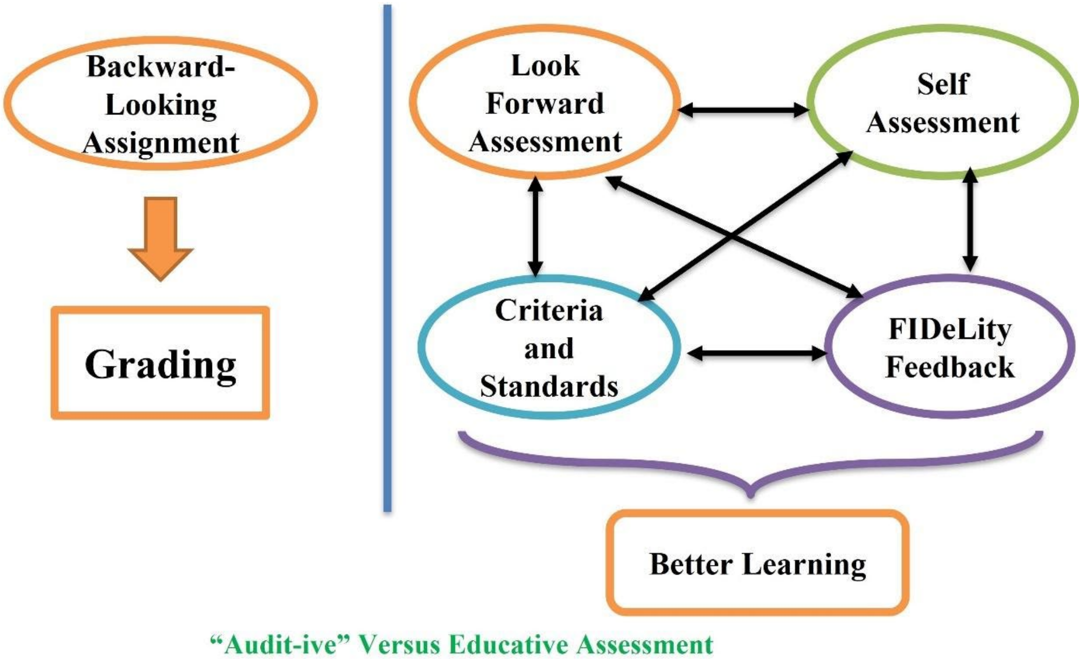


Figure 2-19 Comparative analysis of backward-looking traditional assessment with a forward-looking interconnected educative assessment of Integrated Course Design (ICD).

2.8.1 Assessments

In education, there are range of assessments that can be used to measure student learning at different levels of complexity or depth. This can include formative assessments, which are used to guide instruction and help students identify their strengths and areas for improvement (Dunn & Mulvenon, n.d.; Kulasegaram & Rangachari, 2018), as well as summative assessments, which are used to evaluate student learning at the end of a unit or course (Black et al., 2010; Dixson & Worrell, 2016; Dolin et al., 2018; Kibble, 2017; Raupach et al., 2013). Assessment gradients can be useful for helping teachers differentiate instruction and tailor their assessments to the needs and abilities of their students. For example, a teacher may use a range of assessments, such as quizzes, projects, worksheets, take-home assignments and exams, to assess student learning at different levels of complexity and provide multiple opportunities for students to demonstrate their understanding. It is important to consider the reliability and validity of the assessments being used, as well as their alignment with learning objectives and standards. Additionally, it is important to provide appropriate support and accommodations for students who may need them in order to demonstrate their learning effectively.

There are various assessment methods based upon their ease and potential of learning (Figure 2-20).

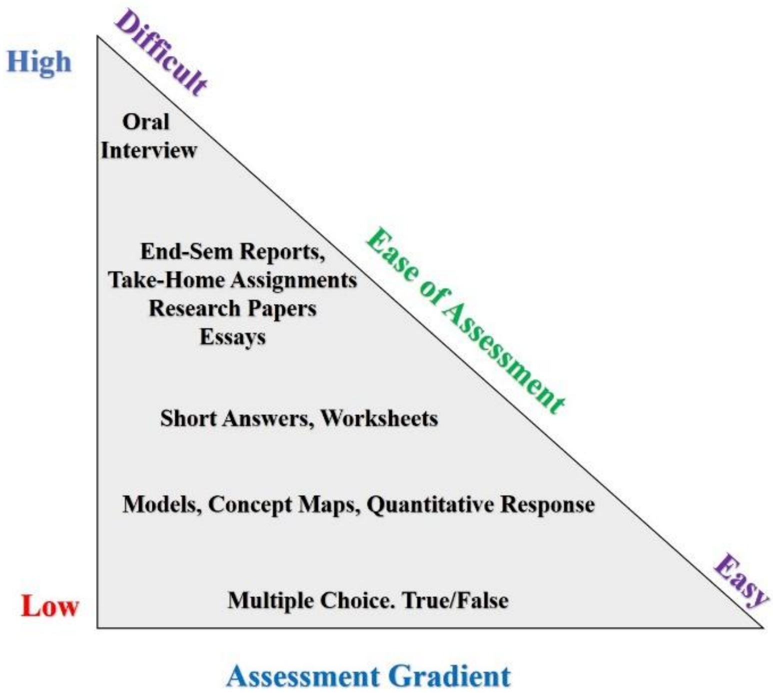


Figure 2-20 Different levels under assessment gradient varying from low to high and easy to difficult.

2.8.1.1 Take-Home Assignments (THA)

Take-home assignments, also known as homework assignments or independent study assignments, are a common tool used by educators to assess students' knowledge and understanding of course material. These assignments are typically given to students to complete outside of class, and may include tasks such as reading a textbook, completing a worksheet or problem set, or writing a paper. There are several benefits to using take-home assignments as an assessment tool in education. First, these assignments allow students to work at their own pace and in their own environment, which can be especially beneficial for students who may have difficulty focusing in a classroom setting. Take-home assignments also provide students with the opportunity to demonstrate their knowledge and understanding of course material in a more authentic and independent manner, rather than simply reproducing what they have learned in class. Additionally, take-home assignments can be an effective way for educators to assess a wide range of skills and knowledge, including critical thinking, problem-solving, and written communication. By providing students with a range of tasks to complete, educators can gain a better understanding of their strengths and areas for improvement. Take-home assignments can be a valuable tool for assessing student learning and promoting student engagement in the classroom. It is important, however, for educators to carefully consider the purpose and format of these assignments, and to provide clear guidelines and feedback to help students succeed (Cordova et al., 2018; Maclean & McKeown, 2013; Stark et al., 2013).

Take-home assignments, are a common method for assessing a student's knowledge and skills in a particular subject. They are typically given to students to complete outside of class time, often with the intention of reinforcing material covered in class or introducing new concepts. Take-home assignments can take many forms, including written assignments or reports, projects, or problem sets. They can be used to assess a student's understanding of course material, their ability to apply concepts and skills to real-world situations, or their ability to work independently and manage their time effectively. There are several benefits to using take-home assignments as an assessment activity. They allow students to demonstrate their understanding of material at their own pace, without the time constraints of in-class assessments. They also provide an opportunity for students to apply what they have learned in a more authentic, real-world context, as they may be required to research or solve problems using resources outside of the class material. Take-home assignments can be a valuable tool for teachers to assess student learning and progress. However, it is important to ensure that the assignments are well-designed, clearly communicated, and appropriately graded to maximize their effectiveness as an assessment activity.

The Take-Home Assignment is an assessment method that involves one out of the class activity in which some a mixture of understanding and application-based short answer questions were given to students followed by in-class activity of discussion of the same questions (Moraros et al., 2015)(Figure 2-21).

Figure 2-21 A castle-top diagram for the assessment of students by giving them questions outside the class (via email) in the form of Take-Home Assignment (THA) along with in-class Discussion (D) for the tutorial classes

2.8.1.2 Worksheets (WS)

Worksheets are a common tool used in education to help students practice and reinforce learning. They can be used in a variety of subjects, such as math, reading, and writing, and can be used at different grade levels. Worksheets typically consist of a series of questions or problems that students must complete. These questions or problems may be related to a specific topic or lesson that the student is learning. Worksheets can be used as a standalone activity, or they can be used in conjunction with other teaching materials, such as textbooks or lectures. Worksheets can be an effective way for students to practice and reinforce their learning, as they allow students to apply the concepts they have learned in a concrete way. They can also be a helpful tool for teachers to assess their students' understanding of a topic. However, it is important for teachers to use worksheets in moderation and to ensure that they are being used as a supplement to, rather than a replacement for, other forms of instruction. It is also important for teachers to consider the needs and abilities of their students when using worksheets and to make sure that the worksheets are appropriate for the students' age and skill level (Podolak & Danforth, 2017; Ransom & Manning, 2013; Setiawan, 2020).

Worksheets can be a useful assessment activity because they allow students to demonstrate their understanding of the material being covered in a course or lesson. Worksheets can be used to test students' knowledge of specific concepts, as well as their ability to apply that knowledge in different contexts. There are several benefits to using worksheets as an assessment activity: They are easy to create and can be tailored to the specific needs and abilities of the students. They can be used to assess a variety of learning outcomes, including knowledge retention, problem-solving skills, and critical thinking skills. They can be completed in a relatively short period of time, making them a convenient assessment option for busy teachers. They can be used to provide immediate feedback to students, helping them to understand where they need to improve and how to do so. They can be easily graded, allowing teachers to quickly assess student progress and identify areas where additional support may be needed. Overall, worksheets can be a useful tool for assessing student learning and identifying areas for improvement.

A worksheet typically involves a mixture of understanding and application-based question followed by discussion among the students (Figure 2-22).

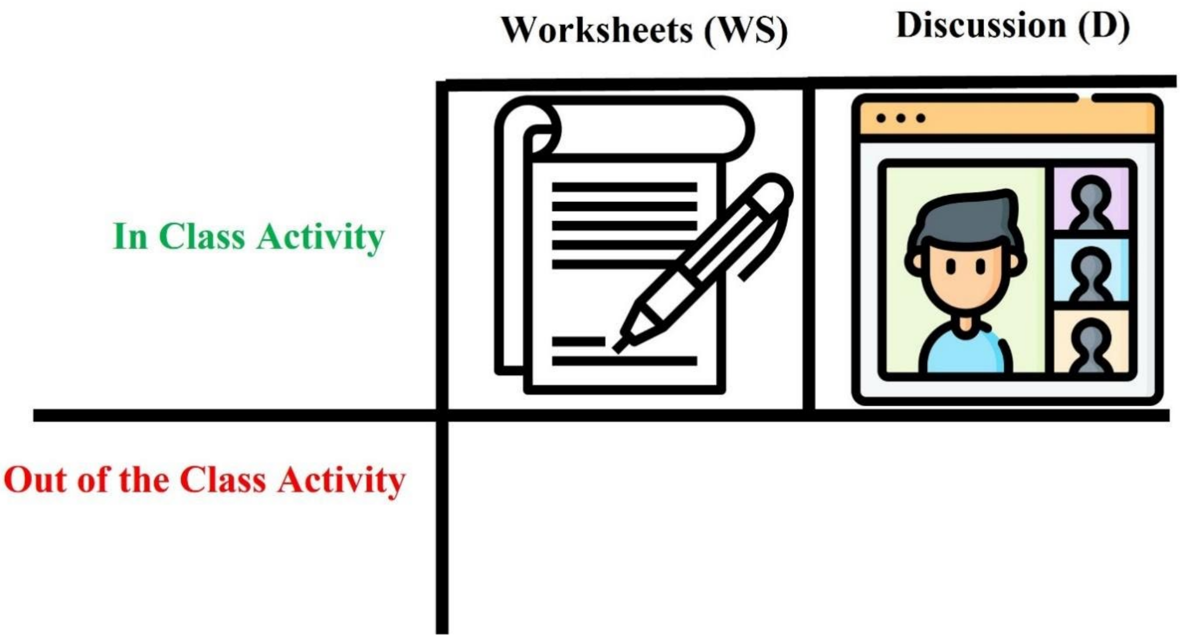


Figure 2-22 A Castle-top diagram for assessing students using in-class Worksheets (WS) followed by in-class Discussion (D) activities in the tutorial classes

2.8.1.3 Hybrid Assessment (THA and WS)

A hybrid method of both Take-Home Assignment (first five session) and Worksheet (remaining five session) followed by Discussion as an assessment technique (Figure 2-23).

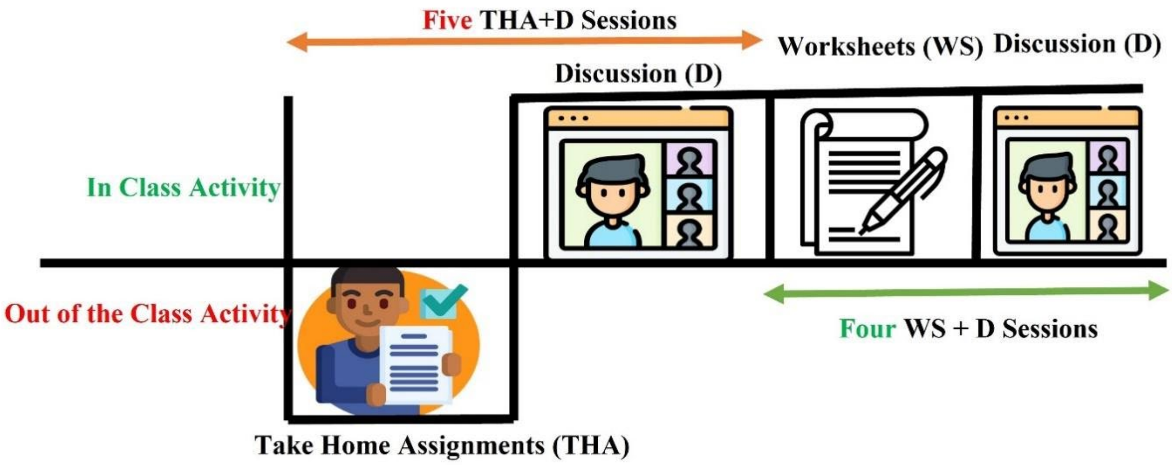


Figure 2-23 A castle-top diagram for assessing the students using a mixture of out and in-class activities like some sessions with Take-Home Assignment (THA) at home and Discussion (D) and remaining sessions with in-class Worksheets (W) and Discussions (D)

2.8.2 Feedback

Student feedback is another valuable resource for educators because it provides insight into how students are learning and experiencing the course or lesson and what could be improved in the course. It can help educators identify areas of strength and weakness, as well as adjust better meet the needs and learning styles of their students. Feedback is an essential part of the learning process in education. It allows students to understand how they are progressing and where they need to improve. It also helps teachers to identify areas where students may be struggling and to provide additional support or resources. There are several different types of student's feedback that can be used in education, including: Formative feedback: This type of feedback is given during the learning process to help students understand where they are and where they need to go. It is often more informal and focuses on the process of learning rather than the final product (Goldin et al., 2017; Hatziapostolou & Paraskakis, 2010; Irons & Elkington, 2021; Ludvigsen et al., 2015; Shute, 2008). Summative feedback: This type of feedback is given after a learning activity or assessment has been completed. It is often more formal and assesses the final product or performance of the student (Hamilton, 2009; Heron, 2011; Smith, 2022). Verbal feedback: This type of feedback is given through spoken communication and can be delivered in person or through electronic means such as video conferencing or online discussions (Johnson et al., 2016; Kannappan et al., 2012; Kerr, 2017; Ozcakar et al., 2009). Written feedback: This type of feedback is provided through written communication, such as a written evaluation of a student's work or a written response to a student's question (Agius & Wilkinson, 2014; Cavalcanti et al., 2020; Cramp, 2011; Nicol, 2010). Nonverbal feedback: This type of feedback is communicated through body language, facial expressions, and other nonverbal cues. It is often used to provide encouragement or support to students (Huang et al., 2019; Moran et al., 2015; W. Wang & Loewen, 2016; Webb et al., 1997) .

It is also common for students to provide feedback to their instructors or professors. This can be done through various channels, such as Written surveys: These can be administered online or in paper form and can include both open-ended and closed-ended questions, One-on-one meetings: These can be conducted with individual students or small groups to discuss their experiences in the course and any suggestions they may have for improvement, Focus groups: These are typically small, informal discussions in which students can share their thoughts and ideas about the course with their peers and the instructor, Classroom observations: An instructor or a representative from the school can observe a class and provide feedback on the teaching style, the learning environment, and the students' engagement and participation.

When providing feedback, it is important for students to be respectful and constructive in their comments. It can be helpful to focus on specific aspects of the course or teaching style, rather than making broad or general statements. It is also important to consider the perspective of the instructor and to recognize that teaching can be a challenging and demanding profession. Overall, student feedback can be a valuable tool for improving the learning experience for both instructors and students. It is important for both parties to be open to and receptive to feedback in order to continuously improve the teaching and learning process.

Effective feedback should be timely, specific, and focused on the student's learning process. It should also be provided in a way that is respectful and supportive and should encourage the student to take an active role in their own learning. There are several ways that educators can gather student feedback, including: It's important to remember that student feedback is just one piece of the puzzle when it comes to improving the learning experience. It should be considered alongside other forms of data, such as grades, test scores, and teacher observations, in order to get a comprehensive picture of student learning.

Feedback analysis in education refers to the process of evaluating and analyzing feedback from students, teachers, and other stakeholders in order to improve the quality of education.

2.8.2.1 Subjective feedback analysis

Subjective feedback analysis is the process of evaluating and interpreting subjective or qualitative data, such as opinions, attitudes, and perceptions. This type of analysis can be useful in a variety of contexts, including market research, customer service, student and employee performance evaluations. To conduct subjective feedback analysis, one might start by collecting a large set of qualitative data, either through surveys, focus groups, interviews, or other methods. This data can then be analyzed to identify patterns, trends, and themes. Some common techniques for subjective feedback analysis include- Coding: This involves breaking down the data into smaller pieces and assigning codes or tags to specific pieces of information. This can help you identify common themes or patterns in the data. Content analysis: This involves looking at the content of the data itself and identifying themes or patterns within it (Lovász et al., 2022, 2023; Papadopoulos et al., 2019; Vergara-Torres et al., 2020). This can be done manually or using software tools. Discourse analysis: This involves looking at the language used in the data and analyzing how it is used to convey meaning. Sentiment analysis: This involves using natural language processing techniques to identify the emotional tone of the data, such as whether it is positive, negative, or neutral.

Subjective feedback analysis involves analyzing feedback that is based on personal opinions, feelings, and experiences. This type of feedback can be difficult to quantify and analyze, but it can provide valuable insights into how individuals perceive a particular product, service, or experience. To analyze subjective feedback, it's important to first identify the key themes and sentiments that are being expressed.

2.8.2.1.1 Sentiment analysis

Sentiment analysis is the process of using natural language processing and machine learning techniques to identify and extract subjective information from text. It involves classifying text as either positive, negative, or neutral based on the sentiment it conveys. There are many different techniques and approaches to performing sentiment analysis, ranging from simple rule-based systems to more complex machine learning models. Some common techniques include Rule-based systems: These systems use a set of predefined rules or dictionaries to identify and classify sentiments in text. For example, a rule-based system might use a dictionary of positive and negative words to classify the sentiment of a sentence. Machine learning models: These systems use training data to learn patterns and relationships in the text that are indicative of different sentiments. Common machine learning models used for sentiment analysis include support vector machines (SVMs), naive Bayes classifiers, and deep learning models. Lexicon-based approaches: These approaches use dictionaries of words that are associated with sentiments, such as the Bing Liu lexicon or the SentiWordNet lexicon. Hybrid approaches: These approaches combine multiple techniques, such as rule-based systems and machine learning models, to improve the accuracy of sentiment analysis. Sentiment analysis is used in a variety of applications, including customer service, social media monitoring, and market research (Batrinca & Treleaven, 2015; Bohlouli et al., 2015; Bonta et al., 2019; Ducange et al., 2019; Kauffmann et al., 2020; Rodríguez-Ibánez et al., 2023; Sudhir & Suresh, 2021). It can help businesses and organizations understand the sentiment of their customers or users and make informed decisions based on this information.

Sentiment analysis is a process of analyzing the emotions and opinions expressed in text data. In the context of student feedback, sentiment analysis can be used to understand the overall sentiment of students towards a particular course, instructor, or educational experience. This can be helpful for educators and administrators to get a sense of how well their teaching is being received and identify areas for improvement. To perform sentiment analysis on student feedback, you can use natural language processing (NLP) techniques to process and analyze the text data. There are several approaches to NLP, including using machine learning algorithms to classify text as positive, negative, or neutral, or using lexicons or dictionaries of words with known sentiments to assign scores to individual words or phrases (Ahmed et al., 2020; Aung & Myo, 2017; Cho et al., 2014; Wu et al., 2018; S. Zhang et al., 2018). It's important to note that sentiment analysis is not a perfect science, and it can be affected by the tone and context of the text, as well as the subjectivity of the person performing the analysis. Therefore, it's important to use multiple approaches and carefully evaluate the results to get a more accurate understanding of the sentiment expressed in the student feedback.

We can use sentiment analysis (one of the hottest topics and research domains in machine learning and Natural Language Processing) to analyze students' affective or emotional domain by analyzing their feedback in the teaching-learning environment. Sentiment analysis is the most frequently employed technique to analyze subjective feedback in various disciplines, especially student feedback in education. It involves understanding the meaning, tone, context, and intent of students' feedback by analyzing and categorizing students' opinions into positive, negative, and neutral classes.

A web-based sentiment analysis tool using various python-based libraries can be used to classify the sentiments expressed by students in their respective subjective feedback data(El-Masri et al., 2017; Singh, 2021). Sentiment analysis of student feedback needs a lot of attention as a research topic because the brief personal feedback given by students contains lots of information. The earlier studies showed binary classification and multi-classification system for analyzing the emotional feedback of students.

2.9 Research gap after literature review

One major gap in existing pedagogy is the lack of attention to individual differences among students. Traditional teaching methods often rely on a one-size-fits-all approach, where all students are expected to learn the same material at the same pace. However, research has shown that students have different learning styles, strengths, and needs and that teaching method that takes these differences into account can be more effective (Kubat, 2018; Pashler et al., 2008; Zapalska & Brozik, 2006). Another gap in existing pedagogy is the lack of emphasis on hands-on, experiential learning. Many educational systems rely heavily on lectures and textbooks rather than providing students with opportunities to engage with the material through hands-on activities and real-world experiences. Research has shown that experiential learning can be more effective in helping students retain information and develop critical thinking skills (Bradberry & De Maio, 2019; Dimmitt, 2017; Franco Valdez & Valdez Cervantes, 2018; Spanjaard et al., 2018). The third gap in existing pedagogy is the lack of emphasis on social and emotional learning. While traditional teaching methods have focused mainly on academic skills, research has shown that social and emotional skills, such as empathy, communication, and problem-solving, are also crucial for student success. Overall, educational research has identified several areas where existing pedagogy could be improved. There is a growing recognition of the importance of taking a more individualized, experiential, and holistic approach to teaching and learning. The key gaps are as follows:

1) Status of Biology Education Research (BER) in the world vis-à-vis the status in India

2) Curricula based upon Biology Education Research, Taxonomy of Significant Learning and Problem based Learning are not available in India

3) Assessment based mainly on the cognitive domain rather than learning domain of students in Biology

4) Student feedback of teachers is very generic and does not capture the learning experience students have had. Broadened to check if the learning has been effective. Not only will this help the instructor, it would also be used as an institutional tool to assess teacher quality.

2.10 Objectives of the proposed research

To address the aforementioned gaps the following objectives were framed:

1) To design and implement Integrated Course Design (ICD), encompassing the six aspects of Fink's Taxonomy of Significant Learning (TSL) and small group activities.

2) To create appropriate assessment methods to evaluate student learning resulting from the implementation of the above.

3) To identify among the existing classroom management platforms and tools appropriate modules that help in effective implementation of Team Based Learning and different assessment methods in order to facilitate the instructor.

4) To evolve a student feedback questionnaire that is customizable according to the instructor/institutional needs, which accurately brings out the student learning outcomes, rather than only the process.

