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Developing a New Teaching Paradigm for the 21st Century Learners in the Context of Socratic Methodologies

Horace Crogman[1*], Maryam Trebeau Crogman[2], Laurelle Warner[1,3], Ana Mustafa[1] and Raul Peters[4]

[1]Department for Research and Curriculum Development, The Institute for Effective Thinking, 18318 Barton, RD Riverside, CA 92508, USA.
[2]Department of Psychology, University of California, Merced, 5200 N. Lake Road, Merced CA 95340, USA.
[3]Hepker School of Social Work and Sociology, Walla Walla University, Missoula Site 735 Michigan Ave, Missoula, MT 59804, USA.
[4]Department of Physics, Paine College, 1235 15th St. Augusta, GA 30901, Georgia.

Authors' contributions

This work was carried out in collaboration between all authors. Authors HC and RP designed the study, wrote the protocol and supervised the work. Authors HC and MTC carried out all laboratories work and performed the statistical analysis. Authors HC and MTC managed the analyses of the study. Author HC wrote the first draft of the manuscript. Authors LW, AM, RP and MTC managed the literature searches and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Issue: The ever-growing plethora of teaching methodologies in the past decade has only confused and scattered the focus of the learners and teaching curricula. Though education's progress claimed offering ways to educate more equally, weak students are still far apart and neglected.
Aim: Shifting landscape technology has provided a unique opportunity for various proven pedagogic methodologies to be combined in such a way as to enhance and improve student learning, and

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**Corresponding author: E-mail: hcrogman@gmail.com;*

closing the achievement gap. We developed and implemented a teaching paradigm that allows educators to connect with learners through an inquiry-based learning framework where the practitioner flexibly bridges and moves between enhanced Socratic and Didactive teaching methodologies throughout instruction, and uses simple methods to assess weaknesses, group students and improve their academic outcome.

Method: Our method was implemented in college science classes over the course of 5 years. Students were tracked on their progress and gaps between the weakest and the strongest students were assessed before and after implementation of the method.

Results: The use of the Pseudo-Socratic teaching (PST) methodology demonstrated improvement in students' learning and more importantly a decrease of the gap between the weakest and strongest students in the classroom.

Conclusion: Our PST method is accessible and adaptable to the various disciplines. We demonstrated that the majority of the success in a classroom does not depend on who are the students, their background, or their performance levels, but relies on flexible, approachable, and organized practitioners who excite the critical thinking skills and curiosity of their learners, connect with them, become their friendly guide, and keeps high hopes and expectations in the context of Inquiry-based and socratic learning.

Keywords: Critical-thinking; interactive classroom; achievement gap; inquiry-based learning; Socratic; didactive; student learning; student success; peer-group learning; connectivity; comfortability; organization and preparedness.

1. INTRODUCTION

Over time, there has been significant deterioration in the educational system's quality as it has attempted to educate its citizens [1]. According to the 2012 study of the Organization for Economic Co-operation and Development (OECD), after World War II the United States had the #1 high school graduation rate in the world. Today, we are #22 among 27 industrialized nations [2]. Adler [1] argues that because our democracy has achieved only the same quantity of public schooling, and not the same quality, it failed by violating our democratic principles. For Dewey [3] it is a democratic society's responsibility to provide equal access to education for all and education must also be qualitatively the same for all. Consequently, the philosophical questions of how does a democratic society educate the masses equally has not been adequately answered. In responding to this problem, there is often a tension among discipline-specific teaching proposals to give students requisite repertoire of knowledge and skills, challenging them to think about their value systems and encouraging them to consider how to practically apply information to contexts of the real world so that they reflect on inherent ethical issues, conflicts and dilemmas [4,5]. Further, education gaps among various groups are ever widening in the United States. Its mediocre to low performance vis-à-vis other countries speaks to the poor quality of the educational system [6], with some 21% of children under age 18 living in poverty and roughly 2.7 million of children ages 5-17 experiencing difficulty in English [7]. Educational reforms in the 1980s tried to address this growing problem and culminated in President Bush's unsuccessful attempt to help American children excel in mathematics, reading, and science with the *No Child Left Behind* national program [8]. Unfortunately, there were many drawbacks to this initiative, which stifled the creativity of teachers and constrained them to focus on a limited range of subjects to ensure increased performance level on standardized tests [9]. This also shifted students' focus from learning, to a mechanistic preoccupation with producing high grades [10,11], risking turning students into grade machines largely missing critical thinking skills.

