A Study of Common Concerns Inhibiting Teacher Enactment of Computational Thinking into Project-based Mathematics and Career Technical Education

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Abstract: Recent studies have shown that US high school students are not as prolific as other countries in terms of their performance in mathematics. One of the most effective solutions can be a change in the way mathematics subjects is taught in high school. The NSF-funded "Understanding How Integrated Computational Thinking, Engineering Design, and Mathematics Can Help Students Solve Scientific and Technical Problems in Career Technical Education (INITIATE) project is a collaboration of The University of Toledo and high schools in Toledo that aims to improve mathematics teaching. Project-based learning (PBL) and integrating math with career technology education (CTE) have been established as efficient ways to improve high school students' understanding of mathematics. Nevertheless, implementation of new ways of teaching is not always easy for the teachers, and many factors may inhibit the teachers from implementing PBL methods. This research analyzes common concerns teachers experienced regarding enacting new teaching methodologies in their classroom. The Stages of Concern Questionnaire (SoCQ) was used to measure the teachers' perceptions of and comfort with implementing computational thinking (CT) concepts PBL lessons. Possible relationships between teachers' SoCQ CBAM score and other variables such as their understanding of PBL and CTE are examined and discussed.

1 INTRODUCTION

The importance of mathematics preparation for students pursuing higher education degrees is well documented. Researchers at UCLA (2019) have found that 60% of students entering community colleges in the United States are not eligible for college level mathematics courses. Based on placement test results, these students arrive to community colleges enrolling in remedial mathematics courses. Enrolling in remedial mathematics coursework increases time to degree, which can lead to changes in degree pursuit (WOLPERT, 2018). The Bureau of Labor Statistics (*Employment in STEM occupations : U.S. Bureau of Labor Statistics*, n.d.) reports that Science, Technology, Engineering, and Mathematics (STEM) employment rates are low when compared to overall employment in the United States. One finding that may contribute to a lack of engagement in mathematics by students in secondary school may be mathematics anxiety.

According to Maloney and Beilock, mathematics anxiety may also be a product of poor mathematics skills due to a lack of mathematical practice, which may lead to a lack of conceptual understanding (Beilock & Maloney, 2015). Mathematics anxiety is

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being experienced by many learners. Anxiety for too many students is expressed as “that feeling of fear, apprehension, and helplessness when tackling a math problem” (TRAN, n.d.). Tran citing the work of Brooks (2014) discusses the possibility of turning “anxiety into excitement”(Brooks, 2013). Brooks (2014) researched how anxiety and excitement are linked to increased heart rates but have different psychological effects. Excitement, according to Brooks is related to “I can do something” while anxiety can lead to a “threat mindset.” Prior to presenting a difficult mathematics problem, participants in Brooks’ study were shown the message “try to get excited.” This message resulted in improved performance over the messages of “try to remain calm” or “please wait a few minutes.”

The UCLA group (2019) reported that one difficulty for students is a lack of a deep understanding of the mathematics they study. This lack of understanding may be attributed to the memorization of mathematical rules and procedures according to the group(WOLPERT, 2018). Paulos (1991) put this in perspective:

> Imagine that 90 percent of every course in English up until college was devoted to grammar and the diagramming of sentences. Would graduates have any feeling for literature? Or let’s consider a conservatory devoting around 90 percent of its effort to only practicing of the scales. Would this way be good enough for the students to develop understanding or appropriate appreciation of music? Obviously, the answer is no. In fact, this gives proper allowances for the hyperbole. This describes what frequently occurs in our mathematics classes. Mathematics is identified with a rote recitation of facts and a blind carrying out of procedures. (p. 52)(Paulos, n.d.).

Schools across the world are beginning to address this lack of deep conceptual understanding according to (P. Lisette et al., 2012). Addressing conceptual understanding supports students to solve new mathematical problems and to make connections within mathematical concepts (Macmath et al., 2009). This paper addresses a professional development program that partners secondary school mathematics teachers with university engineers, science educators, and mathematics educators. Through this partnership we are striving toward exciting mathematics classrooms where teachers engage students in new mathematical problems, the exploration of connections within mathematics and mathematics to other subject areas, through the study of autonomous vehicles.

2 ISSUES WITH HOW TEACHERS TEACH

Many teachers across the globe are going through professional development with the goal of better way of teaching and these are being proved successful. For example, most teachers with this expertise cover around 40 problems in a day through various types of games, drills, or written work whereas amateur teachers cover around 6-7 problems only (Wilson et al., 2005).