3 Materials and Methods

3.1 Course Design Using Integrated Course Design (ICD) and Fink’s Taxonomy of Significant Learning (TSL) or ICD/SL

The existing curriculum and teaching methods were thoroughly reviewed. Based on this review, an ICD that incorporates the six aspects of Fink’s TSL was designed. The new course design was then implemented in a controlled setting, with careful documentation of the process.

The Department of Biological Sciences at BITS Pilani-Pilani Campus, Rajasthan, India approved the use of Dr. L. Dee Fink's learning-centered pedagogical model on students in the ‘Introduction to Bioinformatics’ hands-on tutorial course for two sessions: 2020-21 and 2021-22. The three-credit course ‘Introduction to Bioinformatics’ combines theoretical and practical components, and each semester lasts 20 weeks with two instructors participating. Three-component evaluation methods was used for hands-on tutorials, and one final grade score assessment report was used in the summative evaluation. The scale runs from 0 to 40, with a 16 minimum passing score. Each semester's data included all students who finished the course.

Before the course design adjustments were applied, the 2019-20 control group was used as a baseline. The ICD/SL adjustments in the two treatment groups included the creation of Fink's three steps for proper ICD design. These comprised a preliminary phase in which situational elements were analyzed (Table 3-1).

Table 3-1 Identification of situational factors by designing factors and challenge form for Bioinformatics tutorial course

Name of Course: Introduction to Bioinformatics		**Within Your Control? (x)**	**Outside of Your Control? (x)**
Area	**Description of Situation**		
Specific context of the teaching/learning situation	• Hybrid/blended format • Tutorial Followed by Lab Class (2 hours’ continuous session) • Large Class 75-80 students • Undergraduate course for Biology majors		x x x x

Expectations of others for what students learn in your course	• Approved by the Course Instructor • AICTE guidelines • Students will able to link all the application and knowledge to build a complete project	 x	x x
Nature of the subject of your course	• The subject is a combination of Theory and Practical • The subject is divergent, and they have to be creative to explore all possible explanations • Practical skills needed • Concepts are connected in a hierarchical way • Strong writing and interpretation skills necessary • Requires significant time outside of the classroom to do assignment and write an interpretation of their results about specific given gene	x x x	x x x
Characteristics of your learners	• Undergraduate students having different background • Little or no prior knowledge of Bioinformatics tools • Students excited to learn a new dimension of interdisciplinary research • Students get one-week time to complete the hands-on assignment before coming to the next class • Residential campus but has limited time to report	x	x x x

			x
Characteristics of you, the teacher	• Eight years of experience in teaching Bioinformatics course both for Undergraduates and Master degree students • My attitude towards teaching is that it should be interactive • High energy instructor, passionate towards subject and teaching • My weakness is Punctuality, and I expect the same from my students • As a Research scholar, I have a limited option to model the course according to my own	x x x	x x

We have also identified the single most important Pedagogical Challenge that an instructor can face in Bioinformatics course on the first day (Table 3-2).

Table 3-2 Special pedagogical challenge for Bioinformatics tutorial course

Special Pedagogical Challenge	Plan to Mitigate or Address this Challenge	Potential Impact on Students if Not Mitigated
My students came from a varied background; some have good programming skills and very little biology knowledge or vice versa	In the first week of the course, we teach students the necessary programming skills to be applied to simple biological problems. Students are given individual specific problems out of the classroom to conduct a simple experiment. We ask them to complete the simple assignment based on the specific problem. Students are encouraged to apply the knowledge taught in the classroom and interpret the results in their own words. To address the students with little biology knowledge we give them a lecture prior to the hands-on tutorial along with in-class worksheets (based upon central dogma, protein structure prediction, sequence alignment etc.) where students can learn the basic concepts that are necessary to solve the problems.	Students who have limited knowledge of programming or biology either 1) have difficulty in completing code or interpreting the results in the assignments or 2) sometimes they cheat in some way by taking help from their friends 3) This could lead to frustration, demotivation, and potentially lower performance.

The students used a virtual classroom with the Google meet platform and various support materials, including readings, take-home assignments, worksheets, and demonstration videos made by the instructor on a YouTube channel, in the intermediate phase, related to the core content identifying desired learning outcomes.

Furthermore, the course was structured in such a way to incorporate active learning approaches such as "flipped classrooms," hands-on demonstration, in-class small group (collaborative) activity and problem-based learning—all of which were arranged logically and progressively by incorporating Fink's Taxonomy's six key areas of learning, as reported previously (Emery & Morgan, 2017; Katyal & Kannan, 2022).

Problem-based learning (PBL) is an active teaching and learning approach that focuses on the use of real-world or authentic problems as the primary vehicle for learning. In PBL, students work in small groups to identify and solve complex, open-ended problems. This approach to learning is thought to be more effective than traditional methods because it allows students to apply their knowledge and skills to real-world situations, encourages critical thinking and problem-solving skills, and promotes student engagement and collaboration. As an assessment method, PBL can be used to evaluate student learning in a number of ways. For example, the problems that students work on in PBL can be designed to assess specific learning outcomes or objectives. The process of solving the problem can also be used as an assessment tool, as students are required to demonstrate their understanding of the subject matter and their ability to apply it to a real-world situation. Additionally, the final product of the PBL process, such as a presentation or report, can be evaluated to assess student learning. Overall, PBL is a powerful assessment tool because it allows students to demonstrate their learning in a more authentic and meaningful way, and it encourages the development of important skills such as critical thinking and problem-solving.

Continuous formative evaluation of take-home assignments and end-semester feedback was taken to support the targeted learning outcomes, which were determined using a follow-up end-semester manuscript report in the final phase, and a greater emphasis was placed on formative assessment activities, such as student participation through take-home assignments and in-class group activity assessments. The use of rubrics with uniform criteria, objectives, and precise evaluations was necessary to standardize the evaluation criteria between teachers and students for this aim.

This work was completed in the order in all three grade reports. All the improvements and adjustments made to the ICD/SL treatment groups entailed creating new learning goals and teaching and evaluation activities in each of Fink's six primary areas (Table 3-3).

Table 3-3 Classification of teaching and learning activities under six domains of Fink's Taxonomy of Significant Learning

	Learning Outcomes	Learning Assessments	Learning Activities
Foundational Knowledge Learners will understand and remember key concepts, terms, relationships, facts, etc. --- Describes what learners will be able to do with information.	Examples of Fink verbs to Consider: Define, Describe, Explain, Find, Identify, List, Name Identify methods used in different fields of Biotechnology Define various critical concepts used for performing comparative genomics Identifying the best algorithm and tool for the analysis of biological data Enlisting the steps which can give answer related to specific genes or protein behavior	Readiness Assessment Test Jigsaw- students work in small groups to develop knowledge about a given topic before teaching what they have learned to another group Guided Notes- the instructor provides a set of partial notes that students complete during the lecture, focusing their attention on key points Online Resource Scavenger Hunt-students use the Internet to engage in fact-finding and information processing exercises using instructor-specified	It will allow discussion and appeals after preparatory reading. Students grouped in a batch of 6 and assigned a specific Gene or disease before introducing the class topic. It will help students to coordinate with their fellow groupmates and learn from each other by combining each piece of information to make a complete picture. In this composite learning exercise, students will able to organize lecture content and get the opportunity to actively respond to material presented in class, resulted in better academic achievement In this, students are grouped and select a topic entirely on their own. The instructor will provide 5-10 websites that contain relevant information related to the topic. The instructor will give some questions that can be quickly answered by the information available on those websites. For example, this type of exercise is quite useful in a database search or to find out a particular gene in the database.

		library and Internet sources.	
Application Learners will perform/" do" important tasks ---- Describes the kinds of activities and tasks learners will be able to perform based on the information they have acquired.	Examples of Fink verbs to Consider: Analyze, Critique, Solve, Demonstrate, Design, Develop, Demonstrate your problem statement in a simple flowchart Analyze various authentic sources like NCBI, EMBL, and SwissProt Develop various algorithms to solve your problem of interest.	Fact or Opinion- encourages students to critically evaluate information by questioning what they read. Triple-Jump- a three-step technique that requires students to think through and attempt to solve a real-world problem Think-Pair-Share- the instructor poses a question, gives students a	In this instructor, write a question on the board and ask students to vote in terms of "Fact" and "opinion" (using index cards). Students are also motivated to explain their selection. Students will work on producing a diagram that could be used to analyze the gene of interest. It should include various parameters like threshold value, percentage similarity, E-value, homology, Conserved domains, etc. supporting their selection. In this collaborative learning approach, students assigned a specific problem, and they have to answer a set of questions about the assigned task. Here each student thinks individually and shares

		few minutes to think about a response, and then asks students to share their ideas with a partner	their ideas with their fellow groupmates. For example, a group assigned an insulin coding gene; then, each individual has to find its attributes in different organisms, i.e., number of base pairs, types of mutation, phylogenetic profile, etc.
Integration Learners will identify/ consider /describe the relationship between "x" and "y" --- Describes the kinds of activities and tasks learners will be able to perform when they synthesize, link to, or relate specific information to other information.	Examples of Fink verbs to Consider: Align, Compare, Contrast, Integrate, Organize, Relate Align your practical approach with course goals Relate your course goals with Institutional goals Organize study material from different sources to support claims, differences of opinion across sources, and potential reasons for their disagreements. Organize team discussion to get consensus points	Group Grid-group members are given pieces of information and asked to place them in the blank cells of a grid according to category rubrics, which helps them clarify conceptual categories and develop sorting skills Sketch Notes- students use handwritten words and visual elements such as drawings, boxes, lines, and arrows to illustrate the main concepts from a lecture, as well as their interrelations Fishbowl- students form concentric circles with a small group inside and a larger group outside. Students in the inner circle engage in an in-depth discussion, while students in the outer circle listen and critique content, logic, and group interaction	Here students retain essential course content by sorting and visually organizing course content into conceptual categories, for example, mapping the relationship between mutation and its effects on different genes. In this, students remember vital visual components of course contents and its relation between them. It is a creative way to map the main elements with handwritten words and visual representation. Students are motivated to perform group discussions by making two concentric circles, where inner circle members carried out a conversation. At the same time, the outer ring listens to the debate and takes notes. This kind of arrangement can be done with different groups so that the integration of varying points of view can be possible.
Human Dimension – Self Learners will better understand themselves	Examples of Fink verbs to Consider: Conclude, Discern,	Role Play- students deliberately act out or assume characters or	In this, students able to learn a concept and strengthen their imagination. In this, students put themselves in an imaginary

--- Describes the kinds of activities learners will be able to perform when they apply information to themselves, i.e., from what they come to know about themselves	Discuss, Identify, Recognize, Relate Conclude your point of view about the type of algorithm or tool selected Find out various ways that support your point of view. Identify the pros and cons of your approach Recognize how your approach is different from the existing system.	identities they would not normally assume	situation to understand the concepts. For example, a student can understand each step of the system biology by a role play.
Human Dimension – Others Learners will interact positively and productively with others --- Describes the kinds of activities learners will be able to perform when they apply the information to themselves and their interactions with others; i.e., from what they come to know about others	Examples of Fink verbs to Consider: Convince, Discuss, Display, Recommend, Reconsider Develop a team environment so that individuals can Collaborate with others to promotes critical thinking Encourage healthy discussion Reconsider the critical points by comparing different people opinions	Test-Taking Teams- students work in groups to prepare for a test. They then take the test, first individually and next as a group Dyadic Interviews, student pairs take turns asking each other questions that tap into values, attitudes, beliefs, and prior experiences that are relevant to course content or learning goals	In this, students collaborate with their peers to prepare for a test first individually for grading and then in groups to submit a collective response to help each other understand the course deeply. Students provided interview questions before introducing the topic in the class and encourages them to generate a wide range of relevant responses.
Caring Students will care more deeply about this subject or issues related to this subject --- Describes the kinds of activities students will be	Examples of Fink verbs to Consider: Act, Challenge, Defend, Propose, Support, Value,	Digital story- students use computer-based tools, such as video, audio, graphics, and web publishing, to tell personal or academic stories about life experiences relevant to course themes	In this, students personify the components and write a story about what they learned.

able to perform when they connect the information to themselves and their personal lives in a meaningful way.	Respectfully defend own choice of tools or algorithm Support the valuable points from other groups Value the effort of each individual of the group	3-Minute Messages- modeled on the Three-Minute Thesis (3MT) academic competition, in which students have three minutes to present a compelling argument and to support it with convincing details and examples Update Your Classmate- a short writing activity where students explain what they learned in a previous class session to set the stage for new learning	Students will choose one of these assignments. They will provide some comparative analysis, evidence, theory, and proper use of tools and algorithms to make an argument. In this, students recall and spell out what they have learned in previous lessons in writing.
Learning How to Learn Students will develop the ability to learn better (more efficiently and effectively), in this course and in their future life --- Describes the kinds of activities students will be able to perform in order to continue to learn more about this topic in the future.	Examples of Fink verbs to Consider: Create, Develop, Formulate, Identify, Organize, Select Create a laboratory record of learning goals Formulate a research plan to analyze a housekeeping genes Develop a strategy to learn foundational knowledge about a new or related topic Formulate a new pipeline to solve the preexisting problem in an efficient way	Personal Learning Environment- a set of people and digital resources an individual can access for the specific intent of learning. Students illustrate the potential connections through a visible network of the set Post-Test Analysis- a two-stage process that is divided into several steps designed to help students develop greater awareness of their test-preparing and test-taking skills	Students establish a personal learning goal, estimate time, and identify tools to achieve those personal goals. Here students use web-based tools to correct and curate relevant content and resources. In this, students prepare themselves for test preparation and test-taking skills. It involves identifying and clarifying learning goals, setting assignment parameters, developing a grading plan, communicating the method to the student, and implementing planning and the last evaluation of effectiveness.

3.1.1 Participants and Study Design

To introduce students to concepts of Bioinformatics, we have developed hands-on problem-based engaging in-and out-of-class assessment activities such as worksheets and take-home assignments using basic bioinformatics and computational biology techniques. Students were first introduced to ten basic bioinformatics concepts in ten different sessions held each week which was followed by hands-on demonstration cum implementation of those introduced concepts using bioinformatics tools (computational biology). After this students had to work independently on their own in ten sessions to apply those concepts using already taught bioinformatics tools (each session a week of 2 hours). In each session, students had to work on a specific gene of a particular organism to 1) identify basic gene sequence statistics using Python, 2) perform pairwise sequence alignment to identify orthologous and paralogous species, 3) perform multiple alignments to find out consensus protein among the orthologous species 4) generate a phylogenetic tree to identify the ancestor descendent relationship of a given organism gene with other species of prokaryotic and eukaryotic origin 5) analysis of the secondary and tertiary structure of the protein to visualize the frequency of alpha-helix, beta sheets and coils present in the protein structure and 6) performing hands-on experiments and documenting and interpreting the results in the form of individual in-class worksheets followed by out-of-class take-home assignment sheets of each given specific Gene of a species. At the end of ten sessions, students had to collaborate their entire ten-session results with their respective teammates and compare their results by writing a concise write-up in the form of a comprehensive end-of-semester team report. The entire activities or topics of these ten sessions in the form of in-class worksheets and out-of-class take-home assignments are listed in Table 3-4 and Table 3-5 respectively.

Table 3-4 List of ten in-class worksheets activities

Session	Individual In-class Worksheet as an Assessment Activity
1	In the given gene sequence, determine the- a) summary of the Gene b) Location in the chromosome c) Exon count and its location d) Base composition (size) e) Coding Sequence (CDS) length

2	Write a Python script to find the number of A, T, G, and C and start and stop codons in your gene sequence.
3	To predict the gene statistics of the given sequence, such as length of gene sequence, G+C %, isochore number, gene number, initial internal and terminal exon, single exon gene, size of the longest promoter, poly A signal, type of strand, maximum coding region score, the maximum probability of exon and length of longest amino acid using GenScan.
4	To predict the number of ORFs, name and size of the maximum length of ORF, location of start and stop codons, the direction of the strand, and the total number of amino acids in the biggest ORF using ORF Finder.
5	To perform pairwise sequence alignment between your gene and protein sequence and reference gene and protein sequence, find out nucleotide and protein threshold and window size using EMBOSS Dot matcher. Also, predict the percentage similarity of your gene and protein sequence with reference gene and protein sequence using EMBOSS needle and water tools.
6	To perform pairwise sequence alignment and find out the top five sets of organisms using BLASTn with their respective E-value and score closely related to the given sequence using MEGABLAST having Max target sequences 100. Also, find that a group of distant organisms using Discontiguous MEGABLAST has Max target sequences 5000.
7	Align the given ten nucleotide and protein sequences and generate a guided tree using Clustal-Omega and T-COFFEE, and logically justify which program has provided the more reliable results
8	To construct a phylogenetic tree using distance-based UPGMA and find out the set of organisms that are recently descended, closely related to each other, with minimum distance value based upon the guided tree. Also, find out distantly associated organisms that have maximum distance values based upon the same guided tree.
9	To predict the secondary structure of given protein in terms of the number of alpha helix, beta sheets, turns, and coils using GOR4, Chou-Fasman, Jpred, and PSIPRED algorithms
10	To visualize and analyze the 3-D structure of a protein using web-based iCn3D and stand-alone Rasmol tools

Table 3-5 List of ten out of the class take-home assignment activities

Session	Team Out-of-class Take-Home Assignment as Assessment Activity
1	To retrieve the given DNA sequences from NCBI in Fasta and Genbank format of your teammate's gene sequence.
2	Write a python script to determine and compare the GC content, restriction sites, transcript, and complementary sequence in all the given gene sequences of your teammates.
3	To predict and do a comparative analysis of the functional (exon number, number of initial, internal and terminal exons, single-exon Gene, coding region score, length of longest amino acid) and structural (introns, TFBS, promotor, poly-A signal) regions and type of strand using Genscan and FGENESH.
4	To predict and compare the number of Open Reading Frames (ORF) present in your teammate gene sequence along with the maximum length of ORF and its protein sequence in all possible frames using ORF Finder.

5	To perform and compare pairwise sequence alignment among your teammate's gene and protein sequences using EMBOSS Dotmatcher, Needle (Global), and Water (Local) tools and find out percentage similarity among them.
6	To perform pairwise sequence alignment among your teammate gene and protein sequence using BLASTn and BLASTp to find out the top five closely and distantly related organisms (either Eukaryotes or Prokaryotes)
7	To perform Multiple Sequence Alignment and construct a guided tree using the gene and protein sequences of your teammates and find out closely related species using the Clustal-Omega and T-COFFEE.
8	To construct phylogenetic trees (using both Distance and Character-based methods) from the nucleotide and amino acid sequences of your teammates and determine the closely and distantly related organisms.
9	To predict the secondary structure of your protein sequence (GOR4, Jpred, PHD, Predator, Predict Protein, PSIPRED)
10	Compilation of end-semester report

The course culminated with an end-semester report collating and presenting the results obtained each week. The student learning experience was assessed through a survey taken at the end of the semester.

3.2 Course Implementation Using Integrated Course Design (ICD) and Fink's Taxonomy of Significant Learning or ICD/SL

The current study was carried out at the Department of Biological Sciences at BITS Pilani, India on the Introduction to Bioinformatics course, which is a semester-long course (about 15 weeks). This three-credit course has a lecture component (3 hours a week) and a practical component in hands-on tutorials (2 hours). The Department approved the use of Dee Fink's learning-centered pedagogical model on students of the course for two cohorts, viz., Academic Year 202021 and Academic Year 2021-22. Before the course design adjustments were applied, the 2019-20 control group was used as a baseline.

There were 200 students who were part of this study, including 51 in the control group , 77 in the 2020-21 cohort, and 72 students in the 2021-22 cohort. The same instructors taught all the three groups for the three years.

In the control group, a two-component evaluation method was used (i.e., class participation and weekly assignments) for hands-on tutorial and a final grade score assessment report (i.e., end-semester report) was used as summative evaluation. The total marks/score of the two components was 30 (equally distributed among 10 different experiments) with a 12 minimum passing score. The mode of teaching was designed as per the traditional passive approach of "lecturing", (with no specific assessment activity for achieving the learning outcome of the course) followed by an unstructured hands-on demonstration of an experiment by the instructor on a random or unconnected problem/gene in an online setup using a virtual classroom with a google meet platform. In the end, each student must combine the results of all ten experiments to write an end-semester report.

In the treatment groups, three-component evaluation methods were used for hands-on tutorials, and one final grade score assessment report was used in the summative evaluation. The total marks/score of the three components was 40 (equally distributed among 10 different experiments) with a minimum passing score of 16. Each semester's data included all students who finished the course. The ICD/SL adjustments in the two treatment groups included the creation of Fink's three phases for proper ICD design. These comprised of a preliminary phase in which situational elements (i.e., the specific context of teaching/learning situation, expectations of others for what students learn, nature of the subject, characteristics of the learner, and characteristics of the teacher) were analysed. In the intermediate phase, students used a virtual classroom with the Google meet platform and various support materials, including readings, take-home assignments, worksheets, and demonstration videos made available to students by the instructor.

In this study, non-parametric tests, specifically the chi-square test, were utilized to examine the associations between categorical variables, namely class participation percentages, overall percentage scores, assignment completion percentages, and tutorial ratings, across different years (Control and Treatment). The choice of the chi-square test was appropriate due to the categorical nature of the variables and the non-normal distribution of the data.

The descriptive statistics of all three groups are shown in Table 3-6.

Table 3-6 Descriptive statistics table for the representation of proportionally of different groups

	2019-20 Without ICD/SL	2020-21 With ICD\SL	2021-22 With ICD\SL
Student Number	51	77	72
Percentage Mean Score	74.05228758	85.66558442	77.82291667
Percentage Standard Error	4.038025926	2.149416988	2.072385776
Median	84	91.25	83.25

Mode	100	96.25	84.25
Percentage Standard Deviation	28.83727315	18.86105752	17.58477642
Sample Variance	831.5883224	355.7394908	309.2243618
Kurtosis	0.1923412872	6.581673314	0.9094803742
Skewness	-1.196968193	-2.502242155	-1.309853924
Range Percentage	100	97.5	68.25
Minimum Percentage Score	0	2.5	30
Maximum Percentage Score	100	100	98.25
Sum	3776.666667	6596.25	5603.25

To facilitate visualization and categorize student results in each score report and the final assessment, the academic performance assessment was based on a quantitative scale of 40 (Table 3-7).

Table 3-7 The overall scoring scheme for Bioinformatics course

Experiment/ Assignment No.	Marks for Class Participation/ In-class worksheets	Marks for Experiment/ Out-of-the-class Take-home Assignment	Marks for Collaboration/ Teamwork	Total Marks
1	1	2	1	4
2	1	2	1	4
3	1	2	1	4
4	1	2	1	4
5	1	2	1	4
6	1	2	1	4
7	1	2	1	4
8	1	2	1	4
9	1	2	1	4
10	1	2	1	4
Total Marks				40

The proposed scale was applied to the results acquired by each student in every evaluation report. The final evaluation in each score report in the two treatment groups with ICD/SL corresponds to the summative assessment resulting from the evaluated activities and is weighted for each of the three major categories: class participation, take-home assignments, or in-class collaborative worksheet activities under six domains of Fink's Taxonomy.

The results of the study were collected, stored, and distributed in an Excel-formatted matrix. For nonparametric testing, the P-value was determined using the Kruskal-Wallis test for the ranking of hands-on tutorials, and a parametric P-value determination was done for the summative scores using Z-test in the statistical analysis.

3.3 Creation of Appropriate Assessment Methods

New assessment methods were developed that evaluate student learning outcomes resulting from the implementation of the ICD and TSL. These methods included a combination of formative and summative assessments, as well as self-assessment and peer-assessment strategies.

The assessment methods like in-class worksheets and out-of-class take-home assignments were created and used as an evaluation tool to access students' learning at the Department of Biological Sciences, BITS-Pilani, Pilani Campus. These in-class worksheets and out-of-class take-home assignments were successfully incorporated as a pedagogical approach for the assessment of third-year biology students to promote a student-centered interactive, personalized, and collaborative learning environment. The purpose of the study was to increase students' active engagement and improvement of learning in the "Introduction to Bioinformatics" course. It was necessary to assess student satisfaction with these assessment methods and to increase the assignment completion rate.

