Physics Educators' Efforts to Improve Conceptual Understanding in Physics

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Abstract- A review of the past and current literature on physics education have revealed to the greater physics community that instructors around the world have struggled to impart a conceptual understanding of physics onto their introductory college students. Several efforts to create a more interactive physics curriculum are evaluated in this paper in an attempt to understand trends in physics education research. A concerted effort to streamline the physics curriculum across physics departments is minimal. Those who have adjusted the curriculum to go beyond lectures still struggle to perform even with enhancements in the curriculum. Several researchers have led the charge to understand the gaps in understanding among novice physics students. By comparing their results and attitudes to expert physicists, researchers were able to determine a curriculum that addresses gaps in understanding for novice students. Last but not least, the idea of self-efficacy is explored because a student's attitude and behavior towards physics can impact their ability to learn the material. The review of the literature has highlighted a need for physics associations to synchronize an effective curriculum across universities in order to address the cyclical challenges of physics learning that many students and physics faculty have battled for decades.

I. Introduction

Many students regard physics as one of the most difficult subjects in school. This common stereotype raises one simple question: why do the majority of students find physics so difficult to comprehend? Many introductory college physics courses consist of lectures that fail to engage students into intuitively understanding physics concepts. Lectures alone do not sufficiently allow students to gain complete understanding and mastery of the subject. In this literature review about physics education, it was found that educators can begin to implement a more effective teaching method for college students that go beyond lectures. The role of self-efficacy course performance, alternative curriculums that promise more interactive and effective physics learning, and the effective implementation of physics comprehension among college students will be discussed. Boosting students' intuitive understanding should be the goal of educators in order to motivate students towards effective physics learning.

II. Testing Traditional Physics Education

Traditional physics teaching curriculums have failed to help students complete physics objectives that are desired by professors and instructors. For decades, educators have struggled to improve the physics education model. One researcher in the 90s, Alan Van Huevelen, performed a review of instructional strategies to identify the core issues. He states there are three main problems that have led to poor physics performance among students. One reason students struggled to have physics understanding is due to a lack of qualitative representations such as diagrams. A second reason was a lack of a physics framework and lacking the ability to correctly recall ideas and concepts from this framework. The third reason was an overemphasis on lecture-based education.

Diagram

Heuvelen found that only 10% of precalculus introductory physics students and 20% of engineering physics students utilized diagrams when solving physics problems (Heuvelen 891). Diagrams are important in physics as they allow students to analyze the essential aspects of a given physics system while excluding unnecessary details. Diagrams also help students make connections to physics concepts from models, helping to illustrate qualitative information based on these quantities. Lastly, diagrams help students formulate mathematical equations from these diagrams (Heuvelen 891).

In the study, Heuvelen uses the following problem as an example:

"A parachutist whose parachute did not open landed in a snowbank and stopped after sinking 1.0 m into the snow. Just before hitting the snow, the person was falling at a speed of 54 m/s. Determine the average force of the snow on the 80-kg person while sinking into the snow." (Huevelan 892)

Using diagrams and representations, students can intuitively connect physics concepts that may be difficult to comprehend otherwise. Heuvelen notes the first step is to use a pictorial representation which allows students to convert written words into a picture that shows two scenes of the parachutist: a beginning y position along with the initial velocity and a final y position along with final velocity (Heuvelen 892). This helps to build a connection between the variables within the scenario and their purpose. The second step is to create a physical representation by using the pictorial representation in order to isolate important physical quantities. For this, a free-body/force was created using arrows to show the forces acting upon the parachutist which are the normal force of the snow (with a direction going up) and force of gravity (with a direction going down). After creating these diagrams thus far, students are able to qualitatively reason through the information isolated (ie. the forces) to make relevant connections (Heuvelen 892). The final step is to create a mathematical representation to connect the physical quantities and solve for unknown variables. To solve for the average force that the snow exerted on the person,
Heuvelen shows that the kinematics equation 2 $2a(y - y) = v - v^2$ can be used since the diagrams show that 0 some given quantities were y, y , 2, and v 2(Heuvelen 892). Solving for a (acceleration) through algebra, this v 0 0 quantity can then be used to solve for the average force that the snow exerts through the mathematical equation for Newton's Second Law $\Sigma F = ma$.