2.1 PBL as a Promising Approach

According to several research studies, problem-based learning (PBL) is considered to be a compelling possibility to enhance students’ ability to perceive and solve mathematical problems (Tarmizi et al., 2010). Through PBL, students learn to develop their critical thinking and, as a result, create a foundation for the application of skills to new situations. Authors in (Han et al., 2015) have investigated whether participating in STEM PBL activities effected students who had varied performance levels and to what extent students’ individual factors influenced their mathematics achievement. Since STEM PBL embodiment in schools has been a critical challenge, the effect of STEM PBL on various factors should be examined. Teachers from 3 highs schools participated in sustained professional development training conducted by a STEM centre based in a Southwestern University. They were asked to develop STEM based PBL lesson plans once in every 6 weeks for a period of 3 years(Han et al., 2015). 836 high school students participated in Texas Assessment of Knowledge and Skills (TAKS) test at least in the initial year. The scores were analysed along with demographic information by hierarchical linear modelling to project the longitudinal study. The results show that student achievements in mathematics by both demographic backgrounds and performance levels were influenced by STEM PBL instruction. Over the 3 years of this experiment, the students with low performing skills showed significantly better improvement than high and middle performing students.

Another promising way is integration of Math in CTE. Despite the fact the combination is not a curriculum, this strategy has been proved successful at several high schools as this led to increased academic engagement and achievement for students (Newmann Editor, n.d.). Invoking PBL, putting Math and CTE together and other established promising techniques could have eradicated the whole issue of "high school students lagging in Mathematics" by their own. Except there is a major concern which causes several other significant obstacles for this prosperous journey.

2.2 Issues Related to Making Change in Classrooms

As interaction with students in a classroom is the major factor for them to learn, changes in the way of teaching is one of the major steps. Students must find fun in their studies to improve their ability to solve mathematical problems and it is teachers' responsibility to make learning interesting and fun for the students. Although there might be no teacher who will not value collaboration, creativity and curiosity in their classrooms, many classes are devoid of these very traits (Herrmann, 2017). From the past experiments it is given that the results of experimenting changes in high school curriculums are equivocal.

Aguirre and Speer adopted an inclusive view of beliefs as "conceptions, personal ideologies, world views and values that shape practice and orient knowledge"(Aguirre & Speer, 1999). Two important aspects of beliefs get highlighted by this view which receive general agreement among researchers and are relevant to the current study. First is the conviction that beliefs and behaviors are inherently linked (Di Martino & Zan, 2011), (Forgasz & Leder, 2008). While Ernest (Ernest, 1989) and Furinghetti and Morselli in (Furinghetti & Morselli, 2011) consider beliefs to be the main regulators of teachers' practices, others acknowledge the general influence they have on teachers' pedagogical decision-making (Goldin, 2009). Second is the relationship between knowledge and beliefs. As teachers' beliefs play a significant role in conducting their practices suggests that their beliefs act as subjective knowledge; "knowledge" that the teachers believe to be true but actually it is not (Beswick, 2011). Their beliefs play one of the most significant roles in their classrooms. Hence, teachers' beliefs are considered to be the fundamental factor to the investigations of teaching and learning mathematics. While many categorizations of beliefs exist in the literature, they can be broadly grouped according to beliefs about the discipline, its teaching and student learning (Cross, 2009). Often researchers who study teachers' beliefs focus on a cluster of related beliefs, such as their beliefs about teaching proof (Furinghetti & Morselli, 2011). In (Bobis et al., 2016) teachers' mathematical beliefs about student engagement relating to the discipline of mathematics were examined, mathematics teaching and learning, and about themselves as teachers and learners of mathematics. As far as we are aware, there are few studies that focus on the priority the teacher places on the intervention in relation to his/her job as a teacher.

2.3 Common Reasons Change Does Not Happen in Classrooms

"Taking a new step, uttering a new world, is what people fear most"-Fyodor Dostoevsky. People get accustomed to things over time, similarly teachers are also accustomed to orthodox curriculum standards and due to normal human behaviour adapting a change in those might cause hiccups. Some states claim the possibility of Common Core State Standards (*About the Standards | Common Core State Standards Initiative*, n.d.) eliminate the need for students to undergo remedial courses upon admission to postsecondary institutions within the system. This claim can stand as an excuse to bypass these standards. However, there are some states which try to update their curriculum standards to help students improve their skills for their career. In this the authors have experimented work-based learning experience to improve English and Mathskills of physically challenged students (Cease-Cook et al., 2015).