3.3.1 Conceptual framework

Student learning is aided by worksheets in a variety of ways. They assist students in remembering information for extended periods of time, which helps them perform better on the end-semester reports. Additionally, worksheets encourage students to attend class routinely. Additionally, graded take-home assignments make students study to be prepared for the weekly submissions. It is believed that completing take-home assignments will improve student comprehension of the course information and memory recall. However, if they fail to complete the tasks, the students might not gain anything from working on them.

3.3.2 Data

Data from three years (2019-20, 2020-21, and 2021-22) of the "Introduction to Bioinformatics" course were used to create the study. In the first-year traditional approach was used, while in the second and third years, the same topics were taught using Integrated Course Design (ICD) problem-centered model and following the same course outline.

There were no take-home assignments or worksheets in the first segment, instead, a weekly non-evaluative experiment submission was monitored, and the evaluation was based on the end-semester report only (Figure 3-1). The grading scheme for the second and third-year portions consisted of in-class worksheets and take-home assignments, along with end-semester report submission and evaluation have a separate component for both worksheets and take-home assignments (Figure 3-2).

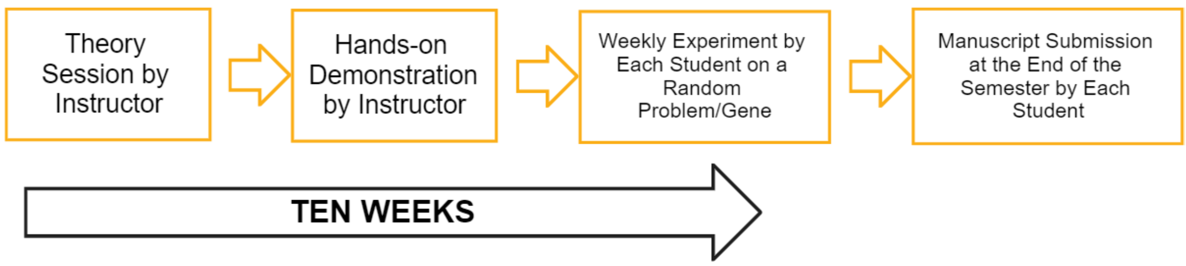


Figure 3-1 The control group 2019-20 assessment activities

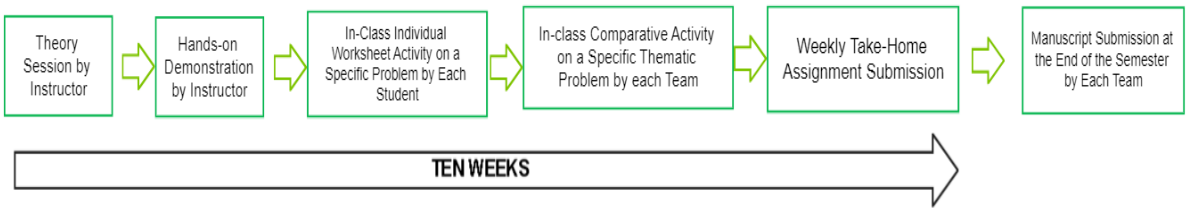


Figure 3-2 The treatment group (2020-21 and 2021-22) assessment activities

3.3.3 Overview of course and assessment

Since 2019-20, we have been developing the "Introduction to Bioinformatics" (BIO F 242) tutorial course to examine how our knowledge of Python and computational tools can help in understanding the concepts of bioinformatics. Additionally, we have used Integrated Course Design (ICD) along with problem-centered collaborative assessment activities like in-class worksheets and out-of-the-class take-home assignments while designing the teaching and learning activities for BIO F 242 in 2020-21 and 2021-22 respectively. Thirteen specific genes were given in the course, one per group. Every week, each module was presented through one hour lecture followed by a hands-on class session. All students were expected to participate in hands-on demonstrations because both theory and hands-on sessions are intended to be interactive. A formative worksheet assessment and a summative take-home assignment were used to count student participation and grading of the course.

3.4 Identification of Classroom Management Platforms and Tools

A review of existing classroom management platforms and tools was conducted to identify those that can effectively support the implementation of Team Based Learning and the new assessment methods. The selected platforms and tools were then integrated into the teaching and learning process.

To effectively incorporate a pedagogical approach to teaching in sophomore and freshman years for biology education that may promote a student-centered interactive and collaborative learning environment, the TBL method was established at the Department of Biological Sciences, BITS-Pilani, Pilani Campus and Plaksha University, SAS, Nagar, Punjab. The study's goal was to provide an overview of the creation and application of a TBL educational model in a course on biology education. The promotion of student learning as determined by knowledge acquisition was to be evaluated, and student happiness with the TBL experience was to be examined.

3.4.1 Team Assignment and Preparation

Based on guiding principles developed by Michaelsen and Richards, team-based learning was put into practice. The educational intervention for the sophomore biology students at BITS-Pilani, Pilani Campus, and freshman course at Plaksha University, SAS Nagar, Punjab used TBL in two to five tutorial sessions for around two hours per session. The students were given an orientation that explained the format of this teaching strategy in detail and gave out instructional materials and team rosters. Before the tutorial class, the allocated homework had to be finished by the students. The faculty participants in each session met to discuss the cases that would be presented and the supporting materials that would be offered. The students had access to preparation materials on Google Drive through the online Learning Management System (Nalanda, DLE), including literature readings, videos, and textbooks.

TBL activities comprised of 77 students in Genetics, 78 students in Integrated Biology and 48 students in Engines of Life course. In each course nearly eight to thirteen teams were formed containing 5-7 students. Instead of letting the students choose their own team members, the course teacher randomly selected teams. To encourage team building, the team assignments stayed the same throughout the course. All TBL sessions had to be attended by the students.

3.4.2 Instruments for Team-Based Learning

In Team-Based Learning (TBL), various instruments are utilized to assess different constructs related to student learning and performance. These instruments are designed to measure both individual and team-based outcomes, providing valuable insights into students' understanding and collaboration skills. Below are some common instruments used in TBL, along with the constructs they measure and the corresponding data analysis techniques:

1. **Readiness Assurance Test (RAT):** Constructs measured: Individual preparedness, comprehension of pre-class materials, retention of key concepts.
2. **Data analysis techniques:** Quantitative analysis, including calculation of individual and team scores, item analysis (e.g., item difficulty, discrimination index), and comparison of pre- and post-test scores to assess learning gains.
3. **Individual Readiness Assurance Test (iRAT):** Constructs measured: Individual understanding of pre-class materials, ability to apply knowledge independently.
4. **Data analysis techniques:** Similar to RAT, focusing on individual performance metrics such as correct/incorrect responses, individual readiness scores, and comparisons over time.
5. **Team Readiness Assurance Test (tRAT):** Constructs measured: Team collaboration, communication, consensus-building, collective problem-solving skills.
6. **Data analysis techniques:** Assessment of team performance metrics, including team readiness scores, consensus answers, and comparison of team scores with individual scores to evaluate collaboration effectiveness.
7. **Application Exercises:** Constructs measured: Application of knowledge to real-world scenarios, critical thinking, problem-solving, decision-making.
8. **Data analysis techniques:** Qualitative analysis of student responses to open-ended questions, rubric-based scoring to evaluate depth of understanding and reasoning abilities, and thematic analysis to identify common patterns or misconceptions.
9. **Peer Evaluation:** Constructs measured: Contribution to team activities, teamwork skills, communication, reliability, professionalism.
10. **Data analysis techniques:** Quantitative analysis of peer evaluation scores, calculation of individual and team ratings, identification of outliers or discrepancies, and assessment of inter-rater reliability.

11. **Team-based Discussions:** Constructs measured: Collaboration, active participation, knowledge sharing, peer teaching, synthesis of diverse perspectives.
12. **Data analysis techniques:** Qualitative analysis of group discussions, identification of key themes or arguments, evaluation of contributions from each team member, and assessment of overall group dynamics.

3.4.3 In-class Session

The Backwards Design was used in the course design for TBL preparation by first defining the application activities that typically occur at the conclusion of a TBL session, then figuring out the essential background information the students needed to approach and solve the problem. Finally, the instructor created the multiple-choice questions for the individual and team Readiness Assurance Test (RAT) and chose the pre-reading materials.

The selected tutorial session began with a RAT, in which the students were required to complete it in two ways: first, alone, and then in teams, working on identical problems. For 15 minutes at the start of class, students used Nalanda or DLE (Learning Management System)/ Google Forms/ print copy to complete a 5-10-question multiple-choice test called the individual RAT (iRAT) to gauge their preparation. Every student responded to the questions on their own and sent in their responses for evaluation after iRAT. Following the individual RAT (iRAT), the predetermined teams of students retook the identical multiple-choice questions for a further 15 minutes, this time engaging in active debate to choose the correct answer. This procedure is known as the team RAT (tRAT). The students in each team in each session had to provide their answers as they worked earlier on the same set of questions as individual students.

After the team RAT (tRAT) and discussion, students could choose to complete an optional application exercise that included a case study connected to “Genetics”, “Integrated Biology” and “Engines of Life” courses. This exercise required them to apply their fundamental knowledge to complex tasks that called for problem-solving and critical-thinking abilities. An independent t-test was used to compare and analyze the impact of TBL through collaborative learning on both the individual and team RAT ratings. Excel was used to perform all of the analyses. Reflective writings were used to gauge student opinions of the effects of TBL on the development of their learning and communication abilities in the Genetics course.

3.5 Development of a Student Feedback Questionnaire

A new student feedback questionnaire was designed that captures the student learning outcomes more accurately. The questionnaire was customizable according to the instructor/institutional needs. It was tested and refined based on feedback from students and instructors.

The designing and analysis of the student feedback questionnaire for the third-year course of Bioinformatics (BIO F242) were done at the Department of Biological Sciences, BITS-Pilani, Pilani Campus. The goal of this study was to make a questionnaire for student feedback and analyze the student's subjective and open-ended feedback analysis using the web-based sentiment analysis tool "Pratikriya" using open libraries of python in the teaching-learning environment. The typical questions in the questionnaire are represented in Supplementary Data Sheet -I

3.5.1 Design of the questionnaire

It involved determining the objectives of the feedback and creating questions that would gather the information that is relevant and useful for improvement. In our study, our focus of the questionnaire was to check students' responses regarding the use of Active learning techniques and assessment strategies like take-home assignments and worksheets in the hands-on tutorial setup of the Bioinformatics course. We have constructed a questionnaire for the Introduction to Bioinformatics (BIO F242) course at BITS, Pilani for assessing the feedback of students.

To ensure the reliability and validity of a questionnaire, it was checked by experienced teachers or instructors. This process involved the expertise of individuals familiar with the subject matter and knowledgeable about the measurement properties of the questionnaire. The experienced teachers or instructors reviewed the questionnaire items to assess content validity. They examined whether the questions accurately reflected the concepts being measured and ensured that the wording was clear and comprehensible to the target students. Their expertise and understanding of the topic allowed them to provide valuable insights and make necessary revisions to enhance the content validity of the questionnaire.

3.5.2 Mode of delivery and sample size

The mode of administration or conducting the survey was online using Google forms where a link was sent to students and nearly a week duration was given to them followed by a gentle reminder before the day of deadline was given. The target audience was third-year students of the Introduction to Bioinformatics course (BIO F242) having a sample size 51 for 2019-20, 77 for 2020-21, and 72 for 2021-22 respectively.

3.5.3 Collection and analysis of data

Collection and analysis of data typically involve the use of a sentiment analysis tool which is useful in the identification and extraction of subjective information from the feedback (text) data of students. It can be used to analyze student feedback to assess the effectiveness of a course or instructor. To perform sentiment analysis on student feedback, natural language processing (NLP) techniques can be used to analyze the text data and classification can be done in terms of positive, negative, or neutral. This can be done manually or with the help of a software tool. Overall, sentiment analysis can be a useful tool for assessing the effectiveness of a course or instructor based on student feedback. It can provide valuable insights into the strengths and weaknesses of a course and help instructors identify areas for improvement.

We have made used the web-based sentiment analysis tool "Pratikriya" using open libraries of python (https://share.streamlit.io/ashishkatyal/pratikriya/main.py) for feedback analysis in terms of polarity, subjectivity (Figure 3.3). A web-based sentiment analysis tool is advantageous because it is accessible from anywhere, has a user-friendly interface, provides real-time analysis, can handle large volumes of data, allows for collaboration and sharing, and can be regularly updated and improved. These benefits make it convenient and efficient for instructors to analyze sentiment in subjective feedback data.

Figure 3-3 Pratikriya- The Sentiment Analysis Tool

A typical sentimental analysis involves dividing the feedback text into smaller words followed by normalization and vectorization so that we can determine the sentiment of the feedback using machine learning. (Figure 3.4)

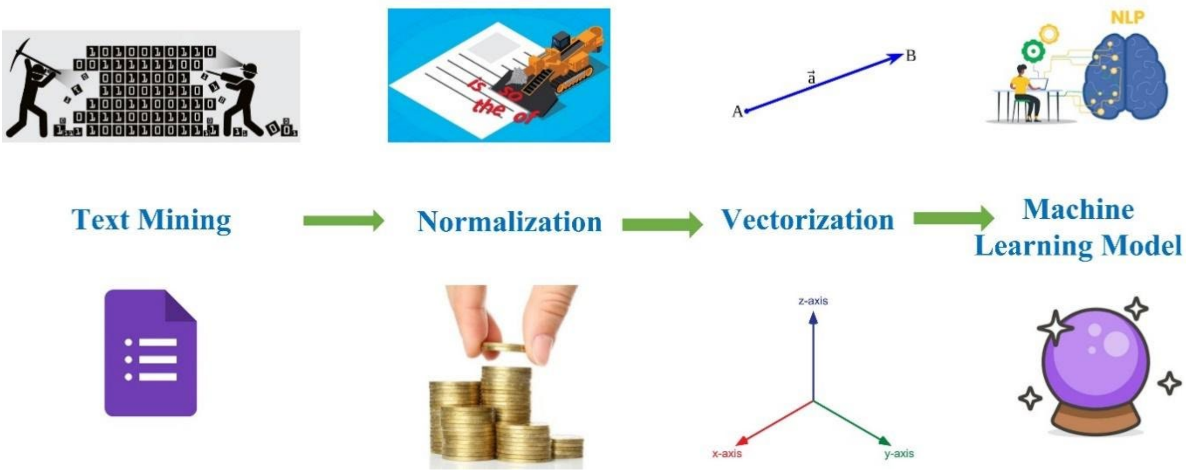


Figure 3-4 The overview of "Pratikriya" application involves four step process

The “Pratikriya” application involves a simple interface of scanning a barcode followed by submission and analysis of feedback (Figure 3.5).

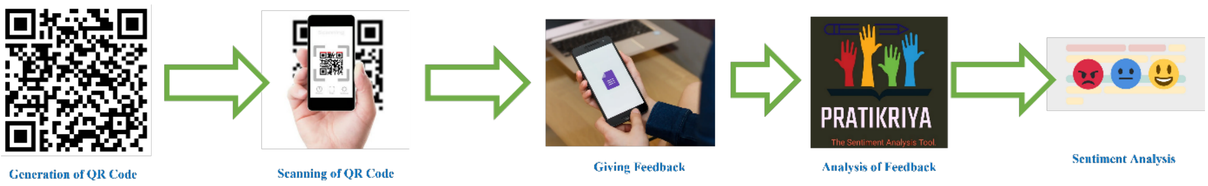


Figure 3-5 The layout of web-based tool “Pratikriya”

3.6 Data Collection and Analysis

Data were collected throughout the implementation of the new course design, the utilization of the new assessment methods, and the administration of the new student feedback questionnaire. To assess the internal consistency of the questionnaire used in this study, Cronbach's alpha coefficient was computed. Cronbach's alpha evaluates the extent to which items within a scale or questionnaire measure the same underlying construct. A value closer to 1 indicates higher internal consistency reliability.

The questionnaire comprised nine items designed to gauge the extent of agreement or disagreement among students regarding the provided statements. Each item was rated on a scale of 1 to 5, with 1 indicating "strongly disagree" and 5 indicating "strongly agree". The data were analyzed using Microsoft Excel, which calculated the Cronbach's alpha coefficient.

A value exceeding 0.70 is generally considered acceptable for Cronbach's alpha, signifying satisfactory internal consistency. However, values above 0.80 are preferable to ensure robust reliability. This data was analyzed to evaluate the effectiveness of these new approaches in addressing the identified gaps in existing pedagogy.

3.7 Reporting and Dissemination

The findings from the data analysis were reported in a clear and comprehensive manner. The results were disseminated through appropriate channels to reach educators, researchers, and policymakers who could benefit from this research.

4 Results and Discussion

4.1 Integrated Course Design

There are specific key points that have been observed:

1) Class participation increased by 23 to 27 % in 2020-21 and 2021-22 also, class absenteeism reduced by nearly 34 to 69 % in 2020-21 and 2021-22 (Figure 4-1). The chi-square test was conducted to investigate the association between class participation percentages and years (Control and Treatment). The results indicate a strong relationship between these two categorical variables. The computed chi-square statistic is approximately 53.71. This value signifies the strength of the association between class participation percentages and years. A higher chi-square value indicates a stronger association.

The p-value associated with the chi-square statistic is approximately 7.85×10^{-9}. This extremely low p-value suggests strong evidence against the null hypothesis. In practical terms, it indicates that the likelihood of observing such an extreme association between class participation percentages and years purely by chance is nearly impossible. Therefore, there is very strong evidence to suggest that there is indeed a relationship between the years and class participation percentages.

The degrees of freedom for this test are 8, which is calculated based on the number of rows and columns in the contingency table. In this case, 8 degrees of freedom indicate that there are enough independent observations to make reliable inferences.

The expected frequencies table shows the frequencies expected under the assumption of independence between the two variables. The observed frequencies are compared to these expected frequencies to compute the chi-square statistic.

So, with such a low p-value, we reject the null hypothesis of independence. This suggests that there is a significant association between the years and class participation percentages in the context. In other words, the differences observed in class participation percentages across the years are unlikely to be due to random chance alone. These findings are crucial for understanding the dynamics of class participation over time.

2) Significant difference was observed for in-class participation between control (2019-20) and treatment groups (2020-21, 2021-22) using the Z test and has $P<0.05$.

3) The number of students increased by about 12 to 20 % in the Excellent and good category, and the failure rate decreased by about 45 to 63 %. Here, we have categorized the data into five class where 20 or less represents Poor 20-40 represents Bad, 40-60 represents Fair, 60-80 represents Good and 80-100 represents Excellent (Figure 4-2).

4) A significant difference in overall score between control (2019-20) and treatment (2020-21) using Z test and has $P<0.05$ and but not between control (2019-20) and treatment (2021-22).

The chi-square test was conducted to investigate the association between overall percentage score and years (Control and Treatment). The results indicate a strong relationship between these two categorical variables. The computed chi-square statistic is approximately 108.077. The chi-square statistic is quite high, indicating a significant association between the overall percentage scores and the years.

The p-value associated with the chi-square statistic is approximately $6.85 \times 10-22$. The very low p-value suggests strong evidence against the null hypothesis, indicating that there is a significant relationship between the years and overall percentage scores.

The degrees of freedom for this test are 8. With 8 degrees of freedom, we have a sufficient number of independent observations to make reliable inferences.

The expected frequencies table shows the expected counts for each combination of overall percentage scores and years, assuming that there is no relationship between the two variables. So, based on these results, we can conclude that there is a significant association between the years and overall percentage scores.

5) Also, the assignment completion rate increased by about 15 to 20 %, and assignment incompletion reduced to about 38 to 67 % (Figure 4-3).

The chi-square test was conducted to investigate the association between percentage assignment completion and years (Control and Treatment). The results indicate a strong relationship between these two categorical variables. The computed chi-square statistic is approximately 10.141. The chi-square statistic is moderate, indicating a noticeable association between the assignment completion percentages and the years.

The p-value associated with the chi-square statistic is approximately 0.0395. The p-value is less than the conventional significance level of 0.05, indicating that we reject the null hypothesis.

The degrees of freedom for this test are 8. With 8 degrees of freedom, we have a sufficient number of independent observations to make reliable inferences.

The expected frequencies table shows the expected counts for each combination of assignment completion percentages and years, assuming that there is no relationship between the two variables. So, based on these results, we reject the null hypothesis and conclude that there is a significant association between the years and assignment completion percentages.

6) The negative rating about the course also reduced by 36 to 100% in the treatment groups (Figure 4-4).

The chi-square test was conducted to investigate the association between tutorial ratings and years (Control and Treatment). The results indicate a strong relationship between these two categorical variables. The computed chi-square statistic is approximately 85.854. The chi-square statistic is high, indicating a significant association between the tutorial ratings and the years.

The p-value associated with the chi-square statistic is approximately $1.504 \times 10{-}17$. The very low p-value suggests strong evidence against the null hypothesis, indicating that there is a significant relationship between the years and tutorial ratings.

The degrees of freedom for this test are 8. With 8 degrees of freedom, we have a sufficient number of independent observations to make reliable inferences.

The expected frequencies table shows the expected counts for each combination of tutorial ratings and years, assuming that there is no relationship between the two variables. So, based on these results, we reject the null hypothesis and conclude that there is a significant association between the years and tutorial ratings.