Physics Frameworks

In physics, it is imperative to have the ability to build, elaborate, and adjust a physics framework, and yet, students must have the ability to recall the correct concepts to solve the problem. In Heuvelen's research, a question about springs and conservation of energy was given to the students on a cumulative final. However, over 50% of the students started to use the most recent spring equation taught in class, which was about simple harmonic motion rather than the correct energy concepts (Heuvelen 892). This led Heuvelen to believe that students had disconnected perceptions of physics concepts rather than seeing physics chapters as interconnected. Students often used unrelated ideas to solve problems showing that they had trouble recalling the correct concepts for a given physics problem. An example of what a physics framework could look like is shown in a model, where a top-down structure is used to solve problems. At the very top is the "Newtonian Mechanics" box. From this box, there are two types of motion that students can choose from (Heuvelen 893). The "Dynamics" is accelerated motion which consists of translational motion, circular motion, and rotational motion (Heuvelen 893). The "Conserved Motion" consists of linear momentum conserved, angular momentum conserved, and statics (Heuvelen 893). When a student is able to identify that a system has no interactions with things outside of it, they should realize that some aspect of that system is conserved which helps to identify appropriate concepts to utilize. Vice versa, if they can identify that a system does have outside interactions, students will see that some aspect within that system has been changed. Building a unified physics framework while using a top-down recalling method through cues can help with problem-solving.

Overemphasis on Lectures

Lectures can be efficient tools for conveying information to a large group of students. Standard lectures have been the solution to account for a large number of students in classrooms. However, lectures alone are not sufficient as many students have different learning styles. Therefore, simply telling students information regarding physics can often cause a lacking understanding. This is because students are unable to gain experimental evidence in order to support their conceptual understanding. Heuvelen compared efficient physics education to a transformer. In order for an efficient transfer of knowledge is given to the student, the methods in which these ideas are taught must be similar in characteristic to the student's mind itself (Heuvelen 893). Vice versa, the difference between the teaching methods and traits of the student's mind would cause an ineffective learning experience. In the future, physics education must improve its curriculum to enhance basic physical quantities and concepts, problem-solving skills, quantitative understanding, concept interconnectedness, active learning, and constant use of all concepts learned.

III. Interactive Learning Efforts

The effort to improve conceptual learning has been on the rise, though sporadic. Many researchers agree that lectures have been ineffective in developing conceptual learning among students. Several tests have been developed throughout the years to understand just how ineffective traditional curriculums have been. The following efforts show how researchers have strived to comprehend physics learning.

Active Learning Problem Sheets

In the late 90s, at the time of his research, Huevelen proposed a small group-based learning style in which students could elaborate on their physics knowledge by working on carefully designed worksheets, called the Active Learning Problem Sheets (The ALPS kit). The kit exists to provide key feedback from the professor and students' peers about how their perceptions of the concepts may be improved (Heuvelen 893). The special worksheets were designed to help students learn physics through a series of thought experiments, which helped to build a logical framework of the subject. To retain the information taught, constantly going over past topics and their applications help students see that all parts of physics are fundamentally interconnected and that they each serve an important purpose.

Force Concept Inventory

In 1992, David Hestenes at Arizona State University devised the Force Concept Inventory (FCI) to understand a student's conceptual learning of mechanics (Redish and Steinberg 26). Over 2000 students were provided the survey before and after a college calculus-based physics course. This survey was created in order to understand student difficulties in fundamental physics concepts, which are imperative for physics problem-solving. David Hammer at UC Berkeley interviewed students and defined their beliefs and expectations about physics in three areas: independence/authority, coherence/pieces, and concepts/equations (Redish and Steinberg 27). Building off of Hammer's observations, the Maryland Physics Expectations survey gave way to three more areas which include physics-reality link, a math-physics link, and the effort variable (Redish and Steinberg 27).