Similar legislative and policy errors have been committed by subsequent administrations, e.g., the current proposal to link teachers' salaries to students' performances [12]. In fact, in a study conducted by the Ohio Department of Education in 2013 that looked at the value added scores and ratings for about 16,000 teachers in 450 district, teachers' pays and their teaching quality had little to no relationship [13]. Given the social disparities that must be addressed in order to improve our education system [14], evaluating teachers based on the criteria of students' performance and their standardized testing outcomes does not reflect a well-thought out, rational evaluative framework [15]. Such models of evaluation are inequitable when one considers the fact that: 1.) the educational system varies in its standards and norms, hence is unstandardized; 2.) there are inconsistent efforts and investment of resources to enhance teachers' effectiveness; and 3.) disparity is still a significant problem in American schools and neighborhoods [16]. Instead of focusing on these types of initiatives, it would be of greater and long-lasting benefit to make the teaching profession one of value as Adler [1] suggests, given that it educates our workforce and our citizens of tomorrow.

Unfortunately, the road to educational excellence is paved with drawbacks. Take for example universities' role in educating the masses. Some academic cultures tend to unintentionally create quasi-robotic professors. For example, in one physics class, a student complained that his instructor was often "going off topic speaking about real life" and insisted that time would be best spent working on more examples. On the surface this sounds responsible, but is illustrative of a serious fallacy in education. Limiting one's focus to only teaching on the subject creates robotic behaviors in learners who cannot think for themselves through issues or contemporary problems [17-20]. The administrator asking the instructor to "stick to the subject," ultimately created an environment void of opportunities to critically think and relate concepts to real life. These demands are inhibiting instructors' intention to prepare learners for "adult life" by not using the classroom to simulate real life experiences through discussions and research, ultimately showing the role each skill plays in solutions [4,5].

Another problem is found in instructors tending to be more discipline-oriented which can prove to be difficult for challenging students' value systems, or help students relate information received in the classroom to the real world [1]. Thus, learners primarily receive information about a particular subject, but may have limited ideas about the associated ethical issues, or applicability to live contexts [4]. Supporting this idea, Adler [1] argues that we may be better off finding a better balance between refusing specialization, and over specializing. He goes on to say that we need specialists in each of society's professional category, however, we may also benefit from having professionals who are capable of generalization and know some information about everything.

Globalization calls for a renewed focus on educational reforms. Youths must become more globally competitive given the new emerging markets and the advancement of scientific technologies [21]. Adler [1] argues for a reformed educational system which must offer three fundamental skills: "to earn a living in an intelligent and responsible fashion, to function as intelligent and responsible citizen, and to make both of these things serve the purpose of leading intelligent and responsible lives." Therefore, the focus on educational development has to shift from structural reforms to improving the quality and relevance of education [22]. This research hopes to contribute to the restoration of old landmarks combined with modern teaching for an optimal teaching environment and contends that the key behind any solution to the education failure lies fundamentally in the hands of the educational practitioner. Indeed, Adler's three fundamental skills may emerge in youth by having practitioners who are well trained in specific content, experienced in various pedagogical methodologies, and having a high success expectation for the youths they are educating. The proposed model is an operative pedagogical tool inspired by a positive vision of education around the educational practitioner. In setting forth this model, traditional teaching methodology is first discussed, then the South Korean and Finnish educational systems' success are considered. Finally, the Socratic methodology's meritis reviewed setting the stage for the proposed model called the Pseudo-Socratic teaching (PST) method.