2.4 Concerns Teachers Have

At the time of implementing those changes in classrooms, a major issue comes into play: teachers' beliefs (Handal & Herrington, 2003). They rely on their beliefs more than on going trend in pedagogy. Herrman, (Herrmann, 2017) presented possible resistances to changes for teachers: A traditional sense of one's own competence, the comfort of predictability, and familiar successes. When a teacher is asked to apply changes in their classroom, it also changes the way they see themselves. They face fear to go out of their comfort zones where they lack confidence. Also, when teachers make some innovative moves, success is not guaranteed. They will face failure inevitably as not every experiment will be successful. Last but not the least, the author also pointed out how asking teachers to leave their comfortable lesson plans behind for a new environment in which the students may struggle may create hindrance. The change in attitudes of 29 self-selected middle and high school teachers towards interdisciplinary teaching is described in (Al Salami et al., 2017). The teachers went through a profession Development (PD) and delivered interdisciplinary teaching for 12-15 week. Over these weeks they designed problem units which spanned multiple STEM subjects. Quasi-experimental pilot study had been made by the researchers. This study used several survey methods and implemented a single group pre-test and post-test design from the data collected at two intervals; first one was done at the time of PD workshop and the later one was conducted after the completion of the teaching unit which emphasized a long-term engineering design problem. The goals of this research were:

- Assess the changes in attitudes to interdisciplinary teaching, attitudes to teamwork, teaching satisfaction, and resistance to change.
- Explore relationships among these changes.
- Describe the variation in these changes across teachers' gender, school level, discipline taught, and education level.

2.5 Concerns-Based Adoption Model (CBAM) as an Approach for Identifying and Remedying Concerns

Human relation in curriculum change has proved its value for individuals and groups interested in the improvement of education (Benne & Muntyan, n.d.). Charalambous et.al (Charalambous & Philippou, 2010) have analysed data collected from 151 elementary mathematics teachers. They examined how teachers' beliefs and efficacy beliefs come into play when mandatory changes occur in traditional mathematic curriculums. Some researchers have utilized anecdote circles, storytelling via moderated group discussions, to investigate teachers' needs related to developing and implementing authentic, interdisciplinary PBL activities in an urban, public STEM high school (deChambeau & Ramlo, 2017). The experiences and viewpoints of teachers towards this approach were explored within three broad themes: assessment; coaching and training; and authentic learning. These analysis delivers insights for implementing PBL, improving teaching and learning best practices in a school.

The integration of STEM subjects offers students opportunities to solve real-world problems in real-world-like situations (Tsupros et al., n.d.) where knowledge is used as a tool to solve problems rather than a body of facts or procedures to be learned with little contextual significance (Herschbach, 2011). Despite the growing emphasis on and demonstrated importance of integration in STEM education, teachers and teacher educators are not typically trained to work in areas that rely on the integration of multiple disciplines. Thus, teachers have not likely experienced integration themselves and are not well prepared to engage students in the cross-disciplinary learning called for by the latest national standards documents in math and science, such as the Next Generation Science Standards (Krajcik et al., 2014) and Common Core State Standards for Mathematics (*Branding Guidelines | Common Core State Standards Initiative*, n.d.). STEM teachers may face several challenges when they attempt to integrate content from different disciplines. These challenges include (a) knowledge of disciplinary specific differences between subject areas (Lederman & Lederman, 2014), (b) a lack of breadth in their own content knowledge needed for teaching (Loewenberg Ball et al., 2008) in multiple subject areas, and (c) the contextual challenges of co-planning and/or co-teaching across disciplinary boundaries (Berlin & White, 2010), (Frykholm & Glasson, 2005).

This project (INITIATE) combines multiple theories (the fusion of activity theory, social constructivist learning theory, and project-based learning) to form its conceptual framework or approach to address this concern. For the guidance of professional development using problem-based learning to make grade 9-12 science teachers capable to integrate Computational Thinking into their teaching, this project uses the conceptual framework of Concerns-Based Adoption Model (CBAM). Activities will use smart vehicles as a mechanism to engage mathematics teachers in Career Technical Education, alongside with 9-12 students to better understand why and how to embed computational thinking in their curriculum. The program should contribute meaningfully to the understanding of effective characteristics of professional development. Funded by the STEM Computing program, this project seeks to address emerging challenges in computational STEM areas. The project integrated computational thinking with computing activities within disciplinary STEM teaching and learning in early childhood education through high school (preK-12).