Workshop Physics

Around the same time, Priscilla Law and others at Dickinson College developed Workshop Physics which were lab-based sessions (consisting of lectures, recitations, and laboratories) of two 3 hour sessions a week where students work in small groups to complete a lab with an activity guide in order to understand physics concepts through observation (Redish & Steinberg 28). Workshop Physics replaced traditional curriculum. The survey contained 29 introductory mechanics physics questions that aimed to locate conceptual difficulties within physics students. Another researcher named Richard Hake from Indiana University created an equation for something called the Hake factor in regards to the FCI. This factor is a meritorious figure which measured the normal gain for a student's test score before and after the physics course. It is calculated by dividing the gain in percentage (the final score on the FCI subtracted by the initial score on the FCI) by the possible gain (the highest achievable score, 100, subtracted by the initial FCI score). For a traditional curriculum with recitations, the Hake factor was calculated to be 0.16 ± 0.03, the Hake factor for a traditional curriculum with tutorials was calculated to be 0.35 ± 0.03, and the Hake factor for a Workshop Physics class was 0.41 ± 0.03(Redish & Steinberg 29). The results show that the use of tutorials showed improvements in scores after the class.

Physics by Inquiry and Tutorials in Introductory Physics

For nearly 20 years Lillian Christie McDermott from the Physics Group at the University of Washington studied physics learning and received the 2002 Medal of the International Council in Physics Education of IUPAP at the GIREP Seminar (Quality Development in Teacher Education and Training). Throughout the 80s and 90s, for her award-winning research, Lillian Christie McDermott presented a physics problem to over 1000 students asking them to rank the brightness of light bulbs of different electrical circuits. Of them, only 15% of the participants were able to answer the question correctly (McDermott 1128). When analyzing the results, it was found that the most common error within the problem stemmed from the lack of a conceptual understanding of physics in terms of an electric circuit. Based on these results, the Physics by Inquiry (PbI) curriculum was developed. This curriculum is a laboratory-based learning method that uses specific experiments and activities that aimed to help students develop an understanding and framework of physics conceptually.

They also developed another curriculum known as Tutorials in Introductory Physics. This curriculum along with PbI was developed through trends that the researchers noticed after studying the problems of a traditional physics curriculum. The Tutorials in Introductory Physics include four-step sessions in which students work together in small groups. The first part consisted of a pretest that conveyed to the students about topic objectives. The second included the worksheet which is when the small groups collaborate amongst each other in order to develop reasoning, conceptual understanding, and framework building. Then, homework was assigned to help reinforce the ideas learned. Finally, the post-test was administered to check for conceptual understanding and reasoning. Score comparisons between pre-tests and post-tests showed an increase in a score higher than those who were not a part of the tutorial experience (McDermott 1135).

The Impact of Instructional Strategies in Colleges

In 2008, Henderson and Dancy set out to understand physics teaching methods among several college faculty through an in-depth study. With the assistance of the American Institute of Physics Statistical Research Center (SRC), they developed a survey in order to learn about the impact of Physics Education Research (PER) among students. The survey aimed to understand whether or not physics faculty were aware of RBISs, if it was utilized in class, how often RBISs were changed within a physics course, and if teachers discontinued the uses of RBISs over time.

The online survey was given to physics faculty members from three different colleges which consisted of 61 questions, divided into five categories. Participants' teaching situation, class size, attitudes toward RBIS, instructional goals and practices, job responsibilities, productivity in their research, education, and general demographic questions were included in the survey. The results of the survey showed that about 87.3% of faculty members have heard of at least 1 RBIS with 50.3% knowing 6 or more (Henderson and Dancy 020107-6). About 48.1% say that they use 1 or more RBIS, 34.3% say that they use 2 or more RBIS, and 22.6% say that they use 3 or more RBIS (Henderson and Dancy 020107-6). "Attractiveness" of an RBIS was determined by the usage percentage of the method. With this definition, the four most used (out of people who knew about the strategy) RBIS was Peer Instruction (46%), Ranking Tasks (40%), TIPERS (32%), and Interactive Lecture Demonstrations (31%) (Henderson and Dancy 020107-6).