1.1 The Traditional Methodology of Teaching

In the traditional form of teaching, standard classroom sizes are typically 25-30 students up to 400 or more at larger educational institutions. Whether large or small, teachers control the learning environment in traditional classrooms. They hold power and responsibility as they instruct (in the form of lectures) and make decisions (with regards to curriculum content and specific outcomes). Students are regarded as having 'knowledge gaps" needing to be filled. Traditional teaching, views the teacher as the cause of learning [23], which is chiefly associated with the classroom. The lesson's content and delivery are considered to be the most important and students master knowledge through drill and practice, such as rote learning. Integrating learning into a range of contexts is not considered a primary focus [24,25]. Practitioners or students learn to master and practice the correct methods under the scrutiny of the teacher as mistakes are identified and corrected [26].

In evaluating traditional classrooms, Dewey [3] notes that teachers transmit skills rather than promoting initiative, learning and inquiry. He further says that traditional schooling is based on a flawed understanding of human faculties. Namely that imagination, thinking, feeling, and doing can be trained separately. Dewey [3] believes this process to encourage the teaching of skills without concern for students' "collateral learning," i.e., the impact of these skills on pupils' dispositions and desires. Educational research has also shown the failure of solely using traditional methods to prepare students for college and similarly, many variants of diverse methodologies have only produced mixed results [27-31]. McNeil [32] speaks to this very issue in regards to Physics education. Several methods were used in the past two decades to investigate how best to instruct students in Physics Education. The main approach has traditionally been a unidirectional delivery of knowledge in which students have very little interaction with the professor and the course, and this was largely proven ineffective [32]. Moreover, Hestenes [33] contends that traditional teaching assumes a uniformity of students' beliefs on the presented material, which is erroneous and counterproductive to learning.

Nevertheless, this paper proposes that one cannot and should not, despite its many criticisms, remove traditional methods entirely from educational practices to achieve an effective education. Students and teachers would benefit more if both traditional and modern methods were fused in order to create a more effective, fun and interactive learning experience. To accomplish this, Reif [34] suggests that instruction must transform a system S (called the *student*) from an initial state S_i to a desired final state S_f where S can now accomplish things, which S could not do initially. Reif [34] expresses the transformation process as follows: $T: S_i \rightarrow S_f$

Our goal is to show what this transformation looks like in practice, by inviting educators to shift and transform the common focus of educational best practices. Prior to describing this approach, Finland's educational process will be examined.

1.2 In Search of A Finnish Way

Let's determine from current examples what a true educational success story should look like. A recent statement [35] on the world's top educational systems reported Finland and South Korea's educational systems as the two best. This prompted President Obama to use South Korea's apparent success to make a case for longer school days. Further, Choi [36] points out that both of these countries, fifty years ago, had terrible education systems. Today's high ranking of their educational outcomes have made them relevant to educational research and policy makers as shown in Fig. 1. These two countries' z-indices (composite of both cognitive skills and education attainment) are at the top of the international rankings above 0.30 pts ahead of the third ranked country and the rest of the world. Finland shares with South Korea the similar belief that education was necessary to pull them out of economic misery. Both countries committed to an equal-opportunity educational system [37]. Also, a strong respect for teachers helped mobilize parents in participating in the gigantic reformation process. However, both countries differ in their steps to success.

We must ask whether the South Korean modelisa viable option for the US Educational system. Sorensen [38] argues about Korea's method that, what makes Korean students so unique is their motivation and social pressures to succeed rather than the quality of their education. Korea's success comes from: (1) Parents involvement, (2) Use of technology in the classroom, (3) Going above and beyond for students, (4) Teachers are willing to learn new methodologies (5) Teachers motivate their students to work hard, and send positive feedback to parents. Primarily however, the Korean education system is heavy in testing, which forces teachers to teach to the test [37,38].

Producing educational stellar results came about with casualties among Korean students. The academically untalented are emotionally burdened, lose of self-esteem and display delinquent behaviors [38]. Korea's unattractive educational feature is its long culture of success sacrifices and the family's honor attached to it. Korean students are intensely pushed resulting in chronic stress levels, overexertion, and failure anxiety. Many Korean students do anything not to fail including cheating, which is one of the highest rates in the world [38,39]. In fear of not succeeding, 75% of middle and high school South Korean students have considered running away from home or committing suicide, primarily because of parental pressure over their lack of success at school [39]. The problem of excessive study, attendance of extracurricular cram schools, and use of tutors stems from competitive educational pressures created by the improved financial position of more families in Korean society [38]. This lead to unsuccessful government reforms in the 1980s [38]. Despite high-class sizes and moderate levels of education for teachers, Sorensen [38] contends that the Korean educational system is not doing a better job than other countries.