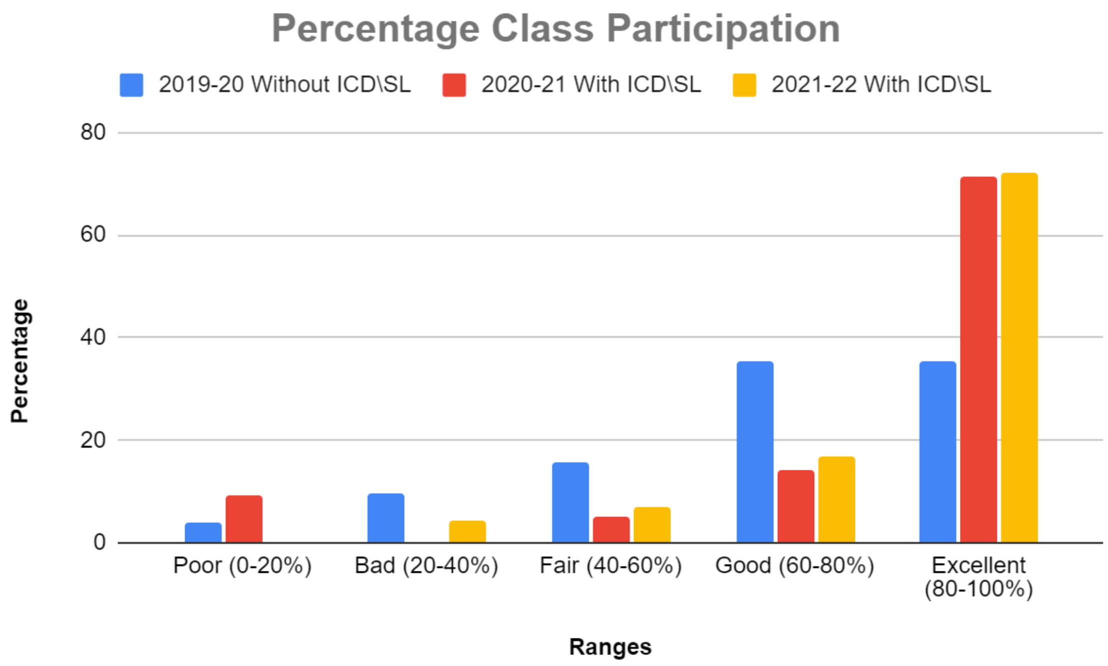


Figure 4-1 Class participation of students in the control (2019-20), and treatment groups (2020-21 and 2021-22)

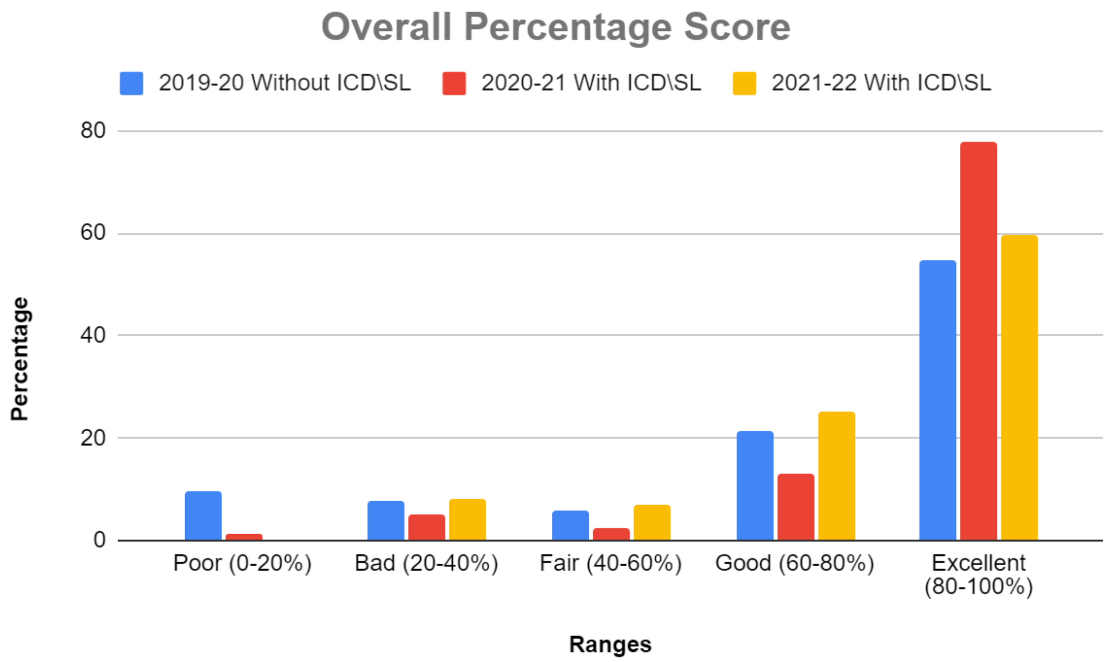


Figure 4-2 Overall percentage score of students in the control (2019-20), and treatment groups (2020-21 and 2021-22)

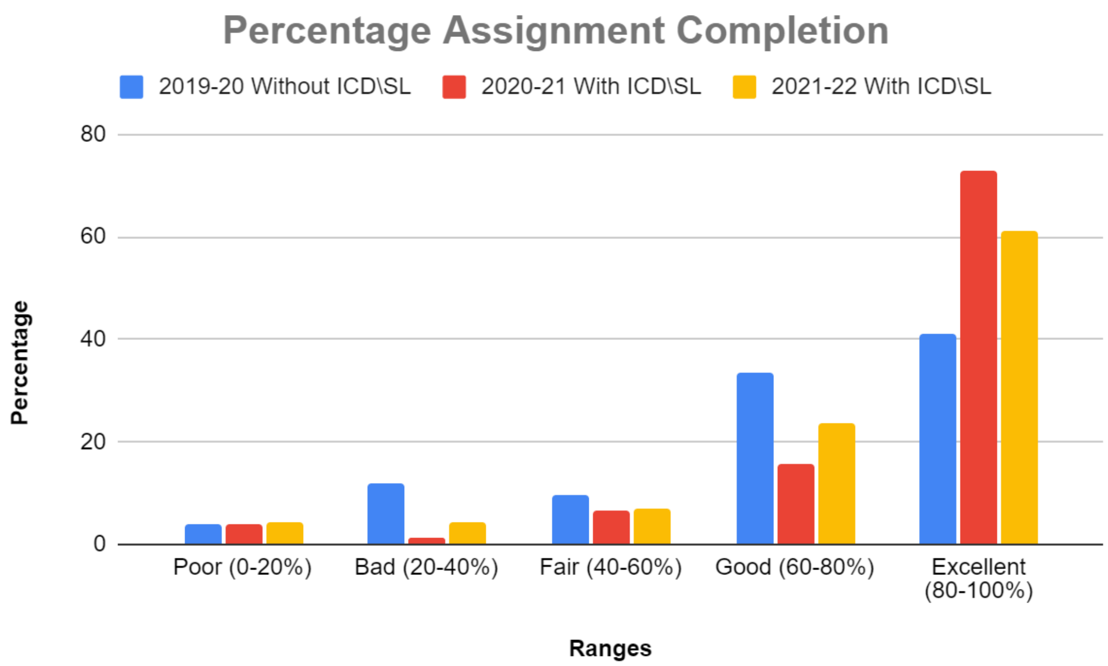


Figure 4-3 Percentage assignment completion of students in the control (2019-20), and treatment groups (2020-21 and 2021-22)

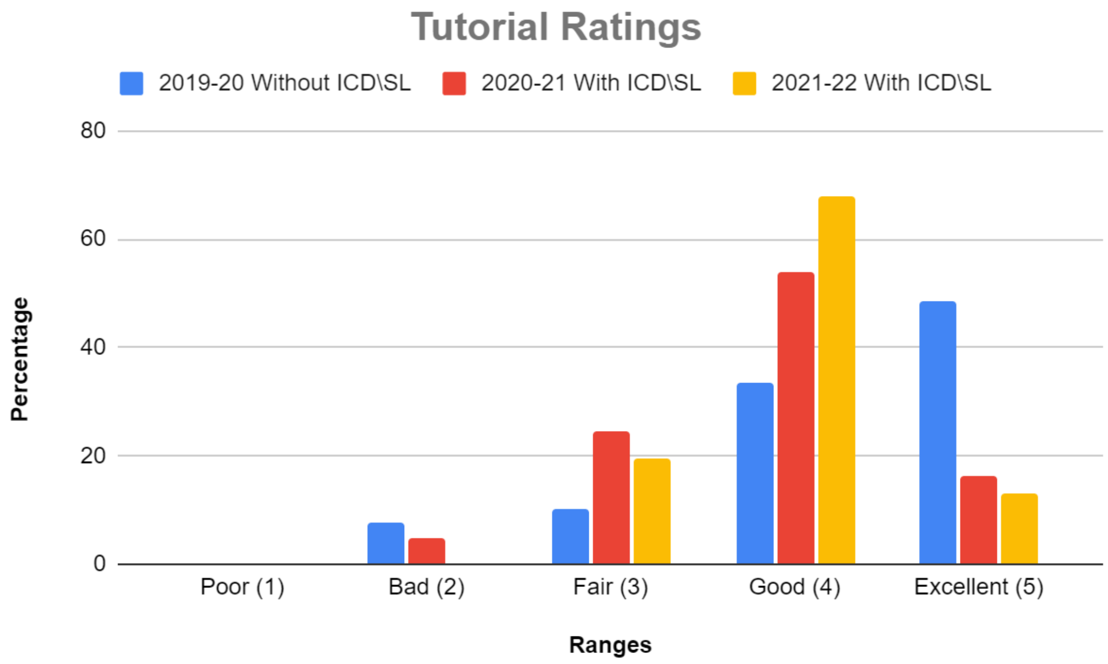


Figure 4-4 The overall ratings by the students in the control (2019-20), and treatment groups (2020-21 and 2021-22)

The overall outcomes of this study corroborate the findings of other researchers who used the ICD/SL and saw considerable gains in academic performance in various disciplines of sciences, engineering, and arts (Branzetti et al., 2019; Jenkins, 2015; Killian & Brandon, 2009; L. E. Levine et al., 2008). To the best of the authors ' knowledge, this study was the first to investigate the influence of ICD/SL in an undergraduate course on bioinformatics; no such study associated with teaching of this subject was discovered in any of the consulted databases (Kedraka, 2020).

According to Biology Education Research (BER), all biologists should emphasize practical hands-on knowledge, effective communication, teamwork, professional and ethical behavior, the use of emerging technologies, and developing critical thinking to effectively solve diverse biological problems (Kedraka, 2020). As a result, the course syllabus should emphasize these skills and the learning experiences that support their growth and methods for assessing their attainment while encouraging students to be active participants in their learning.

This study aimed to fill a gap in the bioinformatics teaching with respect to Fink's Taxonomy and course design model to guide the educational community in the implementation of more effective teaching and learning activities that will enable students to develop the full range of competencies that all bioinformaticians must possess. The most significant change observed in terms of increase in average class participation, overall students score, percentage assignment completion and overall ratings by the students during this study. There was a shift in the learning behavior of students from rote memorization to development skills based on collaboration, critical thinking, reflection, and integration due to in-class worksheets, take-home assignments and collaborative team activities.

This study highlighted a favorable and statistically significant link between the two treatment groups that utilized the ICD/SL and the control group that did not use the ICD/SL update as evidenced by skewness value (Table 3-6) that represents that trend of increase in marks in the treatment groups and shifting of histogram curve towards right. Fink's Taxonomy framework's efficacy in teaching is determined by its utilization. It’s critical to concentrate more on the formative portion of the evaluation and include student participation, allowing for clear communication and good/excellent feedback.

It is apparent that academic performance improved as the course progressed, as evidenced by the evaluation reports where students were able to analyse and interpret the data on their own. The authors attribute these gains to the following factors: appropriate learning goals were incorporated into each of the teaching/learning and assessment activities using the ICD/SL model; attention was paid to the Human dimension, Care, and ‘Learning How to Learn’ learning types; and group work, reflection, and integration with other areas of knowledge were included in the learning activities (Jenkins, 2015).

The study found out that students do better in active learning situations like problem-centered learning. These factors improve students' intrinsic desire and commitment to the course, their peers, and their teachers. These findings are also in line with earlier research (Kellesarian, 2018; Lone et al., 2018) that suggests that a combination of active learning strategies enhance student interest and has a substantial impact on commitment and learning as it foster critical thinking, and engagement of the students. The development of these aspects is critical in the field of biology education because it allows our current students to integrate the various contexts in which they will work and make a swift and successful transition to challenging situations of exponential biological data handling as future bioinformaticians.

There were also some significant differences like mean score and average class participation between control (2019-20) and the two treatment periods (2020-21 and 2021-22) when analyzing the results; this is likely because of the ICD/SL-related activities were implemented for the first time in the 2020-21 period, and subsequently during the second treatment period of 2021-22.

Analyzing these three periods has allowed us to show that, independent of the student group or the teacher/student relationship or rapport, the ICD/SL method of course design is practical and flexible since it can be tailored to the needs of each group of students based on the situational elements.

Teachers must analyze and monitor the individual needs of each team and alter the course design accordingly on a regular basis. The course structure necessitates the employment of active pedagogical actions by the instructor, which requires teachers' ongoing quest for ideas and research that point to modifications that will improve students' academic performance.

4.2 Assessment Methods

To assess the student's perception of these inside and outside class assessment activities, we surveyed students using a Likert scale and asked them to rate these activities and give written reflective feedback on these in and out-of-the-class worksheets and take-home assignments, respectively. Separate marks were allocated to these inside-the-class worksheets (1 mark) and out-of-the-class take-home assignments (2 marks).

There are specific key points that have been observed:

1) The worksheet incompletion rate was reduced by about 10% in 2021-22 in comparison to 2020-21 (Figure 4-5).

2) The percentage of students increased by about 17% in the Excellent category, and the failure rate decreased by about 3% in the bad category for the take-home assignment. Here, we have categorized the data into five classes where 20 or less represents Poor 20-40 represents Bad, 40-60 represents Fair, 60-80 represents Good and 80-100 represents Excellent (Figure 4-6).

3) The survey results showed that most students, about 80.3% in the 2020-21 batch and 96.8 % in the 2021-22 batch, reported that they enjoyed the assessment activities in the form of in-class worksheets and out-of-class take-home assignments and these activities should be continued for future batches of students too (Figure 4-7).

4) The survey results also showed that about 71-87 % of students of both 2021-22 and 2020-21 batches agreed that there was a great role of in-class worksheets and out-of-the-class take-home assignments in achieving better learning (Figure 4-8).

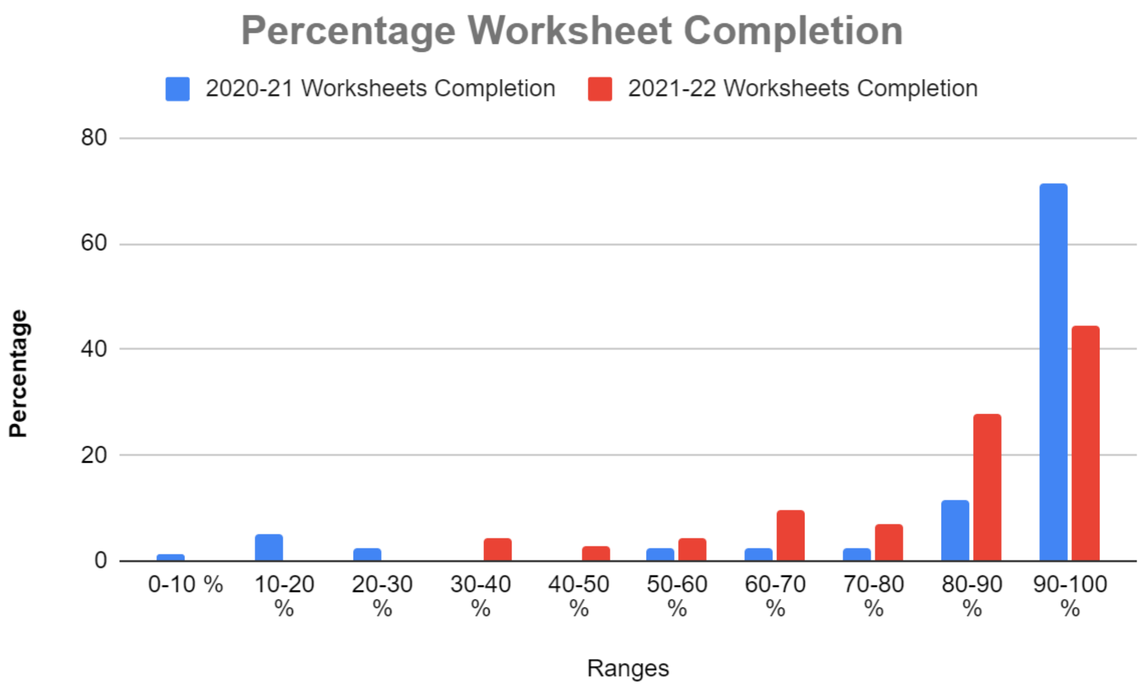


Figure 4-5 Percentage of worksheets completed in the treatment year 2020-21 and 2021-22 respectively

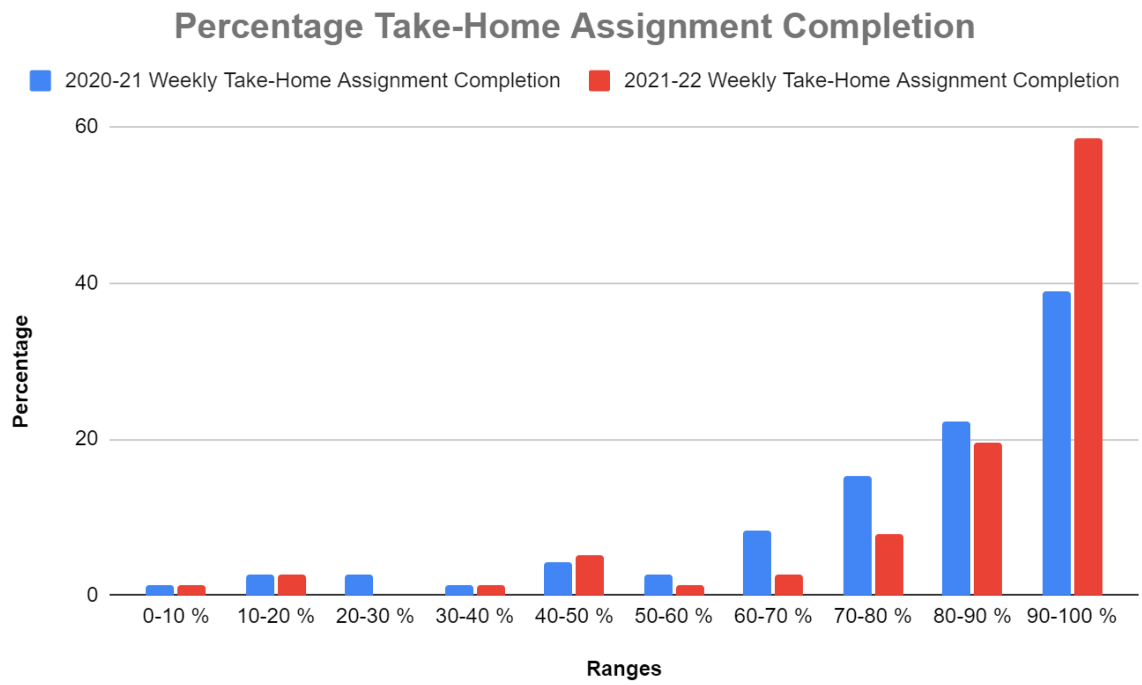


Figure 4-6 Percentage of take-home assignment completion in the treatment year 2020-21 and 2021-22 respectively

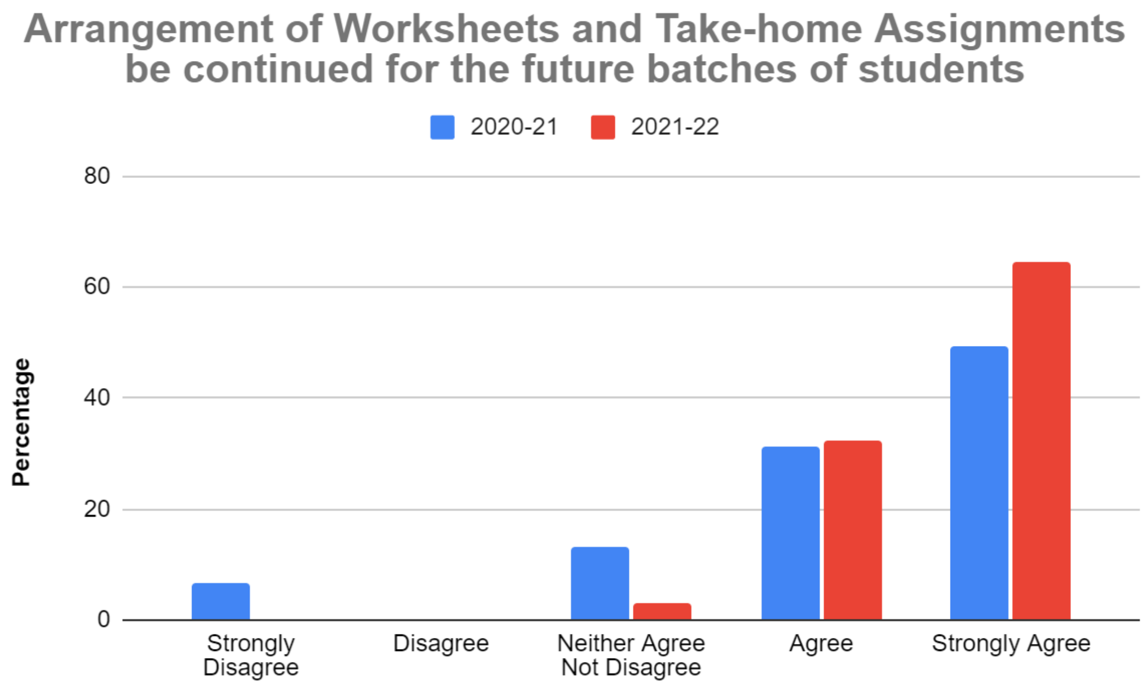


Figure 4-7 Survey reported an agreement of students of the 2020-21 and 2021-22 batches to use the arrangement of worksheets and take-home assignments as an assessment activity for future batches of students

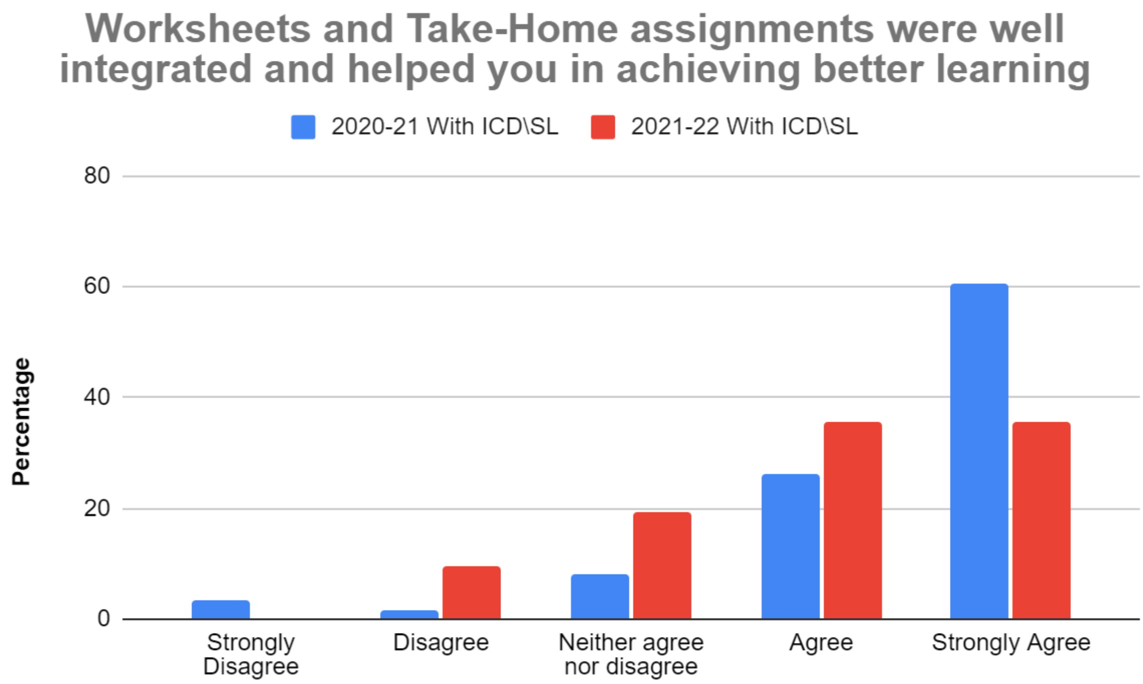


Figure 4-8 Student feedback survey about the role of worksheets and take-home assignments and their role in learning

Take-home assignments provided an opportunity for students to engage with the material outside of the classroom, which helped them in reinforcing their understanding of the concepts being taught in the class. While, worksheets are particularly useful for practicing specific skills, such as computational thinking or programming language exercises in class. Take-home assignments also allowed students to explore and apply concepts in their own time and at their own pace. It also helped the students to develop self-discipline and time-management skills, as they must complete the assignments on their own without direct supervision before the deadlines. In addition, worksheets and take-home assignments acted as valuable feedback to both students and the instructors. Students can use the feedback to identify areas where they need improvement, while teachers can use the feedback to adjust their instruction and tailor their teaching to meet the needs of individual students. However, it's important to note that the effectiveness of worksheets and take-home assignments is dependent on how they are designed and implemented. The assignments mentioned in Tables 3-6 and 3-7 were challenging, engaging, and relevant to the course material.

The subjective student feedback also gives an insight into students' learning experience about assessment aspects of the tutorial course was useful. This includes:

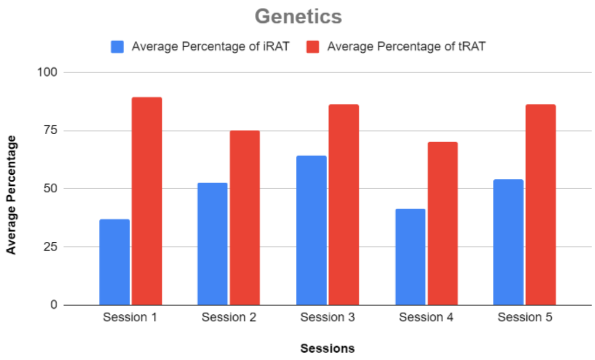
Some subjective feedback from students also gives an insight into their experience about assessment aspects of the tutorial course was useful. This includes:

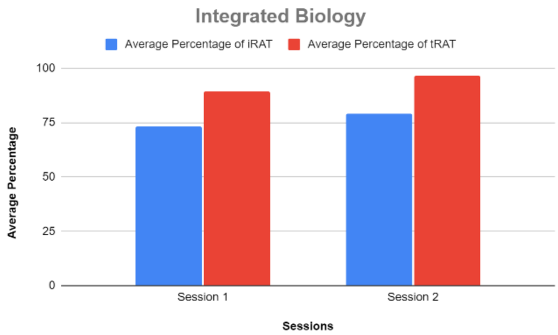
1. Class assessment activities and efforts by the instructor created a more interactive environment that helped me focus better and the whole session became more engaging.