The researchers also noted that all of these RBISs were methods that could more easily be implemented within a traditional college physics curriculum. Survey results also indicated that faculty members usually modified RBISs in various ways. 47.9% of faculty members who used Peer Instruction and 41% of faculty members who used Cooperative Group Problem Solving stated that they made drastic modifications to the RBIS before implementation (Henderson and Dancy 020107-7). However, certain RBIS that faculty use such as Ranking Task and RealTime Physics Laboratory only have a 21.2% and 21.3% (respectively) chance of making drastic modifications (Henderson and Dancy 020107-8). The working theory as to why this is the case is because RBISs such as Peer Instruction and Cooperative Group Problem Solving is that without modification, they would change many aspects of the entire course while RBISs such as Tanking Task can be implemented without much modification flexibly. The RealTime Physics Laboratory RBIS was theorized to have a low significant modification rate due to the laboratory setting being ready to utilize already.

Time constraints was another issue in which 12.3% of discontinued users referred to showed that although research-based instructional strategies have the potential to be of use, researchers should also consider how these instructional strategies would transfer into the actual classroom (Henderson and Dancy 020107-7). The alternative to this would be physics faculty shifting their conditions in order to better replicate a setting in which classes are made to be the best settings for research-based instructional strategies. Either solution or one in between would ideally help with the creation and implementation of physics research-based instructional strategies with fewer issues.

In terms of the rate of discontinuation of RBISs, this measure was defined as the number of users who discontinued an RBIS divided by the number of users who discontinued an RBIS plus the number of people who are still using an RBIS. The percentages ranged from 27.1% (TIPERS RBIS) to 80% (Workbook for Introductory Physics RBIS) (Henderson and Dancy 020107-8). Out of the participants who discontinued using RBISs, about a third said that it was because they either did not work (19.8%) or they took too much class time (12.3%) (Henderson and Dancy 020107-8). However, about 20% of all faculty members indicated that they were working on instructional improvements upon or outside of the RBISs (Henderson and Dancy 020107-6).

IV. Comparing Novices to Experts

Over the course of 20 years, a couple of studies have revealed how experts and novices approach physics learning. By understanding the differences in approaches between the novices and the experts, researchers were able to observe how experts practice conceptual thinking and pinpoint why novices fail to do so. Kohl and Finkelstein made significant use of the representations in order to grasp their effectiveness. Mason and Singh discuss how novices can develop intuition about a given problem the way experts do.

Experiment One

In 2008, researchers Patrick B. Kohl and Noah D. Finklestein organized an interview with 11 undergraduates (novices) who were taking an algebra-based physics course and 5 physics graduate students (experts). Within the set of 11 undergraduate students, 6 were students from a first-semester algebra physics class (Physics 201) while 5 students were from a second-semester algebra physics class (Physics 202). The students from Physics 201 were given a question known as "the car problem." This question asked the students to organize as many representations of the motion of a car into different groups from a collection of graphs (varying from velocity-time graphs to position-time graphs), animations showing the motion of a car, and written descriptions of a car's motion. The students from Physics 202 were given 5 problems (with the 5th being a challenging problem) about calculating force or charge within electrostatics with the inclusion of a free body diagram. Experts (the graduate students) were given both the car problem and the electrostatics problems, along with a pulley problem that would challenge the experts.

The interviews were divided into increments of 10 seconds where any pictures, graphs, models, equations, and math used/created were noted along with a secondary measure of 6 periods of time: reading/translating (into equations and diagrams), an analysis (solving for variables or conceptually understanding the problem), exploration (of other problems and methods), planning (for the solution), implementation (in a process-oriented manner), and verification. In order to characterize the different types of problem solvers with more detail and specificity, a case study was performed on 3 students named Carrie (a novice from Physics 202 who incorrectly answered the questions), Sam (a novice from Physics 202 who performed well), and Jim (a first-year graduate student who was chosen as the strongest expert).

Carrie was a student who incorrectly answered all 5 questions from the electrostatics questions given to the Physics 202 novices. Sam was able to answer 3 out of 5 questions, including the challenge question, correctly with the other two questions being incorrect due to an error in multiplication by 10. Jim, the expert graduate student, was able to solve all problems correctly and quickly. A commonality among all three case studies was that they all used multiple representations such as free-body diagrams in order to solve their problems. However, further analysis showed that Jim and Sam created representations in order to understand the question and how to solve it while Carrie seemed to create representations out of the thought that it was required rather than because it served an important purpose in understanding (Kohl and Finkelstein 010111-7).