It seems therefore that the tradeoff to adopt the South Korean success model could be too costly. This leaves the Finnish educational model as a more acceptable success story. In the early 1980s the Finnish educational system was deemed mediocre by the Global Educational Reform Movement (GERM) standards [40], which strongly promote education reforms to include a combination of competition, choice, information, and accountability as a means of raising the quality of education systems. GERM reforms involve curriculum development, student assessment, teacher development, technology-assisted teaching and learning, and proficiency in basic competencies (i.e., reading, mathematical, and scientific literacy) [40].

Fig. 2 shows strong and consistent student performance in those nations that have employed the GERM reforms. Note, however, that the US's performance is largely below average compared to other nations that have used GERM in a similar way.

Finland itself did not follow the GERM reforms, but used an alternative way throughout the 1990s to today [41]. The foundation for Finnish students' PISA success in the 2000s, were already laid in the 1970s reforms [42]. The Finnish government implemented a compulsory comprehensive 9-years system (for 7-16 years olds) leaving upper secondary education divided into a general or academic upper secondary schools and vocational schools (Fig. 3). There are also no private schools in Finland, which creates a more cost effective system [43]. The new curriculum framework of 1985 gives municipalities and schools freedom to function in concert with core curriculum and guidelines [42]. The emphasis on basic skills and knowledge with applicability in real life became the success of Finnish students in PISA as their systems' framework had very similar goals [42].

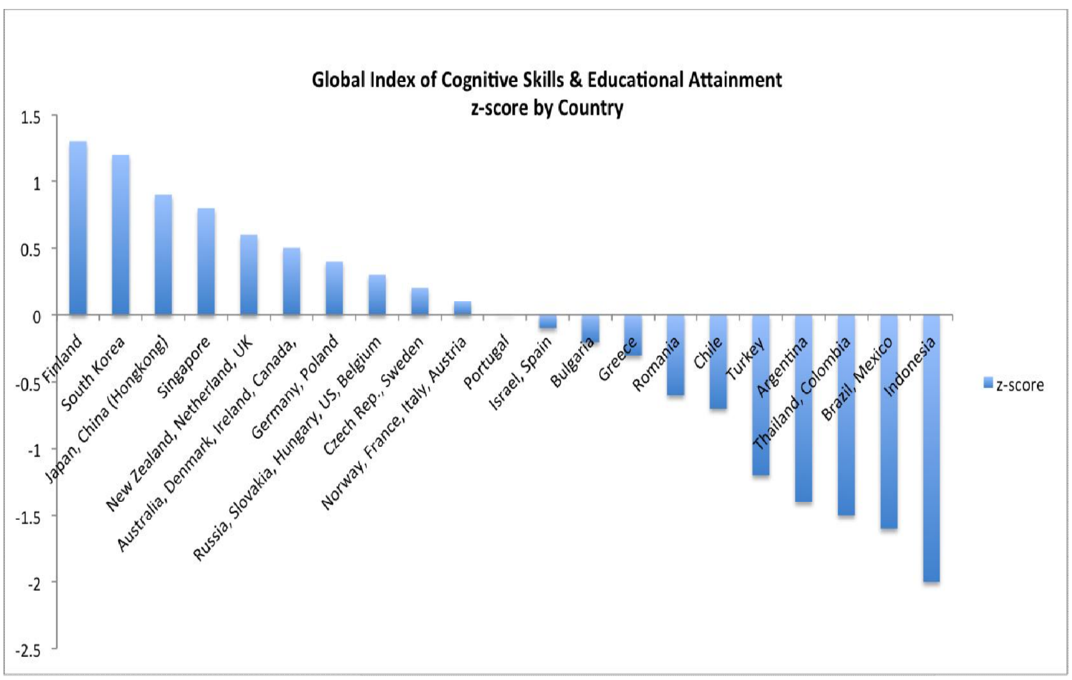

Fig. 1. Overall results of the global index of cognitive skills and educational attainment
Source: Economist Intelligence Unit