3 METHODOLOGY

We have used several instruments and tools such as Teacher Lesson Plans, Teacher concerns with enactment of CT, Focus Group Interviews, etc to create the CBAM model for the participating teachers.

When an innovative idea is introduced to a group of people, the initiative demands not only the provision of materials, resources, and training; the understanding of how each person will react to the new initiative with different attitudes and beliefs is also vital. "The instrument which is used to evaluate the efficacy of the Understanding by Design instructional framework for the implementation plan is called Concerns Based Adoption Model (CBAM)" (Hall Richard C Wallace & William Dossett, 1973).

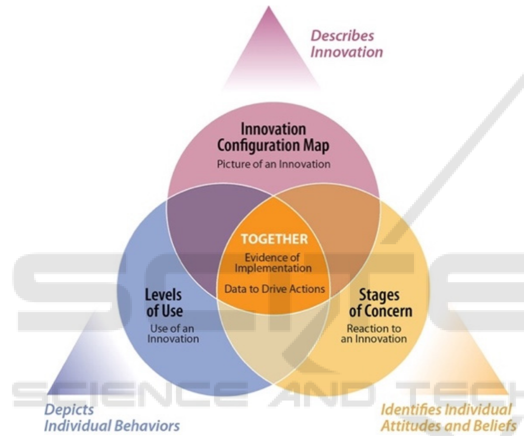

Figure 1: CBAM Model (*Concerns-Based Adoption Model (CBAM)*, n.d.).

This model provides techniques and tools for accessing and facilitating the implementation of new ideas, innovations and reform initiatives (*Concerns-Based Adoption Model (CBAM)*, n.d.). CBAM can be divided into three diagnostic dimensions as follows:

- **Innovation Configuration:**

  Innovation Configuration allows the teacher to provide feedback on the implementation of different types of innovation in the classroom. The teachers could as well realize what adjustments could be made to their teaching behaviour to decrease the difficulty level of the content (Hall & Hord, n.d.). This allows evaluators to monitor the results obtained from the teachers to use an innovation appropriately in the future.

- **Stages of Concern:**
  The Stages of Concerns (SoC) process, which includes a questionnaire, interview, and open-ended statements, enables leaders to identify staff members' attitudes and beliefs toward a new program or initiative. With this knowledge, leaders can take actions to address individuals' specific concerns. The SoC items discussed in this work are as follows:
  - Unconcerned: "I have heard about this but don't have time to put effort in it."
  - Informational: "This looks promising, maybe I would like to read about it to know better."
  - Personal: "The changes I have to make in my daily schedule is making me concerned."
  - Management: I am concerned about how much effort it is going to consume to become a hit."
  - Consequence: "If I successfully make this project run, how it is going to affect my students."
  - Collaboration: "I would like to share these ideas with others also."
  - Refocusing: "Maybe this approach will give better results than the proposed one."

- **Levels of Use:**
  Levels of Use (LoU) analyzes teacher behaviors from the start of making changes in their classroom. It indicates the magnitude and amount of change as the teachers go through with their teaching transition (Horsley & Susan, 1998). Each level of the transition is identifiable by a key decision point and its own behavioural characteristics (Powell-Griner et al., 1997).

In this work, we have looked into the stages of concern encountered by the teachers from this INITIATE project. As teachers hold the prime deciding factor for any changes tried to make in instructional planning and content, their behaviour analysis must be the first step. How they react to this change in their classroom, are they comfortable with this new way of teaching or do the accustomed ways seem more worthwhile to them-these are among those vitals questions which have to be answered before moving forward.

4 RESULTS

Sixteen participant teachers completed the first and second administration of the SoCQ (one teacher had difficulty accessing the survey and did not complete it). As a reminder, SoCQ is divided into three major constructs: concern about impact, concern about the task of implementing (logistics), and concern about self (self-efficacy). Respondents are given a series of statements and are asked, using a 7-point scale to indicate their level of agreement with the statement. Anchors within the scale are:

- 7 = true most of the time
- 4 = true some of the time
- 1 = not true at all at this time
- 0 = this statement is not relevant to me

A score of 0 indicates that the innovation is not a high priority to the respondent. There are six stages of concern and they are illustrated in Figure 2.