Overall, both novices and experts tended to draw a picture immediately after reading a question rather than writing an equation. For the car problem, novices usually started off their problems using the animations or written descriptions as starting points while experts would use all four types of representations in order to start the problem. Along with this, novices solving the car problem would finish creating one group and then move on to the next group, rarely returning to a finished group, while experts would be more likely to try creating multiple groups at the same time or would be more likely to review a completed group. Experts spent 43% of their time in the analysis portion and 1% of their time in the exploration portion of the problem-solving process while novices spent 25% of their time on analysis and 15% of their time on exploration (Kohl and Finkelstein 010111-10). These numbers could be thought of as indicating that experts were more likely to try understanding the given information and produced models in a productive manner and with a specific goal/subgoal in mind (Kohl and Finkelstein 010111-10).

However, it could also be said that the experts' experience could have allowed for a different approach than they would have on a difficult problem. Therefore, the analysis was also done on the pulley problem in which experts scored similarly to how novices scored on the electrostatics questions. The same analysis-heavy trend was found (Kohl and Finkelstein 010111-10).

Experiment Two

Scientists continued to compare novices to experts to understand the gaps in physics learning. In 2016, Andrew J Mason and Chandralekha Singh organized a survey for 541 introductory physics students, 42 Ph.D. physics students, and 12 physics faculty members called the Attitudes and Approaches to Problem-Solving (AAPS) survey which included 16 modified (for clarification purposes) questions from the attitudes towards problem-solving survey (APSS). APSS was a survey developed to study the attitudes of students during physics problem-solving modeled after the Maryland physics expectation survey (MPEX), which they modified by adding 17 of their own inquiries with the feedback of physics students and faculty at a state university. The questions directly asked students about their attitudes and approaches to their problem-solving strategies with response options ("Strongly Agree", "Agree somewhat", "Neutral or do not know", "Disagree Somewhat", and "Strongly Disagree"). An example of this is, "If I am not sure about the right way to start a problem, I am stuck unless I go see the teacher/TA or someone else for help." During this interview, the surveyors employed a "think-aloud protocol" in which the students were told to demonstrate their thinking process by narrating their thought process for several questions, which matched up with the results shown in the survey.

Answers given by faculty members were referred to as "favorable" responses for their physics knowledge and those lacking in physics knowledge were considered "unfavorable." Introductory students responses who participated in the survey on average had the unfavorable responses on questions such as, "After I solve each physics homework problem, I take the time to reflect and learn from the problem solution" (Mason and Singh 8). Four similar questions for least favorable responses led the researchers to suggest that introductory students have a view of physics as a non-intuitive subject (Mason and Singh 8). Introductory physics students had more difficulty solving physics problems with more variables/symbols and would prefer to work with number values due to the prospects of simply plugging and chugging numbers into equations (Mason and Singh 8). The favorable results from faculty members showed that experts had the same level of difficulty solving physics problems with more variables/symbols than with number values. For two other similar questions, the students showed more of the unfavorable response of needing/looking for help from others when they were unable to solve the problem; relative to the faculty results, they also said that they did not enjoy solving difficult physics problems (Mason and Singh 8). This was contrary to the favorable response which was that experts would not look for outside help and enjoyed solving difficult physics problems.

All in all, faculty members very much valued the importance of reflecting upon solving physics problems while a majority of introductory students had differing opinions. Many students also thought that understanding the mathematical concepts of physics was the most important factor when compared to the faculty members. Half of the introductory students noted that they would use their "gut feeling" when answering conceptual physics problems instead of proof through the laws and principles of physics (Mason and Singh 15). Compared to the introductory students, Ph.D. students on average had more favorable answers those similar to that of faculty (Mason and Singh 18). This could mean that students develop a more favorable attitude and approach to physics while learning physics and/or that those who have already possessed favorable attitudes and approaches comprise a large portion of the Ph.D. students.