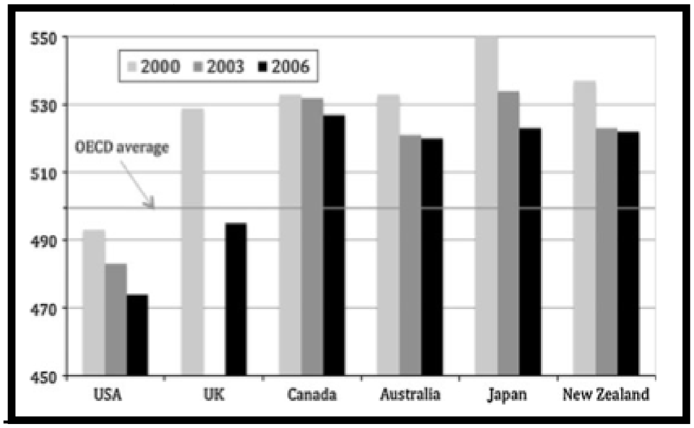

Fig. 2. National averages of students' performance in the OECD Program for International Student Assessment(PISA) mathematics scale of 2000, 2003, and 2006 in selected countries (OECD PISA database at www.pisa.oecd.org) Sahlberg [40]

Although, the Finnish education system's development trajectory, in the last decade, has reflected that of many other Western countries, there are two clear differences [42,40]. One, Finland has not adopted the strong version of teachers' consequential accountability with national testing.

Secondly standards are relatively open to local flexibility with a strong emphasis on basic literacy and numeracy concurrent with a wide-range education for all. Further, Sahlberg [40] describes that a fundamental principle in Finnish education ("The Fourth Way of Finland"), consists in integrating both low and high performing students into a supporting framework that pushes the bottom up and motivates the top to push forward. The Fourth Way also gives committed instructors the opportunity to build up students into self-sustained, yet socially oriented, driven and constructive professionals [41]. Finland [43] proposes that effective teaching must be committed to growing the bottom, while keeping the top engaged. This, we believe, should be the first step to solve the outcome disparity gap in the US education system and provide a quality education for all.

One other problem addressed by the Finland model is the lack of training in teaching pedagogies. For them, in education, "less is more", meaning that it is more beneficial to reduce content and facilitate the formation of a learning environment where students and professors can engage in a mutual process of questioning. Elder and Paul [44] argue that, without questions there is no understanding, or superficiality in students lacking intellectual skill and "their minds are silent as well" (p.3). Thus, the Finnish system's approaches lead to a greater understanding of the subject matter in students and a revival of those silent minds, through less cramming and more meaning-making interactions.

The Finnish success is rooted in: (1) Teachers collaborating with each other, (2) Relaxed schools environments, (3) Teachers connected to the same students over longer periods, (4) more play time for students (5), Teachers free to think outside the textbook and using various methodologies, (6) Teachers receiving regular professional development, and (7) Struggling schools paired up with successful ones [39].

The outcome gap between the weakest and the strongest Finnish students is the smallest in the world [45]. Engaging students can close achievement gaps and better prepare them for academics and professional life. It would seem, then, that teachers who are able to spark the interest of the most disinterested contribute to diminishing the achievement gap. Given the importance of educators, increasing the number of formally trained educators in higher education should be a reform priority [46]. Program for International propose, as is done by the Finnish system that teachers should receive ethical and social foundations, cooperation skills, understanding learning dynamics, difficulties, exclusion, multiculturality, they should know how to counsel, communicate, use technology, know curriculum development, and understand how to plan and assess learning.