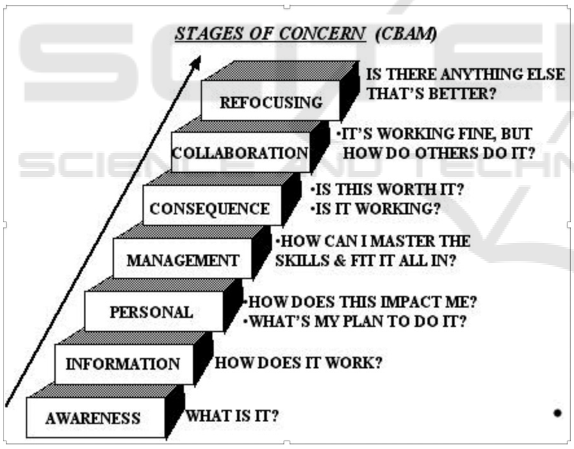

Figure 2: Stages of Concern Scales.

The stages are developmental in that one progress from the lowest "step" to the highest as he/she becomes more comfortable implementing the innovation.

Figure 2 illustrates the group distribution of the 2019-20 cohort. The first administration was completed on the first day of the Summer Institute and the second administration was in January 2020—approximately 6 months after completing the Institute and after (in most cases) implementing a lesson that based upon Summer Institute content.

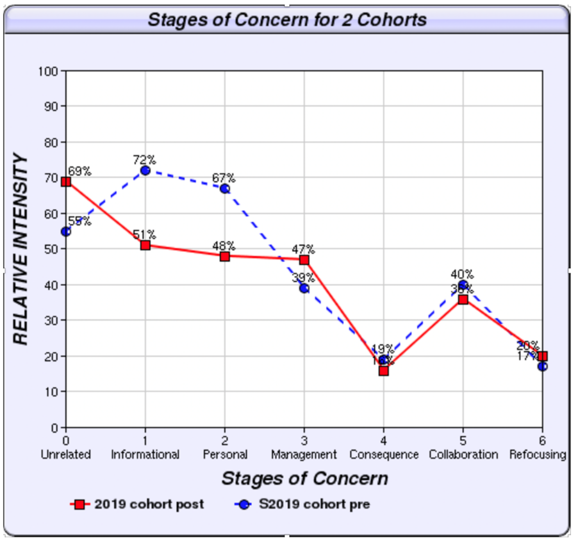

Figure 3: Group Distribution of the cohort 2019-2020.

Notice that the post scores show the group moving lower on the Informational and Personal scales (interest in the INITIATE model but not quite sure it was relevant to their teaching and need for more information regarding the specifics of the innovation before being willing to implement, respectively) and slightly higher on the unrelated category suggesting that they have gained some information needed to implement the lessons but in some cases this information has moved them to a position where they feel the INITIATE teaching strategies are not relevant to what they do in the classroom. The remaining four categories have remained relatively similar on pre and post testing. The low score for Consequences indicates that the teachers as a group do not have concerns as to how the innovation might affect the students, particularly adversely. Similarly, the low score on the Refocusing scale suggests that the teachers have little interest in refining and adjusting the INITIATE teaching approach to better serve students and make it more useable by other teachers. Overall, the main conclusion that can be drawn is that the teachers' concerns about implementing INITIATE teaching strategies has not changed much over the past six months.

Individual change can provide insight as to how teacher concerns might be addressed to help them better embrace the innovation. Table 1 (next page) illustrates the individual percentile scores for the Stages on pre and posttest. Cells highlighted in yellow indicate the highest percentile for each testing occasion per individual. As recommended by the Stages of Concern Instrument Manual, when another stage score is within one or two percentile points of the highest score, both scores have been highlighted. Concerning the adoption of an innovation, the typical non-user profile will have high scores for Stages 0 – 2 and low scores for 4 -6. The typical user will have the highest score at Stage 3 or above. Stage numbers represent the following stages:

0 = unconcerned	1 = Informational
2 = Personal	3 = Management
4 = Consequence	5 = Collaboration
6 = Refocusing	