2. Weekly take-home assignments also increased my familiarity with the bioinformatics tools and strengthened the concepts.

4.3 Team-Based Learning

Nearly seventy-seven second year and ninety-six first year students performed five and two separate RAT tests on an individual and team basis for Genetics, Integrated Biology and Engines of Life courses, respectively. The mean individual student scores on the RATs for Genetics ranged from 37 to 64, and the mean team scores were between 70 and 90, While for Integrated Biology, mean individual RAT scores ranged from 73 to 79 and the team mean RAT scores were between 89 and 96 and for Engines of Life, mean individual RAT scores ranged from nearly 56 to 60 and the team mean RAT scores between 72 to 81. (Figure 4-9 a, b and c respectively). Table 4-1 displays summaries of the individual and similar team scores for each RAT both for Genetics and Integrated Biology courses. The highlights of iRAT and tRAT sessions at BITS, Pilani and Plaksha University, SAS, Nagar respectively (see Fig. 4-10 and 4-11).





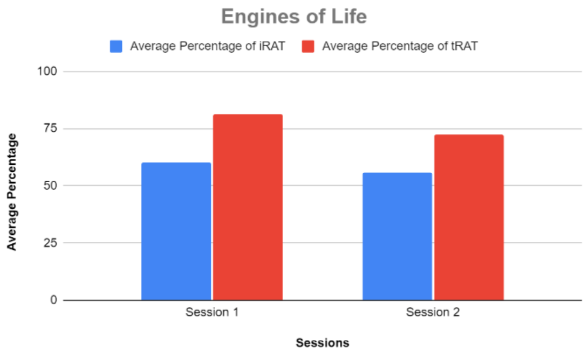


Figure 4-9 a, b and c (counterclockwise): Comparison of individual and team Readiness Assurance Test (RAT) scores of second-year courses of Genetics and Integrated Biology and first-year course of Engines of Life

Table 4-1 Descriptive summary of individual and team Readiness Assurance Test (RAT) scores of Genetics, Integrated Biology and Engines of Life

	Group	N	Range	Maximum	Minimum	Mean	Standard Deviation
Genetics							
Session 1	Individual	77	55.55556	61.11111111	5.555555556	36.78	1.263
	Team	13	33.33333	100	66.66666667	89.56	0.775
Session 2	Individual	77	72.5	87.5	15	52.7	1.614
	Team	13	37.5	92.5	55	75	1.041
Session 3	Individual	77	72.5	92.5	20	64.5	1.683
	Team	13	25.8	100	74.2	86.3	0.846
Session 4	Individual	77	87.4	90	2.6	41.4	0.825
	Team	13	48.8	97.6	48.8	70.2	0.832
Session 5	Individual	77	90	95	5	54	1.015
	Team	13	30	100	70	86.2	0.48
Integrated Biology							

Session 1	Individual	78	70	100	30	73.3	1.51
	Team	13	20	100	80	89.4	0.67
Session 2	Individual	78	80	100	20	79	1.95
	Team	13	20	100	80	96.4	0.7
Engines of Life							
Session 1	Individual	48	82.08	89.77	7.69	60.36	15.88
	Team	8	16.69	89.77	73.08	81.11	6.56
Session 2	Individual	48	68.5	79.46	10.92	55.88	13.69
	Team	8	35.92	85.92	50	72.52	12.92

Figure 4-10 a, b, c and d (left to right). The glimpse of iRAT and tRAT sessions for Team-Based Learning at BITS-Pilani

Figure 4-11 a, b, c and d (left to right). The snapshot of RAT sessions for Team-Based Learning at Plaksha University-SAS Nagar

Teams performed nearly 32 percentage points in Genetics, 17 percentage points in Integrated Biology and 19 percentage points in Engines of Life better on average than individuals did. In three of the five exams—1, 4, and 5—there was a large discrepancy between the team and individual marks in the Genetics course (Bass et al., 2018; Haspel et al., 2019; Hurst-Kennedy, 2018; Park et al., 2019).

The online mode of lessons in Genetics and offline mode in Integrated Biology and Engines of Life made it possible to learn about different aspects of the course. The iRAT and tRAT scores varied significantly, with some extremely pronounced improvements (as discussed before) and an effect size of 29.63 in Genetics, 12.7 in Integrated Biology and 1.49 in Engines of Life courses. The survey's findings were all favorable, and a large majority of students said they would like to do such activities in other courses too.

The student feedback regarding their experience of Team-Based Learning (TBL) was positive in the end-of-semester survey. Most students concurred or strongly concurred that they were able to comprehend class concepts thanks to tRAT and application problem sets. Also, the majority said they used the TBL resources to study for tests and thought understanding genetics was pertinent to their courses. Other comments from students regarding different aspects of TBL which they found useful or valuable are:

“I think the ability to learn from other people's understanding of the topic is very valuable as also being able to share my own idea about the topic”.

“It was great to have a team to discuss and learn. A lot of concepts were clearer as each and every one had to engage and interact and gain some perspective from each other”.

“I was able to learn a lot from my teammates. The activities also helped me apply the knowledge I gained from class to practical contexts”.

“It was very valuable to me because it helped me to know different perspectives of each individual”.

“Team discussions helped to reinforce some of the weak understanding points for me”.

“The spirit of teamwork and scope for improvisation were the valuable aspects of the TBL”.

“I think learning from the other members in the group and exchanging knowledge was extremely valuable and is what ultimately allowed us to arrive at our final answer”.

“TBL is a great way to discuss the concepts taught in the class. Its a nice way of leaning things”.

“It helped me learned better communication and teamwork, thus summing up the whole process we learned”.

“TBL was useful as all of us could discuss our view and reach to one conclusion and if we have any doubt also that are being cleared and it was more of learning from your team members”.

“TRAT was of more help to me in clearing my knowledge gaps and thinking in a linear fashion”.

“The discussions open a whole spectrum of knowledge that you as an individual, didn't have at the start of the process but got by the end. Team-based tests too turn into learning opportunities in contrast to individual assessments”.

“The discussions and application-based questions proved to be helpful. It allowed us to collaborate and improve our answers”.

“There was a quick discussion on every application. I got to know about various approaches to solving the given application. It broadened my horizon on how the applications actually work and my understanding became clearer. Answering questions became more efficient”.

“The TBL was a good revision of all the concepts learned and binding all of them together. The last activity also helped me understand how these conceptual studies can be applied to scientific research and in bioengineering”.

The TBL format promotes communication skills, knowledge application, and peer-to-peer learning; according to reflective writings of students, the class participation and attitude toward the TBL learning skills were found to be better as a comparison to experiences of students in the traditional lecture format. In contrast to learning in a conventional design, the students felt that the TBL format enhanced their self-directed learning and critical thinking abilities.

The current study's findings showed that active contact helps students learn and are happy with the experience. This is consistent with earlier work by Michaelsen LK et al., which found that teams typically outperform their best team members by an average of approximately 14% (Michaelsen & Sweet, 2008). In addition, the group discovered that the weakest team beat the class' top performers in this learning setting.

Compared to students' experiences in the conventional lecture format, the reflective writing to assess student participation and attitude toward the TBL learning skills revealed that the TBL format enhances communication skills, knowledge application, and peer-to-peer learning. Compared to learning in a lecture format, the students felt that the TBL format enhanced self-directed learning and critical thinking abilities. The TBL methodology holds students responsible for their study before class and in small groups in the classroom as part of an active and engaged learning process to foster critical thinking abilities.

It was interesting to notice during the sessions that during team RAT or in the optional application activities, the decision-making process for the team to arrive at a chosen response often started with a tendency to be controlled by a majority opinion in a consensus-based approach. According to faculty members' anecdotal observations, students improved their teamwork abilities as the course progressed, which changed the team dynamics. They were also able to participate in more thoughtful discussions while listening to the opinions of fewer classmates as part of peer teaching and learning. Future studies can include an investigation of this observation from a systemic perspective.

Also, the faculty had to set aside time to record lectures, plan active learning exercises, and develop pre- and post-assessment quizzes to provide TBL materials (such as individual and team RAT questions, Application problems). Given that the materials can be utilized again in subsequent years, this was a crucial consideration, at least for the initial implementation. Facilitating TBL talks was also vital, and faculty training and development opportunities must be carefully designed.

4.4 Questionaire and Feedback

The sentiment analysis of subjective feedback from students involves the collection of raw feedback in the form of student evaluations, surveys, or written comments, cleaning and preprocessing the feedback data (i.e., removing any unnecessary words such as punctuation or stop words, converting the text to lowercase and tokenize it, splitting it into individual words), assigning sentiment scores by using a sentiment lexicon (such as the VADER lexicon), and calculate the overall sentiment.

After conducting a sentiment analysis of subjective feedback from students, the overall sentiment score and polarity showed a neutral and positive emotional tone of the feedback (Figure 4.12).

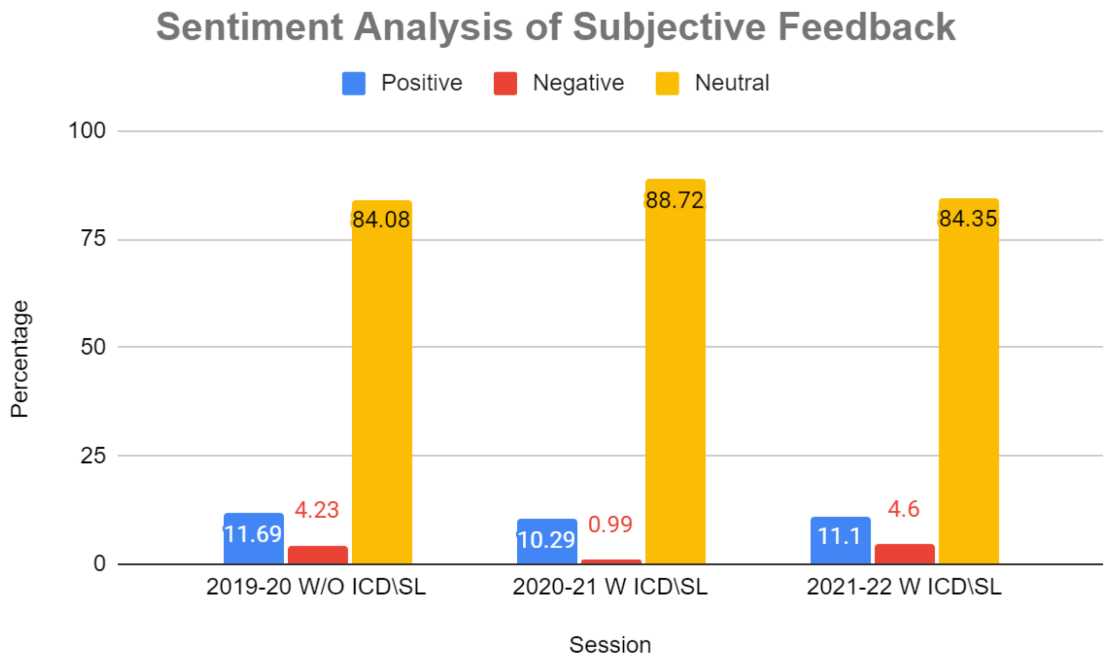


Figure 4-12 The results clearly show that the polarity of feedback is mostly neutral and positive

The positive polarity indicates that the feedback expresses positive emotions, such as satisfaction, enjoyment, or excitement. For example, "I loved this course! The instructor was engaging, and the material was fascinating." In this case, the polarity of the feedback is positive, as it expresses positive emotions and satisfaction with the course.

While the negative polarity, on the other hand, indicates that the feedback expresses negative emotions, such as dissatisfaction, frustration, or disappointment. For example, "I found this course incredibly difficult and frustrating. The material was confusing, and I struggled to keep up." In this case, the polarity of the feedback is negative, as it expresses negative emotions and dissatisfaction with the course.

In contrast, the neutral polarity indicates that the feedback expresses no strong emotional tone and is typically objective or factual in nature. For example, "The course material was challenging, but the instructor was knowledgeable and helpful." In this case, the polarity of the feedback is neutral, as it expresses no strong emotional tone and provides a factual description of the course.

By analyzing the polarity of feedback from students, instructors can gain valuable insights into how their students feel about a particular course or topic. Positive feedback can provide validation that the course is effective and engaging, while negative feedback can help identify areas where improvements can be made. Neutral feedback can provide a balanced perspective and help instructors to better understand the students' experience.

It is important to look at the specific feedback that contributed to the sentiment score and polarity. This helps the instructors to identify critical areas and address any issues where students had positive or negative experiences.

5 Conclusion and Future Scope of the Work

The development and application of an Integrated Course Design framework, drawing upon Fink's model and Team-Based Learning (TBL), offer a structured approach to course design that enhances student engagement, participation, and academic performance. This framework provides educators with a practical methodology for designing effective bioinformatics courses and may be applicable to other disciplines within biology and beyond. The thesis presents empirical evidence supporting the effectiveness of innovative pedagogical interventions, such as in-class worksheets and TBL, in promoting active learning and enhancing student outcomes in bioinformatics education. These interventions contribute to the growing body of literature on evidence-based teaching practices and may be transferable to other courses or disciplines with similar learning objectives. By incorporating both quantitative (student grades) and qualitative (student perception) components in the assessment of student outcomes, the thesis underscores the importance of a comprehensive evaluation approach in measuring the impact of instructional interventions. This contributes to the advancement of assessment practices in biology education and provides valuable insights for educators seeking to assess student learning in diverse contexts. The findings of the study suggest that the integrated course design framework and pedagogical interventions can benefit undergraduate students at the university level, indicating the potential for broader implementation across similar educational settings. This extends the applicability of the research findings beyond the specific context of bioinformatics education, offering insights relevant to undergraduate education more broadly.

5.1 Integrated Course Design

Integrated Course Design using Taxonomy of Significant Learning (ICD/SL) using Fink's model has been implemented in India for the first time, specifically in Biology and its aligned fields. It resulted in higher class participation (in the form of in-class worksheet completion) and improved academic performance of students. The study considered both quantitative (student grades) and qualitative (student perception) components to assess the outcomes in the domains of Human Dimension, Care, and Learning How to Learn.

According to the findings, Fink's model of ICD/SL generates higher individual class participation and academic performance in the 'Introduction to Bioinformatics' course. The trend showed a considerable increase in students' class participation and better academic scores. This approach of significant learning focused on better student engagement and increasing the class's energy. This holistic view of learning creates a change in the learner. This change helped the learner to acquire and know more information, but at the same time, it allowed the learner to know about the meaning and use the information and see its effects on themselves and others.

This study looked at the quantitative component of student grades, taking into consideration student perception, so that their qualitative response to these adjustments would better reflect the outcomes in the domains of Human Dimension, Care, and Learning How to Learn. Finally, this method was employed for a single subject in a curriculum, the findings can be applied to other undergraduate students at the University.

The authors hope that one of the benefits of this study is that it will serve as a foundation for future research that will result in significant learning, and they recommend that more ICD/SL-related research be conducted under Fink's Significant Learning taxonomy to compare the findings of this study. It's helpful in (a) analyzing the extent to which each of Fink's learning categories occurred for students and (b) measuring the influence of specific learning and evaluation activities on student learning, as this would offer a lot of insight on the linkages between teaching and meaningful learning.

5.2 Assessment Methods

Innovative pedagogical interventions, such as in-class worksheets and out-of-class take-home assignments, were found to be effective in enhancing student learning and class participation in a Bioinformatics course.

This study introduces the innovative "worksheets and take-home assessment" bachelor education project. Our study demonstrates the effectiveness of two pedagogical interventions in the form of in-class worksheets and out-of-class take-home assignments on student learning and class participation in a third-year undergraduate bioinformatics course. The Personal Response of students was taken in the tutorial of the "Introduction to Bioinformatics" (BIO F 242) course at Birla Institute of Technology and Sciences, Pilani campus. These out-of-the-class take-home assignments and in-class worksheets were the assessment tasks of the tutorial class and were embedded in the sixth semester of the Introduction to Bioinformatics tutorial course. The evaluation of students revealed that students found this task engaging, exciting, and challenging. Students performed well regardless of their background knowledge, disciplinary interest, or preference for topics within the Introduction to Bioinformatics course. The student's feedback suggests they prefer this new mode of intervention in the form of take-home assignments and worksheets as these activities helped them to stay connected with the topic, and they have to think critically about the topic before answering the questions. Take-home assignments and worksheets not only provide a happy class experience but also give students direction and advice while working on their end-semester projects throughout their hands-on tutorial sessions, according to educational studies in bioinformatics.

According to this study, Fink's taxonomy seems adequate for Take Home Assignments. Because the test items on the "application" level are typically not available on the Internet, the chance of cheating is simply too small. Although there is disagreement in the community regarding whether take-home assignments best facilitate deep learning, this study suggests that for the higher taxonomy levels (HOCS), take-home assignments are preferred by the student's community because they give students more time to engage in higher-order thinking and reflections (and less stress imposed on the students). The student body also appears to concur that cheating on take-home assignments is a minimal issue at the higher taxonomic levels because each team member is focusing on a unique organism with a shared problem gene.

The major difficulty that we found was related to time duration, deadlines, and two hours of continuous intense sessions. As in the student's subjective feedback they have mentioned these limitations –

"It's sometimes difficult to concentrate in 2 hours session. It would be better if 5-10 minutes break is given after 50-60 minutes in the 2-hour session".

"Increase the time for hands-on worksheet submissions because sometimes it will be difficult to complete it due to site issues or any other reason".

"I think that doing and submitting the experiments by every week becomes really hectic. If the deadline would have been pushed to the weekend, that could be better".

"2-hour lab session was also exhausting. Perhaps the lab theory and demo could be taken at different hours".

"The tutorial part was a bit hectic due to weekly submission and presentation".

"Most weekly experiment submissions were equivalent to full-fledged assignments in terms of effort and time they required. The work done in these sessions is not justified by the marks they are assigned. Either increase the weightage given to these submissions or at least design them in such a way that the assignment can be completed and submitted in the duration of the lab session."

5.3 Team-Based Learning

Significant learning focused on better student engagement (in Team-based activities like presentation and end-semester report creation) leading to a holistic view of learning and positive change in the learners.

In the sophomore-year biology courses of Genetics and Integrated Biology, and freshman year course of Engines of Life the teams outperformed the individuals in terms of performance. TBL can encourage a collaborative and interactive learning environment to improve student satisfaction and information acquisition. The TBL educational activities showed the teams' performance was better compared to the individual students in an undergraduate Genetics and Integrated Biology course. These pedagogical practices promote peer interaction, communication, and critical thinking skills in a collaborative learning environment, resulting in an increase in the acquisition of knowledge and satisfaction among students. Students found TBL as a fun-loving activity in biology courses (as highlighted via their subjective feedback); it resulted in improved performance of teams compared to individuals, promoting collaborative learning, communication, and critical thinking skills.

The modest population size of the current study was one of its shortcomings. As this instructional approach is implemented across the curriculum, other research on increased population size will be assessed. The students worked individually first, then in teams. It was also conceivable for a student to disagree with the team's evaluation but to lose the vote or not be included in the process of reaching an agreement. For the next work, it would be helpful to determine how much a person agrees with the team's assessment.

The limitation of the current study is that it has been conducted entirely in an online mode for Genetics due to the Covid-19 pandemic situation while Integrated Biology and Engines of Life

TBL sessions were conducted offline. Additional studies of online or offline or in-class activity can be evaluated as this pedagogical practice gets incorporated across other courses. The students worked as individuals first during iRAT, then as teams using breakout rooms in Zoom found it difficult to build consensus due to online mode. As a part of future work, it may be advisable to conduct in-class or offline TBL sessions in other courses.

5.4 Questionnaire and feedback

In this study, Sentiment analysis was successfully employed to analyze student subjective feedback, which is often neglected due to big data size.

Sentiment analysis is the technique of classifying opinions contained in texts as positive, negative, or neutral based on the polarity of the sentiments held within them. In our study, we used a sentiment analysis technique to examine the text of student feedback, such as comments and suggestions. The tool's expected input, which is casual English, is described as having a highly non-structured nature and being susceptible to emotional vs. neutral tendencies. Our approach combines the field of human computation with the challenge of natural language processing.

Sentiment analysis can analyze popular subjects, such as educational feedback problems, and anticipate the feeling of the students. However, there isn't much material currently available that explores sentiment analysis in students' feedback. In this study, we introduced a novel tool Pratikriya using open libraries of python that employs a set of criteria to analyze students' feedback or comments with English text using sentiment. The parameters are the time the feedback or comments were posted, preprocessing techniques, lexicon-based techniques, and machine learning techniques.

Lexicon-based sentiment analysis is a method of analyzing the sentiment (i.e., the emotional or attitudinal content) of a piece of text by looking at the words used and matching them to a pre-defined list of words that have been annotated with sentiment scores. This list of words is known as a "lexicon." For example, a lexicon might contain words like "happy," "excited," and "joyful," which would be assigned positive sentiment scores, and words like "sad," "depressed," and "angry," which would be assigned negative sentiment scores. The sentiment of a piece of text can then be calculated by summing up the sentiment scores of the individual words in the text.

There are several advantages to using a lexicon-based approach to sentiment analysis:

1) Simplicity: Lexicon-based approaches are relatively simple and straightforward, making them easy to implement and understand.

2) High precision: Lexicons are usually carefully curated and annotated, so they can be highly accurate in identifying the sentiment of words.

3) Contextual sensitivity: Some lexicons are designed to be sensitive to the context in which words are used, which can improve the accuracy of the sentiment analysis.

However, lexicon-based approaches can also have some limitations. For example, they may not be able to accurately analyze sentiment in cases where words have multiple meanings or are used in an unconventional way, or when the text includes slang or colloquial language.

5.5 Implications for theory and practice

The current study demonstrates the theoretical and practical contribution of ICD to course design. The theoretical contribution of this research shows that ICD aligns with Fink's framework of Taxonomy of Significant Learning and promotes deeper learning by addressing each of the six domains of learning. The practical contribution of this research shows that ICD is in alignment with the requirements of the National Education Policy 2020 and can be used as a tool to achieve the policy's vision of a holistic, student-centered approach to education that promotes deeper learning and develops essential skills.

Moreover, this research highlights the importance of incorporating ICD into the curriculum of higher education institutions in India. The National Education Policy 2020 emphasizes the need for a curriculum that is flexible, interdisciplinary, and focused on the development of essential skills. ICD offers a framework for designing such a curriculum that integrates knowledge across disciplines, develops essential skills, and promotes deeper learning.

In addition, study also suggests that ICD can be used to bridge the gap between academic learning and real-world problem-solving. The National Education Policy 2020 emphasizes the importance of developing graduates who are equipped with the skills and knowledge to solve real-world problems. ICD provides a framework for designing courses that require students to apply knowledge from different disciplines to solve real-world problems, thereby bridging the gap between academic learning and real-world problem-solving.

5.6 Revalidation of age-old system

The revalidation of the age-old Indian education system of personalized learning based on rapport is crucial. This approach recognizes that every student is unique and requires individualized instruction to succeed. By establishing a personalized connection with each student, teachers can create a learning environment that is supportive, engaging, and motivating. This can lead to improved academic performance, increased confidence, and greater satisfaction with the learning experience, benefiting both students and teachers alike.