Study Comparison

From the 1990s to recent times, one important commonality of the novices is that these students would often rely and emphasize the mathematical aspects more than the conceptual aspects of the problem. Even when they had the correct equation, they often did not know how to use them in the correct way. As noted in the Kohl and Finklestein study, student Carrie showed how she could remember the correct equation for a particular situation, but was unable to apply it in order to obtain a solution. Similarly, in the Mason and Singh study, the survey showed that students emphasized the mathematical aspect of physics problem solving rather than conceptual understanding. In the Redish and Steinberg study, the survey used within the study showed that half of the engineering physics students thought that proofs and derivations were only important for explaining the viability of a problem, rather than to show how these proofs and derivations relate to fundamental physics concepts. In all three studies, the students tend to use mathematical equations without understanding the physics behind it. It would seem that students are now prioritizing mathematics over physics, causing them to have difficulties understanding conceptual aspects of physics.

Another common theme is that students often utilize problem solving techniques without knowing why they were using them. For example, in the Mason and Singh experiment, 50% of introductory students would use their “gut feeling” when solving conceptual physics questions (Mason and Singh 15). In the Kohl and Finklestein case study of the student Carrie, researchers noted that Carrie created representations simply out of habit without actually knowing what to do with them (Kohl and Finkelstein 010111-7). On the other hand, in the other two case studies, the students used representations to help model and understand a given situation within a problem.

Understanding how novices approach physics problems is paramount to understanding how to design a more effective curriculum for new students. And for over 30 years, it has been proven that lecture-based classes are ineffective in teaching conceptual understanding of physics. Using representations and diagrams is recommended, however, learning how to use them is another matter that educators must address. The key difference between novices and experts is that experts focused on conceptually understanding the problem. For instance, in the Redish and Steinberg study, experts were found to have a favorable view towards having a deep understanding of physics instead of just merely memorizing concepts. In the Kohl and Finklestein experiment, it was found that experts would spend 43% of their problem solving time analyzing and understanding the question (Kohl and Finkelstein 010111-10). A greater portion of the time was spent on problem solving time than on analysis when compared to the novice students. Even in the Mason and Singh experiment, the results noted that experts had favorable attitudes toward reflection, which novices fail to do. Naturally, a physicist has much more time and experience with the subject of physics, therefore, would more likely know and understand it. By analyzing the key characteristics of an expert physicist, education researchers can continue to improve upon the teaching model.

Self-efficacy Among Students

In 1999, Researchers Edward F. Redish and Richard N. Steinberg created the Maryland Physics Expectations (MPEX) survey administered to 1500 physics students from 6 different colleges. The categories these questions tested were designed based on David Hammer’s research student attitudes/expectations towards physics. Expert physics instructors were asked to choose their responses that they preferred their students to have for the questions. These responses were known as the “favorable” response while the opposite responses were considered “unfavorable” (Redish and Steinberg 27). They were trying to understand which characteristics could help students learn and understand physics more effectively by using the MPEX as a component of their analysis.

There were six categories of physics learning used to identify a student’s overall view of learning physics. These categories were independence, coherence, concepts, reality link, math link, and effort (Redish and Steinberg 26). For “independence”, independent thinking to understand concepts was favorable whereas simply absorbing the information was unfavorable. For “coherence”, seeing physics as a connected framework was favorable while seeing physics as unconnected pieces were unfavorable. For “concepts”, understanding concepts were considered favorable while simply memorizing them as unfavorable. For “reality link”, believing that physics concepts were applicable and useful in the real world was favorable while believing that physics concepts did not have much to do with the real world was unfavorable. For “math link”, believing that math was a logical way to represent physics concepts was favorable while viewing math and physics as independent was unfavorable. For “effort”, putting in effort in order to understand and study physics was favorable while not putting in the effort to correct and understand physics was unfavorable.

Redish and Steinberg noted that students decreased in favorability from the beginning of the semester to the end for traditional curricula for several traits in the MPEX (Maryland Physics Expectations) survey (Redish and Steinberg 29). Along with this, another result that they shared was that 50% of students had an unfavorable view regarding their agreeance or disagreeance of the prompt “All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems” even after taking 3 semesters of calculus-based physics (Redish and Steinberg 26). Luckily, the researchers also note that other learning environments, such as Workshop Physics helped students to develop more favorable traits throughout the courses (Redish and Steinberg 29).