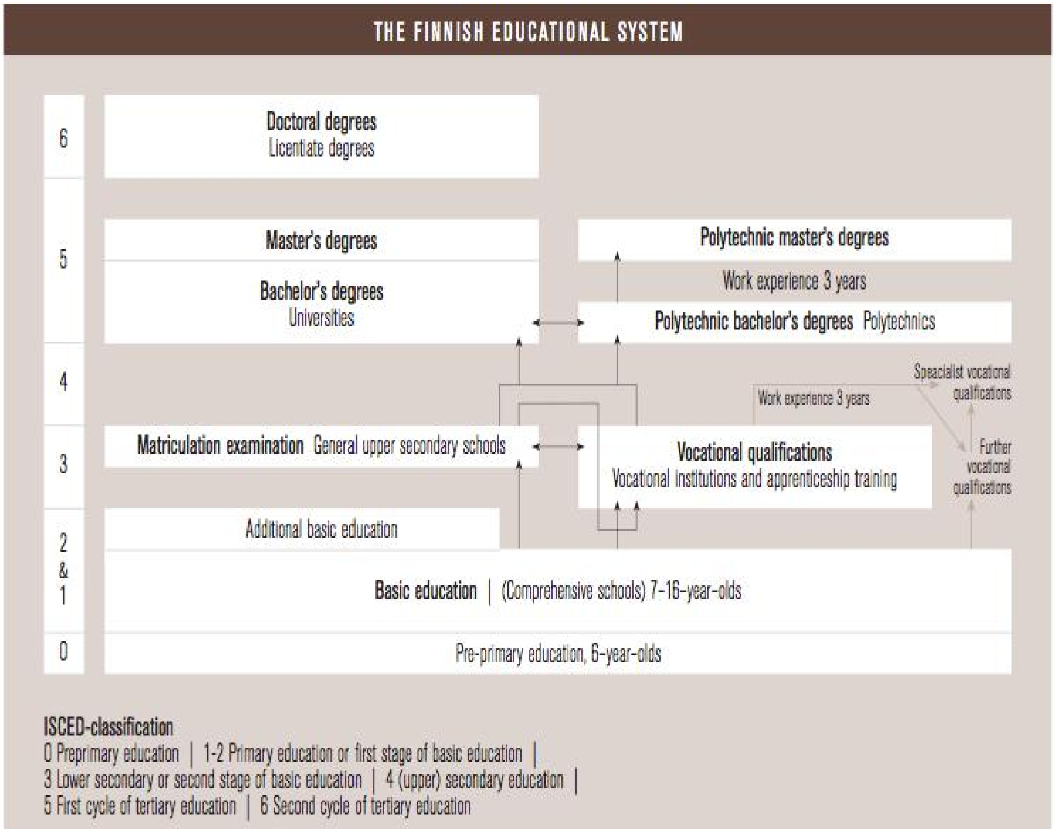

Fig. 3. Illustration of the Finnish school system believed to have lead to Finland's success in PISA during the last ten years – authorized by author [43]

A similar kind of training would prove beneficial for graduate students who are planning on becoming professors [47]. McAuley [48] a professor at the University of Illinois for whom this issue was a concern wrote that a majority of professors have for sole priority to develop their research agenda, and are trained only in skills related to that future demand [48]. Often elements of teaching and service are lacking to make skilled educators, which is yet so fundamental to student learning. McAuley [48] posits that a number of assistant professors believe that teaching takes away time from their research, nevertheless, teaching can inform one's research and vice versa, thus making better researchers and teachers. In Finland, teachers are in the classroom for 600 hours a year compared to 1100 for American teachers. Finnish teachers actually spend the rest of the time in training and development [36]. One could argue that assistant professors are in the class less time than the Finnish teachers however their time is spent more in developing their research goals. Such training, as in Finnish education, could be fully integrated in graduate students' and assistant professors' specific training curricula and professional workshops. We develop in this paper some strategies that could be integrated to such trainings to improve teaching skills.

Having examined South Korea's and Finland's educational systems, next is defined the Socratic Methods and proposed PST model integrating several methodologies, i.e., Socratic Method, Concept-based instruction and Inquiry-based learning.