The Indian education system has a rich history that dates back several centuries. From the gurukul system to modern-day classrooms, establishing a strong connection between the teacher and the student has been a priority. The gurukul system, which dates back to ancient times, was based on personalized learning. The guru (teacher) would establish a strong rapport with his students and provide individualized instruction. This approach allowed students to learn at their own pace and provided them with the necessary support to succeed academically.

Personalized learning involves creating a learning environment and recognizes that every student is different and that they learn at different rates and in different ways. By establishing a personalized connection or rapport with each student, teachers can provide instruction that is customized to their individual needs, making the learning experience more effective and meaningful.

In modern times, personalized learning has taken on new forms, but the importance of rapport remains unchanged. Teachers in Indian classrooms today recognize the value of building strong relationships with their students, and they use a variety of methods such as calling by their names, interacting outside the class, try to get to know their students on a personal level to establish rapport. They may inquire about their hobbies, interests, and family background. This allows teachers to understand their students' unique needs and learning styles, which can help to create a more effective learning experience. The use of technology has also been leveraged to support personalized learning and rapport building. For instance, the use of study guides during online sessions with other learning platforms and video conferencing tools to keep students up to date can result in better engagement, higher class participation and retention rate in the course.

5.7 Recalibration of old system

The Indian education system is one of the oldest in the world, with a rich history dating back several centuries. The pressure on students to perform well, coupled with the high expectations of parents and society, can lead to stress, anxiety, and disengagement. To address this issue, there needs to be a recalibration of the Indian education system to empathize with the high-mental pressure of students by giving them flexible assignment deadlines.

Flexible assignment deadlines would enable students to manage their workload more effectively and alleviate some of the pressure they may feel to complete tasks within a strict timeframe. It would also show empathy towards their mental well-being and help them cope with high-mental pressure. This approach would help reduce the likelihood of students disengaging from their studies and dropping from the course. Flexible assignment deadlines could involve creating a system where students are given a certain amount of time to complete assignments, but within that time, they can work at their own pace. This would enable students to balance their academic workload with other commitments. This approach would also enable teachers to provide feedback on assignments and help students develop their skills, without the pressure of a strict deadline.

The current education system in India has a strict focus on academic performance, with little emphasis on holistic development. This approach can lead to a culture of competition and pressure, which can have negative consequences on the mental health of students. In contrast, flexible assignment deadlines would provide students with the opportunity to focus on their mental well-being and develop skills that are essential for personal and professional success.

One another way is to incorporate the technology into the education system is using online simple study guides, which can provide a more flexible and personalized approach to learning. Study guides can offer students the ability to access course materials online, remain up to date with the topics before coming to class. This can help students manage their workload more effectively and provide greater access to educational resources.

5.8 Future scope of the study

Expansion to Other Courses and Fields: The study can be extended to explore the implementation of Fink's Integrated Course Design (ICD) with Taxonomy of Significant Learning in other related or different courses and fields. This would provide a broader understanding of the effectiveness and applicability of the approach across various disciplines.

Development of an Indian-Centric Model: Further research can focus on developing an Indian-Centric Model for Integrated Course Design (ICD) by incorporating two additional domains: building character and imparting values. This would cater specifically to the cultural and contextual needs of Indian education and contribute to the enhancement of holistic education.

Exploring Rapport in Other Disciplines: The study can examine the aspect of rapport, which was initially focused on biology courses, in other disciplines. Investigating the role of rapport in facilitating student engagement, motivation, and learning outcomes in different academic domains would provide valuable insights into its universality and effectiveness.

Development of Additional Assessment Techniques: Further research can focus on developing and implementing additional assessment techniques that align with the Taxonomy of Significant Learning. This would ensure comprehensive evaluation of student learning outcomes and provide a diverse range of assessment methods that align with the integrated course design approach.

Faculty Training for Integrated Course Design: Future studies can focus on training faculty members on how to design their respective courses based on Fink's Integrated Course Design (ICD) using the Taxonomy of Significant Learning. Faculty development programs can be designed to equip educators with the necessary knowledge, skills, and tools to effectively implement integrated course design strategies in their teaching practices.

Comparison with Other Courses and Longitudinal Studies: The study does not compare the results with other courses or conduct longitudinal studies to track the long-term effects of the interventions.

5.9 Limitations of the study

Limited Generalizability: The study's findings may have limited generalizability due to the narrow focus on BITS-Pilani students and biology-related courses. The results may not be representative of the broader population or other educational institutions.

Small Sample Size: The study's reliance on a small batch of students limits the statistical power and generalizability of the findings. The sample size may not adequately capture the diversity of students or account for individual variations within the larger student population.

Lack of Comparison Groups: The study's narrow focus on a specific biology course without comparison groups limits the ability to establish causal relationships or make comparisons with other courses or instructional approaches.

Lack of Longitudinal Data: The study's cross-sectional design and reliance on different student batches each year may limit the ability to assess long-term effects and changes over time. Without longitudinal data, it becomes difficult to determine the sustainability and durability of the observed outcomes.

6 References

Agius, N. M., & Wilkinson, A. (2014). Students' and teachers' views of written feedback at undergraduate level: A literature review. *Nurse Education Today*, *34*(4), 552–559. https://doi.org/10.1016/j.nedt.2013.07.005

Ahmed, M., Chen, Q., & Li, Z. (2020). Constructing domain-dependent sentiment dictionary for sentiment analysis. *Neural Computing and Applications*, *32*(18), 14719–14732. https://doi.org/10.1007/s00521-020-04824-8

Ajaja, O. (2013). Which Strategy Best Suits Biology Teaching? Lecturing, Concept Mapping, Cooperative Learning or Learning Cycle?. *The Electronic Journal of Science Education*. https://www.semanticscholar.org/paper/Which-Strategy-Best-Suits-Biology-Teaching-Concept-Ajaja/d45c039231bffde9ed9d0a5f7e68b0e18f3c333c

Allen, D. E., Donham, R. S., & Bernhardt, S. A. (2011). Problem-based learning. *New Directions for Teaching and Learning*, *2011*(128), 21–29. https://doi.org/10.1002/tl.465

Al-Neklawy, A. F., & Ismail, A. S. A. (2022). Online anatomy team-based learning using blackboard collaborate platform during COVID -19 pandemic. *Clinical Anatomy*, *35*(1), 87–93. https://doi.org/10.1002/ca.23797

Amer, B., & Baidoo, E. E. K. (2021). Omics-Driven Biotechnology for Industrial Applications. *Frontiers in Bioengineering and Biotechnology*, *9*, 613307. https://doi.org/10.3389/fbioe.2021.613307

Anderson, K. L. (2016). Active Learning in the Undergraduate Classroom: *The American Biology Teacher*, *78*(1), 67–69. https://doi.org/10.1525/abt.2016.78.1.67

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Complete ed). Longman.

Appleton-Knapp, S. L., & Krentler, K. A. (2006). Measuring Student Expectations and Their Effects on Satisfaction: The Importance of Managing Student Expectations. *Journal of Marketing Education*, *28*(3), 254–264. https://doi.org/10.1177/0273475306293359

Aung, K. Z., & Myo, N. N. (2017). Sentiment analysis of students' comment using lexicon based approach. *2017 IEEE/ACIS 16th International Conference on Computer and Information Science (ICIS)*, 149–154. https://doi.org/10.1109/ICIS.2017.7959985

Azer, S. A., Guerrero, A. P. S., & Walsh, A. (2013). Enhancing learning approaches: Practical tips for students and teachers. *Medical Teacher*, *35*(6), 433–443. https://doi.org/10.3109/0142159X.2013.775413

Bailey, E. G., Baek, D., Meiling, J., Morris, C., Nelson, N., Rice, N. S., Rose, S., & Stockdale, P. (2018). Learning Gains from a Recurring "Teach and Question" Homework Assignment in a General Biology Course: Using Reciprocal Peer Tutoring Outside Class. *CBE—Life Sciences Education*, *17*(2), ar23. https://doi.org/10.1187/cbe.17-12-0259

Bass, R. Z., Morgan, D. E., & Brooks, W. S. (2018). A Case of Pancreatic Cancer: Abdominal Anatomy Team-Based Learning Module for Medical Students. *MedEdPORTAL*, 10700. https://doi.org/10.15766/mep_2374-8265.10700

Bassi, F. (2019). Students' satisfaction in higher education: The role of practices, needs and beliefs of teachers. *Quality Assurance in Education*, *27*(1), 56–69. https://doi.org/10.1108/QAE-05-2018-0061

Batrinca, B., & Treleaven, P. C. (2015). Social media analytics: A survey of techniques, tools and platforms. *AI & SOCIETY*, *30*(1), 89–116. https://doi.org/10.1007/s00146-014-0549-4

Bavishi, P., Birnhak, A., Gaughan, J., Mitchell-Williams, J., & Phadtare, S. (2022). Active Learning: A Shift from Passive Learning to Student Engagement Improves Understanding and Contextualization of Nutrition and Community Health. *Education Sciences*, *12*(7), 430. https://doi.org/10.3390/educsci12070430

Bengfort, B., Bilbro, R., & Ojeda, T. (2018). *Applied text analysis with Python: Enabling language-aware data products with machine learning* (First edition). O'Reilly Media, Inc.

Bengtsson, L. (2019). Take-Home Exams in Higher Education: A Systematic Review. *Education Sciences*, *9*(4), 267. https://doi.org/10.3390/educsci9040267

Biggs, J. (1979). Individual Differences in Study Processes and the Quality of Learning Outcomes. *Higher Education*, *8*(4), 381–394.

Biggs, J. B., & Tang, C. S. (2011). *Teaching for quality learning at university: What the student does* (4th edition). McGraw-Hill, Society for Research into Higher Education & Open University Press.

Biggs, J., Kember, D., & Leung, D. Y. P. (2001). The revised two-factor Study Process Questionnaire: R-SPQ-2F. *British Journal of Educational Psychology*, *71*(1), 133–149. https://doi.org/10.1348/000709901158433

Bijlsma, H. J. E., Glas, C. A. W., & Visscher, A. J. (2022). Factors related to differences in digitally measured student perceptions of teaching quality. *School Effectiveness and School Improvement*, *33*(3), 360–380. https://doi.org/10.1080/09243453.2021.2023584

Black, P., Harrison, C., Hodgen, J., Marshall, B., & Serret, N. (2010). Validity in teachers' summative assessments. *Assessment in Education: Principles, Policy & Practice*, *17*(2), 215–232. https://doi.org/10.1080/09695941003696016

Bohlouli, M., Dalter, J., Dornhöfer, M., Zenkert, J., & Fathi, M. (2015). Knowledge discovery from social media using big data-provided sentiment analysis (SoMABiT). *Journal of Information Science*, *41*(6), 779–798. https://doi.org/10.1177/0165551515602846

Bonta, V., Kumaresh, N., & Janardhan, N. (2019). A Comprehensive Study on Lexicon Based Approaches for Sentiment Analysis. *Asian Journal of Computer Science and Technology*, *8*(S2), 1–6. https://doi.org/10.51983/ajcst-2019.8.S2.2037

Bradberry, L. A., & De Maio, J. (2019). Learning By Doing: The Long-Term Impact of Experiential Learning Programs on Student Success. *Journal of Political Science Education*, *15*(1), 94–111. https://doi.org/10.1080/15512169.2018.1485571

Branzetti, J., Gisondi, M. A., Hopson, L. R., & Regan, L. (2019). Aiming Beyond Competent: The Application of the Taxonomy of Significant Learning to Medical Education.

Teaching and Learning in Medicine, *31*(4), 466–478. https://doi.org/10.1080/10401334.2018.1561368

Brown, D. E., & Clement, J. (1989). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. *Instructional Science*, *18*(4), 237–261. https://doi.org/10.1007/BF00118013

Brown, J. A. L. (2016). Evaluating the effectiveness of a practical inquiry-based learning bioinformatics module on undergraduate student engagement and applied skills: Teaching Practical Bioinformatics. *Biochemistry and Molecular Biology Education*, *44*(3), 304–313. https://doi.org/10.1002/bmb.20954

Buijs, M., & Admiraal, W. (2013). Homework assignments to enhance student engagement in secondary education. *European Journal of Psychology of Education*, *28*(3), 767–779. https://doi.org/10.1007/s10212-012-0139-0

Burgess, A., Roberts, C., Ayton, T., & Mellis, C. (2018). Implementation of modified team-based learning within a problem based learning medical curriculum: A focus group study. *BMC Medical Education*, *18*(1), 74. https://doi.org/10.1186/s12909-018-1172-8

Burwash, S. C., Snover, R., & Krueger, R. (2016). Up Bloom's pyramid with slices of Fink's pie: Mapping an occupational therapy curriculum. *The Open Journal of Occupational Therapy*, *4*(4). https://doi.org/10.15453/2168-6408.1235

Cabada, R. Z., Estrada, M. L. B., Hernández, F. G., Bustillos, R. O., & Reyes-García, C. A. (2018). An affective and Web 3.0-based learning environment for a programming language. *Telematics and Informatics*, *35*(3), 611–628. https://doi.org/10.1016/j.tele.2017.03.005

Cadorin, L., Bagnasco, A., Tolotti, A., Pagnucci, N., & Sasso, L. (2017). Developing an instrument to measure emotional behaviour abilities of meaningful learning through the Delphi technique. *Journal of Advanced Nursing*, *73*(9), 2208–2218. https://doi.org/10.1111/jan.13273

Cassidy *, S. (2004). Learning Styles: An overview of theories, models, and measures. *Educational Psychology*, *24*(4), 419–444. https://doi.org/10.1080/0144341042000228834

Cavalcanti, A. P., Diego, A., Mello, R. F., Mangaroska, K., Nascimento, A., Freitas, F., & Gašević, D. (2020). How good is my feedback?: A content analysis of written feedback. *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge*, 428–437. https://doi.org/10.1145/3375462.3375477

Chakraborty, K., Bhattacharyya, S., & Bag, R. (2020). A Survey of Sentiment Analysis from Social Media Data. *IEEE Transactions on Computational Social Systems*, *7*(2), 450–464. https://doi.org/10.1109/TCSS.2019.2956957

Chang, Y.-H., Yan, Y.-C., & Lu, Y.-T. (2022). Effects of Combining Different Collaborative Learning Strategies with Problem-Based Learning in a Flipped Classroom on Program Language Learning. *Sustainability*, *14*(9), 5282. https://doi.org/10.3390/su14095282

Chen, M., Ni, C., Hu, Y., Wang, M., Liu, L., Ji, X., Chu, H., Wu, W., Lu, C., Wang, S., Wang, S., Zhao, L., Li, Z., Zhu, H., Wang, J., Xia, Y., & Wang, X. (2018). Meta-analysis on the effectiveness of team-based learning on medical education in China. *BMC Medical Education*, *18*(1), 77. https://doi.org/10.1186/s12909-018-1179-1

Chickering, A. W., & Gamson, Z. F. (1989). Seven principles for good practice in undergraduate education. *Biochemical Education*, *17*(3), 140–141. https://doi.org/10.1016/0307-4412(89)90094-0

Cho, H., Kim, S., Lee, J., & Lee, J.-S. (2014). Data-driven integration of multiple sentiment dictionaries for lexicon-based sentiment classification of product reviews. *Knowledge-Based Systems*, *71*, 61–71. https://doi.org/10.1016/j.knosys.2014.06.001

Choo, S. S. Y., Rotgans, J. I., Yew, E. H. J., & Schmidt, H. G. (2011). Effect of worksheet scaffolds on student learning in problem-based learning. *Advances in Health Sciences Education*, *16*(4), 517–528. https://doi.org/10.1007/s10459-011-9288-1

Cobos, R., Jurado, F., & Blazquez-Herranz, A. (2019). A Content Analysis System That Supports Sentiment Analysis for Subjectivity and Polarity Detection in Online Courses. *IEEE Revista Iberoamericana de Tecnologias Del Aprendizaje*, *14*(4), 177–187. https://doi.org/10.1109/RITA.2019.2952298

Cordova, C. C., Tan, D. A., & Ucang, J. T. (2018). *Take Home Assignment And Performance Of Grade 11 Students*. *7*(12).

Cramp, A. (2011). Developing first-year engagement with written feedback. *Active Learning in Higher Education*, *12*(2), 113–124. https://doi.org/10.1177/1469787411402484

Crawford, S. Y. (2012). An Innovative Seminar Course in Business Etiquette for Pharmacy Graduate Students. *American Journal of Pharmaceutical Education*, *76*(9), 177. https://doi.org/10.5688/ajpe769177

Culbert, P. D. (2020). Supplementing forestry field instruction with video and online dynamic quizzing. *Natural Sciences Education*, *49*(1). https://doi.org/10.1002/nse2.20015

Curry, L. (1983). *An Organization of Learning Styles Theory and Constructs*. https://eric.ed.gov/?id=ED235185

Davies, A. C., Harris, D., Banks-Gatenby, A., & Brass, A. (2019). Problem-based learning in clinical bioinformatics education: Does it help to create communities of practice? *PLOS Computational Biology*, *15*(6), e1006746. https://doi.org/10.1371/journal.pcbi.1006746

De La Fuente, J., Sander, P., Kauffman, D. F., & Yilmaz Soylu, M. (2020). Differential Effects of Self- vs. External-Regulation on Learning Approaches, Academic Achievement, and Satisfaction in Undergraduate Students. *Frontiers in Psychology*, *11*, 543884. https://doi.org/10.3389/fpsyg.2020.543884

DeMasi, J., Harvan, R. A., & Luca, M. (2019). Online and In-class Team-Based Learning in Undergraduate Immunology: A Comparative Analysis. *Medical Science Educator*, *29*(4), 1193–1199. https://doi.org/10.1007/s40670-019-00814-1

Dimmitt, N. (2017). THE POWER OF PROJECT BASED LEARNING: EXPERIENTIAL EDUCATION TO DEVELOP CRITICAL THINKING SKILLS FOR UNIVERSITY STUDENTS. *CBU International Conference Proceedings*, *5*, 575–579. https://doi.org/10.12955/cbup.v5.988

Dixson, D. D., & Worrell, F. C. (2016). Formative and Summative Assessment in the Classroom. *Theory Into Practice*, *55*(2), 153–159. https://doi.org/10.1080/00405841.2016.1148989

Dolan, E. L. (2015). Biology Education Research 2.0. *CBE—Life Sciences Education*, *14*(4), ed1. https://doi.org/10.1187/cbe.15-11-0229

Dolan, E. L. (2017). Within and beyond Biology Education Research: Steps toward Cross-Disciplinary Collaboration. *CBE—Life Sciences Education*, *16*(4), ed2. https://doi.org/10.1187/cbe.17-10-0224

Dolianiti, F. S., Iakovakis, D., Dias, S. B., Hadjileontiadou, S., Diniz, J. A., & Hadjileontiadis, L. (2019). Sentiment Analysis Techniques and Applications in Education: A Survey. In M. Tsitouridou, J. A. Diniz, & T. A. Mikropoulos (Eds.), *Technology and Innovation in Learning, Teaching and Education* (Vol. 993, pp. 412–427). Springer International Publishing. https://doi.org/10.1007/978-3-030-20954-4_31

Dolin, J., Black, P., Harlen, W., & Tiberghien, A. (2018). Exploring Relations Between Formative and Summative Assessment. In J. Dolin & R. Evans (Eds.), *Transforming Assessment* (Vol. 4, pp. 53–80). Springer International Publishing. https://doi.org/10.1007/978-3-319-63248-3_3

Douglas, J. A., Douglas, A., McClelland, R. J., & Davies, J. (2015). Understanding student satisfaction and dissatisfaction: An interpretive study in the UK higher education context. *Studies in Higher Education*, *40*(2), 329–349. https://doi.org/10.1080/03075079.2013.842217

Ducange, P., Fazzolari, M., Petrocchi, M., & Vecchio, M. (2019). An effective Decision Support System for social media listening based on cross-source sentiment analysis models. *Engineering Applications of Artificial Intelligence*, *78*, 71–85. https://doi.org/10.1016/j.engappai.2018.10.014

Dunn, K. E., & Mulvenon, S. W. (n.d.). *A Critical Review of Research on Formative Assessments: The Limited Scientific Evidence of the Impact of Formative Assessments in Education*. https://doi.org/10.7275/JG4H-RB87

El Islami, R., Sari, I. J., Sjaifuddin, S., Nurtanto, M., Ramli, M., & Siregar, A. (2019). An Assessment of Pre-service Biology Teachers on Student Worksheets Based on Scientific Literacy. *Journal of Physics: Conference Series*, *1155*, 012068. https://doi.org/10.1088/1742-6596/1155/1/012068

El-Hashash, A. (2022). Weekly Quizzes Reinforce Student Learning Outcomes and Performance in Biomedical Sciences in-course Assessments. *Open Journal of Educational Research*, *2*(4), 168–178. https://doi.org/10.31586/ojer.2022.273

El-Masri, M., Altrabsheh, N., Mansour, H., & Ramsay, A. (2017). A web-based tool for Arabic sentiment analysis. *Procedia Computer Science*, *117*, 38–45. https://doi.org/10.1016/j.procs.2017.10.092

Emery, L. R., & Morgan, S. L. (2017). The application of project-based learning in bioinformatics training. *PLOS Computational Biology*, *13*(8), e1005620. https://doi.org/10.1371/journal.pcbi.1005620

Evertson, C. M. (2006). *Looking into Learning-Centered Classrooms Implications for Classroom Management*.

Faize, F. A., & Nawaz, M. (2020). Evaluation and Improvement of students' satisfaction in Online learning during COVID-19. *Open Praxis*, *12*(4), 495. https://doi.org/10.5944/openpraxis.12.4.1153

Fernández-Alonso, R., Álvarez-Díaz, M., Suárez-Álvarez, J., & Muñiz, J. (2017). Students' Achievement and Homework Assignment Strategies. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00286

Fink, L. D. (2013). *Creating significant learning experiences: An integrated approach to designing college courses* (Revised and updated edition). Jossey-Bass.

Flodén, J. (2017). The impact of student feedback on teaching in higher education. *Assessment & Evaluation in Higher Education*, *42*(7), 1054–1068. https://doi.org/10.1080/02602938.2016.1224997

Franco Valdez, A. D., & Valdez Cervantes, A. (2018). Retailing Laboratory: Delivering Skills Through Experiential Learning. *Journal of Marketing Education*, *40*(1), 17–30. https://doi.org/10.1177/0273475317753679

Gálvez-Peralta, M., Szklarz, G. D., Geldenhuys, W. J., & Lockman, P. R. (2018). An Effective Approach to Teaching Pharmacogenomics in the First Year of Pharmacy Curriculum. *American Journal of Pharmaceutical Education*, *82*(8), 6345. https://doi.org/10.5688/ajpe6345

Gholami, V., & Moghaddam, M. M. (2013). The Effect of Weekly Quizzes on Students' Final Achievement Score. *International Journal of Modern Education and Computer Science*, *5*(1), 36–41. https://doi.org/10.5815/ijmecs.2013.01.05

Goldin, I., Narciss, S., Foltz, P., & Bauer, M. (2017). New Directions in Formative Feedback in Interactive Learning Environments. *International Journal of Artificial Intelligence in Education*, *27*(3), 385–392. https://doi.org/10.1007/s40593-016-0135-7

Goolsarran, N., Hamo, C. E., Lane, S., Frawley, S., & Lu, W.-H. (2018). Effectiveness of an interprofessional patient safety team-based learning simulation experience on healthcare professional trainees. *BMC Medical Education*, *18*(1), 192. https://doi.org/10.1186/s12909-018-1301-4

Gormally, C., Evans, M., & Brickman, P. (2014). Feedback about Teaching in Higher Ed: Neglected Opportunities to Promote Change. *CBE—Life Sciences Education*, *13*(2), 187–199. https://doi.org/10.1187/cbe.13-12-0235

Granitz, N. A., Koernig, S. K., & Harich, K. R. (2009). Now It's Personal: Antecedents and Outcomes of Rapport Between Business Faculty and Their Students. *Journal of Marketing Education*, *31*(1), 52–65. https://doi.org/10.1177/0273475308326408

Grebennikov, L., & Shah, M. (2013). Monitoring Trends in Student Satisfaction. *Tertiary Education and Management*, *19*(4), 301–322. https://doi.org/10.1080/13583883.2013.804114

Greenwald, S. J., & Holdener, J. A. (2019). The Creation and Implementation of Effective Homework Assignments (Part 1): Creation. *PRIMUS*, *29*(1), 1–8. https://doi.org/10.1080/10511970.2018.1555564

Gregory, K., & Morón-García, S. (2009). Assignment submission, student behaviour and experience. *Engineering Education*, *4*(1), 16–28. https://doi.org/10.11120/ened.2009.04010016

Hamilton, I. R. (2009). Automating formative and summative feedback for individualised assignments. *Campus-Wide Information Systems*, *26*(5), 355–364. https://doi.org/10.1108/10650740911004787

Haspel, R. L., Ali, A. M., & Huang, G. C. (2016). Using a Team-Based Learning Approach at National Meetings to Teach Residents Genomic Pathology. *Journal of Graduate Medical Education*, *8*(1), 80–84. https://doi.org/10.4300/JGME-D-15-00221.1

Haspel, R. L., Ali, A. M., Huang, G. C., Smith, M. H., Atkinson, J. B., Chabot-Richards, D. S., Elliott, R. M., Kaul, K. L., Powell, S. Z., Rao, A., Rinder, H. M., Vanderbilt, C. M., & Wilcox, R. (2019). Teaching Genomic Pathology: Translating Team-Based Learning to a Virtual Environment Using Computer-Based Simulation. *Archives of Pathology & Laboratory Medicine*, *143*(4), 513–517. https://doi.org/10.5858/arpa.2018-0153-OA

Hatziapostolou, T., & Paraskakis, I. (2010). *Enhancing the Impact of Formative Feedback on Student Learning Through an Online Feedback System*. *8*(2).