Another study was performed in Taiwan regarding self-efficacy. Researchers Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai organized two surveys in 2015, one called the physics learning profile (PLP) survey and the other one called the physics learning self-efficacy survey (PLSE). Both surveys were given to 250 physics undergraduate students throughout several universities in Taiwan. A cluster analysis was used to sort the PLP survey results into one of three groups: reproductive, transitional, and constructive. The PLP survey was a 20 question survey to determine a students conceptual learning process. The constructive learning conception values an opportunity to understand, the reproductive learning conception values a form of memorization, and a third category called the transitional learning conception is somewhere in between the two types. The PLSE is a 32 question survey about self-efficacy divided into 5 categories measuring for confidence level in higher-order cognitive skills, problem-solving, scientific inquiry, practical work, everyday application, and science communication.

The results noted that those with high self-efficacy tended to set bigger goals for themselves, spending greater amounts of effort to achieve those goals, and use flexible learning strategies. These factors have positive correlations with learning and academic achievement. The results of the PLP survey showed that 66 of the 250 (26.4%) students had reproductive learning profiles, 87 of the 250 (34.8%) students had transitional learning profiles, and 97 of the 250 (39%) students had constructive learning profiles (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 615-616). A further breakdown of the PLP survey analyzed for testing, calculating/practicing, and understanding. Reproductive learning profiles tended to score higher on the testing and calculating/practicing portions of the survey, which reflected that this learning profile cared about preparing for physics tests and manipulating formulas/equations (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 616). Transitional learning profiles tended to score higher on the understanding than the reproductive profiles and score higher on calculating/practicing portions compared to the constructive learning profiles which reflected that this learning profile cared about a combination of both reproductive and constructive conceptions (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 616-617). Constructive learning profiles tended to score higher on the understanding portions compared to the reproductive learning profile while scoring similarly to transitional learning profiles which reflected that this learning profile cared about equating physics learning with an in-depth understanding of physics knowledge placing less emphasis on tests and calculating/practicing (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 617).

When dissecting the PLSE survey results, the researchers found that those who had constructive learning profiles tended to have higher scores (meaning they had higher self-efficacy for all 5 components of the PLSE survey) than reproductive learning profiles (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 617). Transitional learning profiles fit in between for levels of self-efficacy (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 617). A further breakdown of the data showed the correlations between PLP learning profiles and the five components of the PLSE survey. Transitional and constructive learning profiles both scored similarly to each other and much higher in self-efficacy compared to reproductive learning profiles for the categories of higher-order cognitive skills and practical work (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 617). Constructive learning profiles had higher self-efficacy scores for the everyday application and science communication portion of the PLSE survey compared to reproductive and transitional learning profiles (who scored similarly to each other in those categories) (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 618). These results helped researchers to conclude that physics teachers should emphasize learning physics and de-emphasize the importance of studying for testing which would help to keep self-efficacy within students higher (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 618). Along with this, they should also help to emphasize the applicability of learning physics which allows for higher self-efficacy scores for the everyday application of physics. For improvement of self-efficacy within science communication, it is said that those who supported constructive over reproductive physics learning conceptions tended to score higher (Tzung-Jin Lin, Jyh-Chong Liang, and Chin-Chung Tsai 618).

V. Conclusion

The greatest challenge in physics education is implementing the numerous tools to improve conceptual learning across universities. A standard has not been set in place, which shows that greater efforts must be made in order to convince other physics departments to reconsider traditional methods in physics learning. Oftentimes, professors are left to their own devices to improve the model while some refer to tools and curriculums created by other researchers to supplement their lectures. For decades, the performance of introductory physics students have suffered; and without a united effort across physics institutions, students will continue to struggle in honing a clear conceptual understanding of the materials.

VI. Limitations

The limitations of the study include an inconsistency with the locations of the studies. Most of the studies were held in the United States, but the paper also includes a study held in Taiwan. It was also a challenge to include every literature related to this topic. Another factor that has yet to be thoroughly researched is regarding the performance of novice students who studied under a more interactive physics curriculum. Conceptual learning is difficult even beyond lecture-based curriculums.

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