As expected, nearly all the teachers scored as nonusers on the pretest (one scored in the 3rd category). Of the cohort, five were CTE teachers, one was a special education teacher, and the remaining were math teachers. Two teachers (24 and 28) scored in the Unconcerned category indicating they felt the innovation was not a priority. The one (ID 20) who scored as a user, was a math teacher. On the posttest, 3 remained nonusers, one (20) slipped from user to nonuser (most likely due to preconceptions prior to the Institute), two were split between user and nonuser status (16 and 30), and two progressed to users (18 and 28). Eight teachers scored in the Unconcerned category. This category does not indicate whether the teacher is actually a user of the innovation but rather indicates that the innovation is low in priority when compared to other tasks associated with teaching. Of the eight, seven moved from a higher category on the pretest to Unconcerned on the posttest. One (16) was split between Management (concern with time and facility management and how the teaching strategies might fit into the class period) and Unconcerned. This suggests that 16 wants to implement INITIATE strategies but is concerned about managing it especially considering other teaching responsibilities. Respondent 30 was split between Refocusing and Information suggesting that this teacher has ideas of ways to modify the innovation but still needs more information about how it works.

A higher score for Stage 6 than for Stages 4 and/or 5 indicates that the respondent has ideas that have more merit than the proposed innovation. Scores highlighted on the posttest in Stage 6 in light green are such occasions. Five teachers fell into this category.

Table 1: individual percentile scores for the Stages on pre and posttest.

ID		0	1	2	3	4	5	6
10	Pre	48	75	63	23	9	19	9
	Post	48	45	48	34	13	22	26
11	Pre	14	66	67	47	38	28	9
	Post	99	51	57	65	44	28	38
16	Pre	61	66	59	23	21	40	17
	Post	94	34	25	94	3	5	20
17	Pre	No pretest data						
	Post	75	34	28	47	5	9	14
18	Pre	14	90	76	43	24	52	9
	Post	14	60	45	23	8	68	14
19	Pre	14	51	39	27	13	22	9
	Post	31	27	28	15	9	9	9
20	Pre	81	69	76	85	24	44	60
	Post	22	93	80	30	59	25	11
21	Pre	55	69	78	69	63	72	52
	Post	91	60	59	65	38	31	52
24	Pre	99	66	67	30	11	64	17
	Post	87	60	59	60	11	68	17
25	Pre	31	78	76	34	16	55	47
	Post	81	96	97	30	21	93	52
27	Pre	48	75	78	27	13	59	3
	Post	40	57	21	30	8	22	26
28	Pre	99	60	48	34	3	7	9
	Post	91	37	55	95	54	55	30
29	Pre	40	69	67	30	21	36	20
	Post	14	43	41	15	8	22	9
30	Pre	7	54	55	39	13	25	9
	Post	55	60	35	34	5	59	2
31	Pre	7	75	76	11	7	25	9
	Post	14	27	25	15	11	16	9
32	Pre	40	97	63	69	38	72	47
	Post	75	45	45	30	21	52	38

Looking at the individual scores as a whole, it appears that many of the teachers feel INITIATE teaching strategies are not a priority and, most likely, they are targeting the implementation of the lessons they developed using the self-driving model cars. In addition, several still feel the need for more information regarding how to implement the strategies/lessons. Others, those who ranked at the Personal level, may have doubts as to whether they are able to implement the lessons correctly.

Delving more into what kinds of information the teachers need as well as their reservations about implementing the lessons could provide insight as to the direction of future teacher support sessions. There has been some difficulty with the technical aspects of using the cars and that may be contributing to the doubt some teachers have. Exploring that as well as other types of support that could be useful may alleviate teacher concerns.

5 FUTURE WORK AND CONCLUSION

In this study, the behavioral changes of high school teachers integrating PBL and Curriculum Technical Education (CTE) in their lesson plans are analyzed and assessed using CBAM scoring system. INITIATE is a National Science Foundation (NSF) program about Autonomous Vehicles that utilizes CTE and PBL in its lesson plans, integrating these concepts in high schools teaching curriculums. The

Stages of Concern Questionnaire (SoCQ) was used to measure the teachers' perceptions of and comfort with implementing computational thinking (CT) concepts PBL lessons. Based on the observations gained from the teacher implementation of the lesson plans, the pre cohort and post cohort results follow the expected behavioral line in the given graphs. Furthermore, the use of technology and integrating it into the lesson plans does indeed bring benefits, but it also causes problems of its own that hinder the use of PBL and CTE concepts in high schools. For instance, if halts occur to the technology, it will require special assistance to fix the errors and it also can cause large delays while teaching the lesson. The initial lessons implementing PBL and CTE topics can be monitored to make sure that they are on the right track. Also, a designated tech-savvy person could always be placed in the classroom for assistance with any problem.

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