Hatzivassiloglou, V., & McKeown, K. R. (1997). Predicting the Semantic Orientation of Adjectives. *35th Annual Meeting of the Association for Computational Linguistics and 8th Conference of the European Chapter of the Association for Computational Linguistics*, 174–181. https://doi.org/10.3115/976909.979640

Heise, N., Meyer, C. A., Garbe, B. A., Hall, H. A., & Clapp, T. R. (2020). Table Quizzes as an Assessment Tool in the Gross Anatomy Laboratory. *Journal of Medical Education and Curricular Development*, *7*, 238212052094182. https://doi.org/10.1177/2382120520941822

Heron, G. (2011). Examining Principles of Formative and Summative Feedback. *British Journal of Social Work*, *41*(2), 276–295. https://doi.org/10.1093/bjsw/bcq049

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Hu, X., Zhang, H., Song, Y., Wu, C., Yang, Q., Shi, Z., Zhang, X., & Chen, W. (2019). Implementation of flipped classroom combined with problem-based learning: An approach to promote learning about hyperthyroidism in the endocrinology internship. *BMC Medical Education*, *19*(1), 290. https://doi.org/10.1186/s12909-019-1714-8

Huang, S. H., Huang, I., Pandya, R., & Dragan, A. D. (2019). *Nonverbal Robot Feedback for Human Teachers* (arXiv:1911.02320). arXiv. http://arxiv.org/abs/1911.02320

Hujala, M., Knutas, A., Hynninen, T., & Arminen, H. (2020). Improving the quality of teaching by utilising written student feedback: A streamlined process. *Computers & Education*, *157*, 103965. https://doi.org/10.1016/j.compedu.2020.103965

Hurst-Kennedy, J. (2018). Cystic Fibrosis as a Theme to Incorporate Team-Based Learning in Cell Biology Courses. *The American Biology Teacher*, *80*(1), 2–5. https://doi.org/10.1525/abt.2018.80.1.2

Huxham, M., Laybourn, P., Cairncross, S., Gray, M., Brown, N., Goldfinch, J., & Earl, S. (2008). Collecting student feedback: A comparison of questionnaire and other methods. *Assessment & Evaluation in Higher Education*, *33*(6), 675–686. https://doi.org/10.1080/02602930701773000

Irons, A., & Elkington, S. (2021). *Enhancing learning through formative assessment and feedback* (2nd edition). Routledge.

James, S., Cogan, P., & McCollum, M. (2019). Team-Based Learning for Immunology Courses in Allied Health Programs. *Frontiers in Immunology*, *10*, 2477. https://doi.org/10.3389/fimmu.2019.02477

Jenkins, D. M. (2015). Integrated Course Design: A Facelift for College Courses. *Journal of Management Education*, *39*(3), 427–432. https://doi.org/10.1177/1052562914540903

Johnson, C. E., Keating, J. L., Boud, D. J., Dalton, M., Kiegaldie, D., Hay, M., McGrath, B., McKenzie, W. A., Nair, K. B. R., Nestel, D., Palermo, C., & Molloy, E. K. (2016). Identifying educator behaviours for high quality verbal feedback in health professions education: Literature review and expert refinement. *BMC Medical Education*, *16*(1), 96. https://doi.org/10.1186/s12909-016-0613-5

Jones, C. H. (1984). Interaction of Absences and Grades in a College Course. *The Journal of Psychology*, *116*(1), 133–136. https://doi.org/10.1080/00223980.1984.9923627

Joyce, J., Gitomer, D. H., & Iaconangelo, C. J. (2018). Classroom assignments as measures of teaching quality. *Learning and Instruction*, *54*, 48–61. https://doi.org/10.1016/j.learninstruc.2017.08.001

Kannappan, A., Yip, D. T., Lodhia, N. A., Morton, J., & Lau, J. N. (2012). The Effect of Positive and Negative Verbal Feedback on Surgical Skills Performance and Motivation. *Journal of Surgical Education*, *69*(6), 798–801. https://doi.org/10.1016/j.jsurg.2012.05.012

Kanwar, A., & Sanjeeva, M. (2022). Student satisfaction survey: A key for quality improvement in the higher education institution. *Journal of Innovation and Entrepreneurship*, *11*(1), 27. https://doi.org/10.1186/s13731-022-00196-6

Kardipah, S., & Wibawa, B. (2020). A Flipped-Blended Learning Model with Augmented Problem Based Learning to Enhance Students' Computer Skills. *TechTrends*, *64*(3), 507–513. https://doi.org/10.1007/s11528-020-00506-3

Kastrati, Z., Dalipi, F., Imran, A. S., Pireva Nuci, K., & Wani, M. A. (2021). Sentiment Analysis of Students' Feedback with NLP and Deep Learning: A Systematic Mapping Study. *Applied Sciences*, *11*(9), 3986. https://doi.org/10.3390/app11093986

Katyal, A., & Kannan, M. (2022). *Employing Collaborative Problem-Based Learning for an Immersive Online Experience in an Undergraduate Bioinformatics Course* (SSRN Scholarly Paper 4026348). https://doi.org/10.2139/ssrn.4026348

Kauffmann, E., Peral, J., Gil, D., Ferrández, A., Sellers, R., & Mora, H. (2020). A framework for big data analytics in commercial social networks: A case study on sentiment analysis and fake review detection for marketing decision-making. *Industrial Marketing Management*, *90*, 523–537. https://doi.org/10.1016/j.indmarman.2019.08.003

Keating, D., McWilliams, S., Hynes, C., Clarke, M., & Strawbridge, J. (2019). Pharmacy Students' Reflections on an Experiential Learning Visit to a Psychiatric Hospital. *American Journal of Pharmaceutical Education*, *83*(5), 6784. https://doi.org/10.5688/ajpe6784

Kedia, A., & Rasu, M. (2020). *Hands-On Python Natural Language Processing: Explore tools and techniques to analyze and process text with a view to building real-world NLP applications*. Packt.

Kedraka, K. (2020). Students' Values and Ethical Concerns in a Biosciences' Course in Higher Education. *Open Journal of Philosophy*, *10*(04), 469–481. https://doi.org/10.4236/ojpp.2020.104033

Kellesarian, S. (2018). Flipping the Dental Anatomy Classroom. *Dentistry Journal*, *6*(3), 23. https://doi.org/10.3390/dj6030023

Kember, D., Leung, D. Y. P., & Kwan, K. P. (2002). Does the Use of Student Feedback Questionnaires Improve the Overall Quality of Teaching? *Assessment & Evaluation in Higher Education*, *27*(5), 411–425. https://doi.org/10.1080/0260293022000009294

Kerr, K. (2017). Exploring student perceptions of verbal feedback. *Research Papers in Education*, *32*(4), 444–462. https://doi.org/10.1080/02671522.2017.1319589

Kibble, J. D. (2017). Best practices in summative assessment. *Advances in Physiology Education*, *41*(1), 110–119. https://doi.org/10.1152/advan.00116.2016

Killian, L. J., & Brandon, C. D. (2009). Using the Significant Learning Taxonomy and Active Learning to Improve Accounting Education. *Journal of Faculty Development*, *23*(3), 30–36.

Koba, S., & Tweed, A. (2009). *Hard-to-teach biology concepts: A framework to deepen student understanding*. NSTA Press.

Kovarik, D. N., Patterson, D. G., Cohen, C., Sanders, E. A., Peterson, K. A., Porter, S. G., & Chowning, J. T. (2013). Bioinformatics education in high school: Implications for promoting science, technology, engineering, and mathematics careers. *CBE Life Sciences Education*, *12*(3), 441–459. https://doi.org/10.1187/cbe.12-11-0193

Krase, K., Pfeifer, E., & Swan, K. (2018). Team-Based Learning Sessions Compared With Traditional Lecture in the Obstetrics and Gynecology Clerkship. *Obstetrics & Gynecology*, *132*(1), 14S-18S. https://doi.org/10.1097/AOG.0000000000002856

Krueger, K. P., Russell, M. A., & Bischoff, J. (2011). A Health Policy Course Based on Fink's Taxonomy of Significant Learning. *American Journal of Pharmaceutical Education*, *75*(1), 14. https://doi.org/10.5688/ajpe75114

Kubat, U. (2018). Identifying the Individual Differences Among Students During Learning and Teaching Process by Science Teachers. *International Journal of Research in Education and Science*, 30–68. https://doi.org/10.21890/ijres.369746

Kulasegaram, K., & Rangachari, P. K. (2018). Beyond "formative": Assessments to enrich student learning. *Advances in Physiology Education*, *42*(1), 5–14. https://doi.org/10.1152/advan.00122.2017

Latif, E., & Miles, S. (2020). The Impact of Assignments and Quizzes on Exam Grades: A Difference-in-Difference Approach. *Journal of Statistics Education*, *28*(3), 289–294. https://doi.org/10.1080/10691898.2020.1807429

Levine, L. E., Fallahi, C. R., Nicoll-Senft, J. M., Tessier, J. T., Watson, C. L., & Wood, R. M. (2008). Creating Significant Learning Experiences Across Disciplines. *College Teaching*, *56*(4), 247–254. https://doi.org/10.3200/CTCH.56.4.247-254

Levine, R. E., Hsieh, P., Kelly, P. A., Carchedi, L., Gibson, J., Haidet, P., Koles, P., Pershern, L., Schatte, D., Talley, B., Wolf, D., & Thompson, B. (2020). The Facilitator Instrument for Team-Based Learning (FIT). *Teaching and Learning in Medicine*, *32*(1), 82–90. https://doi.org/10.1080/10401334.2019.1646653

Lone, M., McKenna, J. P., Cryan, J. F., Downer, E. J., & Toulouse, A. (2018). A Survey of tooth morphology teaching methods employed in the United Kingdom and Ireland. *European Journal of Dental Education*, *22*(3), e438–e443. https://doi.org/10.1111/eje.12322

Lovász, A., Bat-Erdene, B., Cukrowska-Torzewska, E., Rigó, M., & Szabó-Morvai, Á. (2023). Competition, subjective feedback, and gender gaps in performance. *Journal of Behavioral and Experimental Economics*, *102*, 101954. https://doi.org/10.1016/j.socec.2022.101954

Lovász, A., Cukrowska-Torzewska, E., Rigó, M., & Szabó-Morvai, Á. (2022). Gender differences in the effect of subjective feedback in an online game. *Journal of Behavioral and Experimental Economics*, *98*, 101854. https://doi.org/10.1016/j.socec.2022.101854

Ludvigsen, K., Krumsvik, R., & Furnes, B. (2015). Creating formative feedback spaces in large lectures. *Computers & Education*, *88*, 48–63. https://doi.org/10.1016/j.compedu.2015.04.002

Maclean, G., & McKeown, P. (2013). Comparing online quizzes and take-home assignments as formative assessments in a 100-level economics course. *New Zealand Economic Papers*, *47*(3), 245–256. https://doi.org/10.1080/00779954.2012.707530

Mahtani, T., Brotman, Y. S., & Ashok, A. (2020). Promoting Interdisciplinary Learning: A Cross-Course Assignment for Undergraduate Students in Advanced Biology and Drawing Courses. *Journal of Microbiology & Biology Education*, *21*(1), 20. https://doi.org/10.1128/jmbe.v21i1.1919

Martínez-Caro, E., & Campuzano-Bolarín, F. (2011). Factors affecting students' satisfaction in engineering disciplines: Traditional vs. blended approaches. *European Journal of Engineering Education*, *36*(5), 473–483. https://doi.org/10.1080/03043797.2011.619647

Masouleh, N. S., & Jooneghani, R. B. (2012). Learner-Centered Instruction: A Critical Perspective. *Journal of Education and Practice*, *3*(6), 50.

McCarthy, J. P., & Anderson, L. (1999). Active Learning Techniques Versus Traditional Teaching Styles: Two Experiments from History and Political Science. *Innovative Higher Education*, *24*(4), 279–294. https://doi.org/10.1023/B:IHIE.0000047415.48495.05

Mhavan, N., Nair, D., & Gudipudi, A. B. (2022). National Education Policy-2020. In M. S. Manna, K. Sood, B. Balusamy, N. Chilamkurti, & I. Rajathi George, *Edutech Enabled Teaching* (1st ed., pp. 185–200). Chapman and Hall/CRC. https://doi.org/10.1201/9781003254942-12

Michaelsen, L. K., & Sweet, M. (2008). The essential elements of team-based learning. *New Directions for Teaching and Learning*, *2008*(116), 7–27. https://doi.org/10.1002/tl.330

Michel, N., Cater, J. J., & Varela, O. (2009). Active versus passive teaching styles: An empirical study of student learning outcomes. *Human Resource Development Quarterly*, *20*(4), 397–418. https://doi.org/10.1002/hrdq.20025

Mite-Baidal, K., Delgado-Vera, C., Solís-Avilés, E., Espinoza, A. H., Ortiz-Zambrano, J., & Varela-Tapia, E. (2018). Sentiment Analysis in Education Domain: A Systematic Literature Review. In R. Valencia-García, G. Alcaraz-Mármol, J. Del Cioppo-Morstadt,

N. Vera-Lucio, & M. Bucaram-Leverone (Eds.), *Technologies and Innovation* (Vol. 883, pp. 285–297). Springer International Publishing. https://doi.org/10.1007/978-3-030-00940-3_21

Moran, N., Hadley, L. V., Bader, M., & Keller, P. E. (2015). Perception of 'Back-Channeling' Nonverbal Feedback in Musical Duo Improvisation. *PLOS ONE*, *10*(6), e0130070. https://doi.org/10.1371/journal.pone.0130070

Moraros, J., Islam, A., Yu, S., Banow, R., & Schindelka, B. (2015). Flipping for success: Evaluating the effectiveness of a novel teaching approach in a graduate level setting. *BMC Medical Education*, *15*(1), 27. https://doi.org/10.1186/s12909-015-0317-2

Mukhopadhyay, S., & Samanta, P. (2023). *Advanced Data Analytics Using Python: With Architectural Patterns, Text and Image Classification, and Optimization Techniques*. Apress. https://doi.org/10.1007/978-1-4842-8005-8

Nguyen, T., Wong, E., & Pham, A. (2016). Incorporating Team-Based Learning Into a Physician Assistant Clinical Pharmacology Course. *Journal of Physician Assistant Education*, *27*(1), 28–31. https://doi.org/10.1097/JPA.0000000000000061

Nicol, D. (2010). From monologue to dialogue: Improving written feedback processes in mass higher education. *Assessment & Evaluation in Higher Education*, *35*(5), 501–517. https://doi.org/10.1080/02602931003786559

Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: A text analysis of the teachers qualities by gender. *International Journal of Educational*

Technology in Higher Education, *17*(1), 49. https://doi.org/10.1186/s41239-020-00224-z

Olufemi, A. S. (2014). The Effect of Homework Assignment on Mathematics Achievement of Secondary School Students in South West Nigeria. *Journal of Education and Practice*, *5*(28), 52.

O'Neill, G., & Murphy, F. (2010). *Guide to taxonomies of learning*. https://www.semanticscholar.org/paper/Guide-to-taxonomies-of-learning-O%E2%80%99Neill-Murphy/f630b6ef1a76f7b0566627bd0a359881308be296

Oramas Bustillos, R., Zatarain Cabada, R., Barrón Estrada, M. L., & Hernández Pérez, Y. (2019). Opinion mining and emotion recognition in an intelligent learning environment. *Computer Applications in Engineering Education*, *27*(1), 90–101. https://doi.org/10.1002/cae.22059

Ozcakar, N., Mevsim, V., Guldal, D., Gunvar, T., Yildirim, E., Sisli, Z., & Semin, I. (2009). Is the use of videotape recording superior to verbal feedback alone in the teaching of clinical skills? *BMC Public Health*, *9*(1), 474. https://doi.org/10.1186/1471-2458-9-474

Page, G., & Reiss, M. (2010). Biology Education Research. *Journal of Biological Education*, *44*(2), 51–52. https://doi.org/10.1080/00219266.2010.9656193

Papadopoulos, P. M., Natsis, A., Obwegeser, N., & Weinberger, A. (2019). Enriching feedback in audience response systems: Analysis and implications of objective and subjective metrics on students' performance and attitudes. *Journal of Computer Assisted Learning*, *35*(2), 305–316. https://doi.org/10.1111/jcal.12332

Paristiowati, M., Cahyana, U., & Irsa Setara Bulan, B. (2019). Implementation of Problem-based Learning – Flipped Classroom Model in Chemistry and Its Effect on Scientific Literacy. *Universal Journal of Educational Research*, *7*(9A), 56–60. https://doi.org/10.13189/ujer.2019.071607

Park, S. E., Salihoglu-Yener, E., & Fazio, S. B. (2019). Use of team-based learning pedagogy for predoctoral teaching and learning. *European Journal of Dental Education*, *23*(1), e32–e36. https://doi.org/10.1111/eje.12396

Pascarella, E. T. (1985). Students' Affective Development within the College Environment. *The Journal of Higher Education*, *56*(6), 640. https://doi.org/10.2307/1981072

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning Styles: Concepts and Evidence. *Psychological Science in the Public Interest*, *9*(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Podolak, K., & Danforth, J. (2017). Interactive Modern Physics Worksheets Methodology and Assessment. *European Journal of Physics Education*, *4*(2), 39–43.

Purcell, K. P. (2020). *THE USE OF INTEGRATED COURSE DESIGN IN DEVELOPING A HEALTH Abstract: I. INTRODUCTION II. HIT CURRICULUM DEVELOPMENT*. 1–8.

Rahayu, Y. S., Pratiwi, R., & Indana, S. (2018). Development of biology student worksheets to facilitate science process skills of student. *IOP Conference Series: Materials Science and Engineering*, *296*, 012044. https://doi.org/10.1088/1757-899X/296/1/012044

Ransom, M., & Manning, M. (2013). Teaching Strategies: Worksheets, Worksheets, Worksheets. *Childhood Education*, *89*(3), 188–190. https://doi.org/10.1080/00094056.2013.792707

Raupach, T., Brown, J., Anders, S., Hasenfuss, G., & Harendza, S. (2013). Summative assessments are more powerful drivers of student learning than resource intensive teaching formats. *BMC Medicine*, *11*(1), 61. https://doi.org/10.1186/1741-7015-11-61

Razinkina, E., Pankova, L., Trostinskaya, I., Pozdeeva, E., Evseeva, L., & Tanova, A. (2018). Student satisfaction as an element of education quality monitoring in innovative higher education institution. *E3S Web of Conferences*, *33*, 03043. https://doi.org/10.1051/e3sconf/20183303043

Richardson, J. T. E. (2005). Instruments for obtaining student feedback: A review of the literature. *Assessment & Evaluation in Higher Education*, *30*(4), 387–415. https://doi.org/10.1080/02602930500099193

Richert, W., Coelho, L. P., & Coelho, L. P. (2013). *Building machine learning systems with Python: Master the art of machine learning with Python and build effective machine learning systems with this intensive hands-on guide*. Packt Publishing Limited.

Riechmann, S. W., & Grasha, A. F. (1974). A Rational Approach to Developing and Assessing the Construct Validity of a Student Learning Style Scales Instrument. *The Journal of Psychology*, *87*(2), 213–223. https://doi.org/10.1080/00223980.1974.9915693

Rodríguez-Ibánez, M., Casánez-Ventura, A., Castejón-Mateos, F., & Cuenca-Jiménez, P.-M. (2023). A review on sentiment analysis from social media platforms. *Expert Systems with Applications*, *223*, 119862. https://doi.org/10.1016/j.eswa.2023.119862

Rowland, A. A., Knekta, E., Eddy, S., & Corwin, L. A. (2019). Defining and Measuring Students’ Interest in Biology: An Analysis of the Biology Education Literature. *CBE—Life Sciences Education*, *18*(3), ar34. https://doi.org/10.1187/cbe.19-02-0037

Samawi, Z., Haras, M. S., & Miller, T. L. (2012). Age-Appropriate Health Promotion Education: Roots Firmly Established in Baccalaureate Nursing Pediatric Rotation. *Journal of Pediatric Nursing*, *27*(1), 44–49. https://doi.org/10.1016/j.pedn.2010.09.003

Sarkar, D. (2019). *Text Analytics with Python: A Practitioner’s Guide to Natural Language Processing*. Apress. https://doi.org/10.1007/978-1-4842-4354-1

Schinske, J. N., Balke, V. L., Bangera, M. G., Bonney, K. M., Brownell, S. E., Carter, R. S., Curran-Everett, D., Dolan, E. L., Elliott, S. L., Fletcher, L., Gonzalez, B., Gorga, J. J., Hewlett, J. A., Kiser, S. L., McFarland, J. L., Misra, A., Nenortas, A., Ngeve, S. M., Pape-Lindstrom, P. A., … Corwin, L. A. (2017). Broadening Participation in Biology Education Research: Engaging Community College Students and Faculty. *CBE—Life Sciences Education*, *16*(2), mr1. https://doi.org/10.1187/cbe.16-10-0289

Setiawan, A. R. (2020). *Scientific Literacy Worksheets for Distance Learning in the Topic of Coronavirus 2019 (COVID-19)* [Preprint]. EdArXiv. https://doi.org/10.35542/osf.io/swjmk

Shorbagi, S., & Ashok, A. (2016). Designing an Audiocast Assignment: A Primary-Literature-Based Approach that Promotes Student Learning of Cell and Molecular Biology through Conversations with Scientist Authors. *Journal of Microbiology & Biology Education*, *17*(3), 472–474. https://doi.org/10.1128/jmbe.v17i3.1110

Shute, V. J. (2008). Focus on Formative Feedback. *Review of Educational Research*, *78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Silva, E. C. E., Lino-Neto, T., Ribeiro, E., Rocha, M., & Costa, M. J. (2022). Going virtual and going wide: Comparing Team-Based Learning in-class versus online and across disciplines. *Education and Information Technologies*, *27*(2), 2311–2329. https://doi.org/10.1007/s10639-021-10683-0

Singer, S. R., Nielsen, N. R., & Schweingruber, H. A. (2013). Biology Education Research: Lessons and Future Directions. *CBE—Life Sciences Education*, *12*(2), 129–132. https://doi.org/10.1187/cbe.13-03-0058

Singh, P. (2021). *Deploy Machine Learning Models to Production: With Flask, Streamlit, Docker, and Kubernetes on Google Cloud Platform*. Apress. https://doi.org/10.1007/978-1-4842-6546-8

Singhal, Dr. D. (2017). Understanding Student- Centered Learning and Philosophies of Teaching Practices. *International Journal of Scientific Research and Management*. https://doi.org/10.18535/ijsrm/v5i2.02

Smart, K. L., Witt, C., & Scott, J. P. (2012). Toward Learner-Centered Teaching: An Inductive Approach. *Business Communication Quarterly*, *75*(4), 392–403. https://doi.org/10.1177/1080569912459752

Smith, C. (2022). Architecture students' uptake and use of formative and summative feedback. *Assessment & Evaluation in Higher Education*, *47*(1), 29–44. https://doi.org/10.1080/02602938.2021.1892028

Sokoloff, D. R., & Thornton, R. K. (1997). Using interactive lecture demonstrations to create an active learning environment. *The Physics Teacher*, *35*(6), 340–347. https://doi.org/10.1119/1.2344715

Spanjaard, D., Hall, T., & Stegemann, N. (2018). Experiential Learning: Helping Students to Become 'Career-Ready.' *Australasian Marketing Journal*, *26*(2), 163–171. https://doi.org/10.1016/j.ausmj.2018.04.003

Srinivasa-Desikan, B. (2018). *Natural language processing and computational linguistics: A practical guide to text analysis with Python, Gensim, spaCy, and Keras*. Packt.

Stark, B., Li, Z., Smith, B., & Chen, Y. (2013). Take-Home Mechatronics Control Labs: A Low-Cost Personal Solution and Educational Assessment. *Volume 4: 18th Design for Manufacturing and the Life Cycle Conference; 2013 ASME/IEEE International Conference on Mechatronic and Embedded Systems and Applications*, V004T08A036. https://doi.org/10.1115/DETC2013-12735

Steyn, C., Davies, C., & Sambo, A. (2019). Eliciting student feedback for course development: The application of a qualitative course evaluation tool among business research students. *Assessment & Evaluation in Higher Education*, *44*(1), 11–24. https://doi.org/10.1080/02602938.2018.1466266

Subramaniam, K. (2014). Student teachers' conceptions of teaching biology. *Journal of Biological Education*, *48*(2), 91–97. https://doi.org/10.1080/00219266.2013.837405

Sudhir, P., & Suresh, V. D. (2021). Comparative study of various approaches, applications and classifiers for sentiment analysis. *Global Transitions Proceedings*, *2*(2), 205–211. https://doi.org/10.1016/j.gltp.2021.08.004

Trautwein, U., Köller, O., Schmitz, B., & Baumert, J. (2002). Do Homework Assignments Enhance Achievement? A Multilevel Analysis in 7th-Grade Mathematics. *Contemporary Educational Psychology*, *27*(1), 26–50. https://doi.org/10.1006/ceps.2001.1084

Trenholm, S., & Chinnappan, M. (2019). Prospective primary teachers' perceptions about the use of mathematics homework. *Teacher Development*, *23*(1), 50–63. https://doi.org/10.1080/13664530.2018.1490923

Trigwell, K., & Prosser, M. (2004). Development and Use of the Approaches to Teaching Inventory. *Educational Psychology Review*, *16*(4), 409–424. https://doi.org/10.1007/s10648-004-0007-9

Turney, P. D. (2002). *Thumbs Up or Thumbs Down? Semantic Orientation Applied to Unsupervised Classification of Reviews* (arXiv:cs/0212032). arXiv. https://doi.org/10.48550/arXiv.cs/0212032

Uribe Cantalejo, J. C., & Pardo, M. I. (2020). Fink's integrated course design and taxonomy: The impact of their use in a "Basics of Dental Anatomy" course. *Journal of Dental Education*, *84*(9), 964–973. https://doi.org/10.1002/jdd.12183

Usart, M., Grimalt-Álvaro, C., & Iglesias-Estradé, A. M. (2023). Gender-sensitive sentiment analysis for estimating the emotional climate in online teacher education. *Learning Environments Research*, *26*(1), 77–96. https://doi.org/10.1007/s10984-022-09405-1

Van Doren, E. J., Lee, J. E., Breitman, L. S., Chutinan, S., & Ohyama, H. (2021). Students' perceptions on dental education in the wake of the COVID-19 pandemic. *Journal of Dental Education*, *85*(S1), 1187–1189. https://doi.org/10.1002/jdd.12300

Vergara-Torres, A. P., Tristán, J., López-Walle, J. M., González-Gallegos, A., Pappous, A. (Sakis), & Tomás, I. (2020). Students' Perceptions of Teachers' Corrective Feedback, Basic Psychological Needs and Subjective Vitality: A Multilevel Approach. *Frontiers in Psychology*, *11*, 558954. https://doi.org/10.3389/fpsyg.2020.558954

Volerman, A., & Poeppelman, R. S. (2019). A pilot study of team-based learning in one-hour pediatrics residency conferences. *BMC Medical Education*, *19*(1), 266. https://doi.org/10.1186/s12909-019-1702-z

Wang, A., Xiao, R., Zhang, C., Yuan, L., Lin, N., Yan, L., Wang, Y., Yu, J., Huang, Q., Gan, P., Xiong, C., Xu, Q., & Liao, H. (2022). Effectiveness of a combined problem-based learning and flipped classroom teaching method in ophthalmic clinical skill training. *BMC Medical Education*, *22*(1), 487. https://doi.org/10.1186/s12909-022-03538-w

Wang, W., & Loewen, S. (2016). Nonverbal behavior and corrective feedback in nine ESL university-level classrooms. *Language Teaching Research*, *20*(4), 459–478. https://doi.org/10.1177/1362168815577239

Wankhade, M., Rao, A. C. S., & Kulkarni, C. (2022). A survey on sentiment analysis methods, applications, and challenges. *Artificial Intelligence Review*, *55*(7), 5731–5780. https://doi.org/10.1007/s10462-022-10144-1

Webb, J. M., Diana, E. M., Luft, P., Brooks, E. W., & Brennan, E. L. (1997). Influence of Pedagogical Expertise and Feedback on Assessing Student Comprehension From Nonverbal Behavior. *The Journal of Educational Research*, *91*(2), 89–97. https://doi.org/10.1080/00220679709597526

Whittaker, A. A. (2015). Effects of Team-Based Learning on Self-Regulated Online Learning. *International Journal of Nursing Education Scholarship*, *12*(1), 45–54. https://doi.org/10.1515/ijnes-2014-0046

Wilson, J. H., & Ryan, R. G. (2013). Professor–Student Rapport Scale: Six Items Predict Student Outcomes. *Teaching of Psychology*, *40*(2), 130–133. https://doi.org/10.1177/0098628312475033

Wilson Sayres, M. A., Hauser, C., Sierk, M., Robic, S., Rosenwald, A. G., Smith, T. M., Triplett, E. W., Williams, J. J., Dinsdale, E., Morgan, W. R., Burnette, J. M., Donovan, S. S., Drew, J. C., Elgin, S. C. R., Fowlks, E. R., Galindo-Gonzalez, S., Goodman, A. L., Grandgenett, N. F., Goller, C. C., … Pauley, M. A. (2018). Bioinformatics core competencies for undergraduate life sciences education. *PLOS ONE*, *13*(6), e0196878. https://doi.org/10.1371/journal.pone.0196878

Wolff, M., Wagner, M. J., Poznanski, S., Schiller, J., & Santen, S. (2015). Not Another Boring Lecture: Engaging Learners with Active Learning Techniques. *The Journal of Emergency Medicine*, *48*(1), 85–93. https://doi.org/10.1016/j.jemermed.2014.09.010

Wood, W. B., & Tanner, K. D. (2012). The Role of the Lecturer as Tutor: Doing What Effective Tutors Do in a Large Lecture Class. *CBE—Life Sciences Education*, *11*(1), 3–9. https://doi.org/10.1187/cbe.11-12-0110

Wu, L., Morstatter, F., & Liu, H. (2018). SlangSD: Building, expanding and using a sentiment dictionary of slang words for short-text sentiment classification. *Language Resources and Evaluation*, *52*(3), 839–852. https://doi.org/10.1007/s10579-018-9416-0

Yasmin, F., Li, S., Zhang, Y., Poulova, P., & Akbar, A. (2021). Unveiling the International Students' Perspective of Service Quality in Chinese Higher Education Institutions. *Sustainability*, *13*(11), 6008. https://doi.org/10.3390/su13116008

Zapalska, A., & Brozik, D. (2006). Learning styles and online education. *Campus-Wide Information Systems*, *23*(5), 325–335. https://doi.org/10.1108/10650740610714080

Zhang, L., & Sternberg, R. J. (2005). A Threefold Model of Intellectual Styles. *Educational Psychology Review*, *17*(1), 1–53. https://doi.org/10.1007/s10648-005-1635-4

Zhang, S., Wei, Z., Wang, Y., & Liao, T. (2018). Sentiment analysis of Chinese micro-blog text based on extended sentiment dictionary. *Future Generation Computer Systems*, *81*, 395–403. https://doi.org/10.1016/j.future.2017.09.048

7 Supplementary Data Sheet -I Questionnaire

1. What was your perception of the tutorial before you were introduced to it?

a) I was eager to try the hands-on sessions.

b) I was neutral.

c) I was not very excited, for I thought it would be burdensome.

d) I don't recall now how I felt.

2. Have you used any of the bioinformatics resources or tools before coming to this course?

a) No, the course was my first exposure

b) Just heard about them

c) Got exposed to some as part of an earlier course/training

d) Used superficially as part of a project or out of curiosity

e) Used in depth as part of a project or out of interest

3. How likely are you to use in the future the bioinformatics resources and tools discussed in the course? Tick an appropriate response.

Extremely unlikely (1)

Unlikely (2)

Not Sure (3)

Likely (4)

Extremely likely (5)

4. Which of these tools you learned during the hands-on sessions did you use for completing your end-semester project (manuscript writing)?

a) Data analysis methods (e.g., GenScan, ORFinder etc.)

b) Python for solving biological problems

c) Use of data resources (e.g., databases such as GenBank, UniProt etc.)

d) Use of tools (e.g. BLAST, MEGA, EMBOSS etc.)

5. Organization of the Hands-on Tutorial Sessions

i) Problems given during the tutorial sessions were integrated very well with the course.

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

ii) Instructor was clear in stating the problem before the session began.

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

iii) Instructor made himself available during the lab sessions to help with issues

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

iv) Students were encouraged to collaborate during the lab to foster better learning.

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

v) The tutorials helped me understand the theory much better.

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

vi) I looked forward to attending the tutorials every week!

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

vii) Worksheet and Take-Home Assignments were well integrated with the course and helped you in achieving better learning

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

viii) The post-Covid sessions held online were as effective as the face-to-face sessions held.

a) Strongly disagree

b) Disagree

c) Neither agree nor disagree

d) Agree

e) Strongly agree

6. How good was the personal rapport between the practical instructor and students?

a) The rapport was great!

b) The rapport was up to the mark

c) Neither good nor bad

d) Very bad

e) I don't know enough to answer this question.

7. What is your overall rating of the tutorial classes? Tick your appropriate response.

Highly not valuable (1)

Not Valuable (2)

Not Sure (3)

Valuable (4)

Highly valuable (5)

8. In your opinion, should this arrangement of out-of-class take-home assignments, and in-class worksheets be continued for future batches of students?

a) Yes, most certainly!

b) Yes, but with some changes (as I describe in the additional feedback or suggestions section)

c) No, I would not recommend

d) I don't have an opinion on this.

9. How much did take-home assignments or worksheet discussions contribute to achieving better learning?

Very less (1) (2) (3) (4) (5) Very much

10. How good was the personal rapport between the tutorial instructor and students?

a) The rapport was great!

b) The rapport was up to the mark

c) Neither good nor bad

d) Very bad

e) I don't know enough to answer this question.

11. Any additional feedback or suggestions?

12. The data obtained from this survey may be used as part of the pedagogy research work I am doing. Do you consent to this?

a) Yes, Definitely

b) No

8 Appendix I List of publications

Research Articles

1. **Katyal, A.,** Chowdhury, S., Sharma, P.K., Kannan, M., Fink's Integrated Course Design and Taxonomy: The Impact of Their Use in an Undergraduate Introductory Course on Bioinformatics. Journal of Science Education and Technology (2024). https://doi.org/10.1007/s10956-024-10100-4
2. Sumit Kumar Mandal, MD Muzaffar-Ur Rehman, **Ashish Katyal**, Kanishk Rajvanshi, Manoj Kannan, Mohit Garg, Sankaranarayanan Murugesan, P.R. Deepa, In silico anti-viral assessment of phytoconstituents in a traditional (Siddha Medicine) polyherbal formulation – Targeting Mpro and pan-coronavirus post-fusion Spike protein, Journal of Traditional and Complementary Medicine (2024). https://doi.org/10.1016/j.jtcme.2023.07.004.
3. Tiwari P, **Katyal A**, Khan MF, Ashraf GM, Ahmad K. Lead Optimization Resources in Drug Discovery for Diabetes. Endocr Metab Immune Disord Drug Targets. 2019;19(6):754-774. doi: 10.2174/1871530319666190304121826.

9 Appendix II List of Workshops, Conferences and Presentations

Oral presentation

Ashish Katyal, Pankaj Kumar Sharma, Manoj Kannan. Team-Based Learning (TBL): Exploring an Active Learning Strategy for Two Undergraduate Courses in Biology. Conference titled 'International Conference on Best Innovative Teaching Strategies' organized by Birla Institute of Technology and Science (BITS) Pilani, Pilani campus on 09-11 February 2023.

Ashish Katyal, Manoj Kannan. Employing Collaborative Problem-Based Learning for an Immersive Online Experience in an Undergraduate Bioinformatics Course. Virtual Conference titled 'International Conference on Best Innovative Teaching Strategies' organized by Birla Institute of Technology and Science (BITS) Pilani, Pilani campus on 29-31 July 2021.

Poster presentation

Ashish Katyal, Manoj Kannan. "Role of Personal Rapport in Enhancing Student Learning and Performance". 'International Conference on Best Teaching Practices for Engaged Student Learning', 13-15 February, 2020 organized by Teaching Learning Centre, Birla Institute of Technology and Science (BITS) Pilani at Birla Institute of Technology and Science (BITS), Goa.

List of workshops, conferences, webinars attended during the course of degree

10 Four-days online Short Course on "**Youth Mental Health First Aid Course**" affiliated with MHFA Australia on 9-10, 16-17 Oct 2021.

11 One day online webinar on "**Quantitative Data Analysis in R using Statcraft**" organized by Jawaharlal College of Engineering and Technology in collaboration with Statcraft, Bangalore on 18 Nov 2020.

12 One day online webinar on "**Naya Kshitij: NEP-2020 for Higher Education**" organized by Teaching Learning Centre, Birla Institute of Technology and Science (BITS) Pilani on 07 Nov 2020.

13 Two days International virtual conference on "**Computer-Aided Drug Design**" organized by the Department of Pharmacy, BITS-Pilani on 30-31 Oct 2020.

14 Fifteen days of International virtual online short course (20 hours) on "**Significant Learning by Design-I**" certified by Dee Fink and Associates on 30 Sep-15 Oct 2020.

15 One day virtual webinar on "**Covid-19 and its Financial Markets**" organized by McGraw Hill on 14 Sep 2020.

16 Three days National virtual workshop on "**Evidence-Based Teaching and Learning Strategies in Higher Education**" organized by CREATES, IISER, Bhopal under the PMMMNMTT Scheme of MHRD on 20-22 July 2020.

17 One day virtual National webinar on "**Prospects of Natural Products on Human Health in Current Scenario**" organized by the Department of Botany, MMV, Banaras Hindu University, Varanasi on 24 June 2020.

18 One day National virtual webinar on "**Future of Education Post Covid**" organized by McGraw Hill on 18 June 2020.

19 One day National virtual webinar on "**Trends in Publishing**" organized by Springer Nature in collaboration with Inflibnet Centre on 16 June 2020.

20 Two days National virtual webinar on "**NGS Data Analysis and An Overview of Illumina Library Preparation and its application in RNAseq and Metagenomics**" organized by Premas Life Sciences in association with the Department of Biotechnology, BITS-Pilani on 08-09 June 2020.

21 Two days National virtual webinar Series (2 days) on "**An Overview of Next Generation Sequencing Technology**" organized by Premas Life Sciences in association with the Department of Biotechnology, Amity University-Noida on 03 and 06 June 2020 respectively.

22 One day workshop on "**Teaching Learning for Next Generation Academicians**" sponsored by the Teaching Learning Centre at Birla Institute of Technology and Science (BITS), Pilani on 07 Sep 2019.

23 One day workshop on the "**Intellectual Property Rights Awareness Program**" sponsored by Intellectual Property India in association with ASSOCHAM, India at Meerut Institute of Engineering Technology, Meerut on 22 Aug 2019.

24 Two days National workshop on "**Emotional Intelligence**" sponsored by ICT Academy at Meerut Institute of Engineering Technology, Meerut on 27-28 Feb 2019.

25 One-day "**MATLAB**" workshop organized by Mathworks at Meerut Institute of Engineering Technology, Meerut on 09 Feb 2019.

26 Eight days Faculty Development Programme "**Universal Human Values & Professional Ethics**" sponsored by AKTU at Meerut Institute of Engineering Technology, Meerut on 26 Dec 2018- 02 Jan 2019.

27 Two days conference on "**XXVI Annual Congress of Society of Andrology**" sponsored by the Society of Andrology: India at Meerut Institute of Engineering Technology, Meerut on 26-28 Oct 2018.

28 Five days Quality Improvement Programme (QIP) on "**Laboratory and Ergonomic Safety For Engineers**" through CE and QIP organized by IIT Bombay at IIT, Bombay on 11-15 June 2018.

29 Five days Faculty Development Programme (FDP) "**Biosafety and IPR issues in Bio-Pharma Research**" sponsored by AKTU at Meerut Institute of Engineering Technology, Meerut on 21-25 May 2018.

30 One day International mini symposium on "**Biotechnology In Medical Research**" sponsored by the Indian Academy of Biomedical Sciences (IABS) at Meerut Institute of Engineering Technology, Meerut on 24 April 2018.

31 Five days Quality Improvement Programme (QIP) on "**Modern Biophysical Techniques**" through CE and QIP organized by IIT Bombay at IIT, Bombay on 11-15 Dec 2017.

32 One day International Seminar on "**Food Safety and Nutrition**" at Meerut Institute of Engineering Technology, Meerut on 23 Sep 2017.

33 Appendix III Brief Biography of the Candidate

Name: Ashish Katyal

Date of Birth: 12^{th} September, 1988

Education: M.Tech. (Bioinformatics), 2009-2011 from Devi Ahilya Vishwavidyalaya, Indore, Madhya Pradesh, India

B.Tech. (Biotechnology), 2005-2009 from Kurukshetra University, Kurukshetra, Haryana, India

Email: aashishkatyal@gmail.com , p20170101@pilani.bits-pilani.ac.in

Teaching Experience

1. Worked as a Lecturer in the Department of Biotechnology Meerut Institute of Engineering and Technology (MIET), Meerut, Uttar Pradesh (April 2011- July 2012).
2. Worked as an Assistant Professor in the Department of Biotechnology Meerut Institute of Engineering and Technology (MIET), Meerut, Uttar Pradesh (August 2012- August 2019).

Research Experience

3. Worked as an Institute Fellow (IF) research scholar in the Department of Biological Sciences under the supervision of Prof. Pankaj Kumar Sharma, Biological Sciences, BITS Pilani, K.K Birla Goa Campus (August 2017- May 2023).

Research publication(s)

03 research publications in the national and international journals

Award(s)

1. Qualified Graduate Aptitude Test in Engineering (GATE) qualified with All India Rank **1671** in 2011 and **233** in 2015.

2. Awarded the Plaksha Research Fellow (PRF) to carry out doctoral research (April 2022 – March 2023) under the supervision of Prof. Manoj Kannan, Plaksha University, SAS Nagar, Punjab.

34 Appendix IV Brief Biography of the Supervisor

Brief Biography of the Ph.D. Supervisor- Prof. Pankaj Kumar Sharma

Pankaj Kumar Sharma holds the position of Associate Professor in the Department of Biological Sciences at Birla Institute of Technology and Science, Pilani. He completed his M.Sc. (Hons.) in Biological Sciences and M.E. in Biotechnology from BITS, Pilani in 2000 and 2002, respectively. In 2000, he qualified for CSIR-NET (LS) and in 2001, he qualified for CSIR-NET (JRF). His Ph.D. in Biotechnology was earned from Central Institute of Medicinal and Aromatic Plants, CSIR, Lucknow, under the guidance of Dr. R.S. Sangwan. The degree was awarded by Uttar Pradesh Technical University, Lucknow in 2008. His doctoral research focused on "Biochemical and Molecular Investigation of Biotransformation of Terpenoids in Selected Medicinal-Aromatic Plants".

Dr. Sharma commenced his academic career as a Lecturer at BITS, Pilani-Pilani Campus in July 2008 and currently holds the position of Associate Professor in the Department of Biological Sciences. He has authored over 20 papers published in prestigious national and international journals.

Brief Biography of the Ph.D. Co-Supervisor- Prof. Manoj Kannan

Manoj Kannan serves as an Associate Professor and Associate Dean of Student Life at Plaksha University. Prior to joining Plaksha University, Dr. Kannan dedicated approximately 15 years to teaching various courses in biological sciences and introductory computer programming at BITS Pilani's Dubai and Pilani campuses. Alongside teaching, he has actively engaged in academic counseling, mentoring, and providing support to students, activities that hold great significance to him.

During his PhD, Dr. Kannan conducted research on the epigenetic control of mammalian transposons at the National Institutes of Health in Maryland. Currently, his research interests revolve around biology education, particularly focusing on the integration of course design using Fink's Taxonomy of Significant Learning. Additionally, he has contributed to the development and implementation of innovative assessment strategies that promote effective learning. As part of the Collaboratory for Innovation in Education at Plaksha, Dr. Kannan continues to serve as a resource person for faculty development programs conducted for universities and schools.

Brief Biography of the Ph.D. Co-Supervisor- Dr. L.Dee Fink

Dr. L. Dee Fink, born on September 2, 1940, has extensive experience as a consultant in higher education, specializing in teaching and faculty development. With over 30 years of national and international consulting work, he has collaborated with more than 200 colleges and universities in the United States and 16 other countries across various regions. Dr. Fink's expertise in instructional design has earned him recognition from the American Association of Higher Education. One of Dr. Fink's notable contributions is the introduction of an integrated course design model, which aligns learning goals with a method for assessing student learning. This model emphasizes the importance of personal meaning in the learning experience and offers a framework to measure psychological, social, and intellectual dimensions of learning. By considering subjective characteristics, prior experience, course content, learning gained, and effects on later experience, the model provides valuable insights for teachers to plan and evaluate their courses effectively.

Dr. Fink obtained his Ph.D. in Geography and Higher Education from the University of Chicago in 1976. His doctoral research focused on understanding the personal meaning of college geography courses for students and how it related to their subsequent experiences. The research included a model that measured various aspects of the learning experience before, during, and after the course, revealing variations in perceptions and highlighting the importance of acquiring fundamental concepts and problem-solving techniques. Dr. Fink recommends using this model for course planning, evaluation, and communication with students. Beginning his academic career at the University of Oklahoma in 1976, Dr. Fink held positions as an Adjunct Assistant Professor in the Department of Geography and as the Director of the Instructional Development Program until his retirement in 2005. In his role as Director, he provided consultation to faculty members and academic units, conducted orientation and professional development seminars for new faculty, and coordinated the administration of course evaluation systems. Since then, he has continued his work as a consultant, focusing on course design for colleges and universities in the United States and abroad.

Dr. Fink's research aims to develop an approach for integrated course design, which encompasses instructional design, college teaching, faculty development programs, and evaluations to enhance learning experiences and improve outcomes for both teachers and students. His notable works include "Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses," "Pre-Instructional Minitests: An Efficient Solution to the Problem of Covering Content," "Integrated Course Design," and "Team-Based Learning: A Transformative Use of Small Groups in College Teaching."

35 Appendix V Reprints of publications