1.3 Socratic Methodology

The Socratic Method(SM) was named after the Greek philosopher, Socrates, whose disciples wrote the method. SM is "the use of systematic questions, inductive thinking, and the formulation of general definitions" (p.8) [49]. Students are given a scenario and must answer questions from the instructor to be guided in specific thinking processes and concrete use of their prior knowledge. In 2009, a study using the SM brilliantly illustrated by John Houseman in the 1973 movie, “The Paper Chase”, found that more than 55% of the students claimed feeling intimidated [50]. Did Houseman’s arrogant style in imparting knowledge through questioning techniques truly represent SM? In principle, any methodology that uses questioning in an engaging and interactive way classifies as a form of Socratic approach, but there is as much effective as in effective ways to use SM. Rather, its effectiveness depends on how it is being used and on biases about students. Therefore, Houseman failed, not because he did not use a Socratic approach to teaching, but because he demeaned students. A first step in using SM is determining its true purpose, which is to bring hearers to thinking critically and responding through questioning or offering rational arguments held. The above definition does not characterize SM in the 21st century such that the Socratic approach is not inhibited by lecture formats but by the practitioner’s strategy. Further, McKeachie [51] contends that the Socratic Method can create an educational environment where students "actively process knowledge and construct their own understanding”. We believe that contemporary technology and advanced combinations of methodologies and concepts can enhance the learning process of students without leading to rote memorization or taxing anxiety. It should, instead, allow deep understanding of the subject and its interpretations, eliminating any weakness of the practitioner by supplementing their pedagogical practices with effective combined teaching strategies and technology. Overall, these methods yield good learning outcome and facilitate the shifting of ‘cognitive egocentrism’ to a better flexible structure of thinking. Students, thus, become able to better appraise their own points of view, and consider that of others’ in constructive ways. Ross [52] deconstructs SM into four components.SM examines students’ beliefs, principles and values through questions, focuses on morality, creates “productive discomfort”, does not elicit facts but shows complexities, difficulties and uncertainties about the world.

Through these essential components, students learn to master *elenctic* questioning, actively replacing their knowledge with new ideas and pursuing new learning, as instructors practice *elenchus* logics, by probing the students’ responses and pushing them to further examine the consistency of what they bring into the conversation [49]. A majority of students (74.9%), agreed that this type of strategies were fitting their program and 74.3% found that their learning was greatly enhanced [49].

Although SM is well established in the context of the Humanities and Law, other disciplines have adopted it in teaching. Helen [53] developed a Socratic approach for chemistry by giving reading assignments where students are expected to address orally the questions and continue in the discussion (Socratic part) by solving problems on the board, or worksheets. One could argue that this is not typically Socratic, however, the intrinsic nature of the different disciplines warrant to make modifications and adapt SM to the context to help students to be more engaged through interactive dialogues and questioning.

We believe that human beings best learn through questions. It seems natural in the beginning for children to intentionally ask a plethora of questions [54], which drives their discovery of the world and facilitates necessary cognitive foundations. Thus for example, two individuals both looking at a photo may learn differently if one asking questions and engaging a dialogue about the subject while the other is simply contemplating. Learning is not just knowledge but application of knowledge soundly and coherently. Evans and Witkosky [55] point out that, outside of law school, the Socratic Method is used in much less confrontational ways, and more facilitative manners by educators to stimulate students’ exploration. They argue that it only takes a student’s subjective comment to start an explorative discussion in class. Supporters SM suggest that it is a form of structured discourse about ideas and dilemmas, involving students actively in the learning process by relating activities to their own experiences and engaging them emotionally [56,57].

Canestrari & Marlowe [58] say that, the quality of learning in turn depends very largely on the quality of teaching and that it must evolve to a mode of teaching called “maieutic”. This helps students create new ideas, and come to a better appreciation of their own understanding and depth of knowledge. SM provides a pathway where the discussion draws on students’ reading, writing, speaking, and listening skills, and uses them to sharpen their ability to think clearly, critically and reflectively [39].

Therefore, we make the argument for SM to be used at all stages of learning and for students of all ages. The real challenge then lies in how to accomplish such a goal without provoking intimidation, or causing learners to become so uncomfortable that they resist learning. Additionally, how can this method be implemented in the contexts of introductory classes and large lecture classes? Such questions are addressed in our proposal to promote the same quality of education for all.

Socrates asserts that we can create new knowledge but it is based on previous experienced incarnations [59]; we argue that the basis of all knowledge is question asking, and our proposed thesis is that questions drive the critical thought process. Critical thinking allows to ask new questions thus creating new knowledge. In fact, every intellectual field is born out of a cluster of questions to which answers are needed and actively sought for. Furthermore, a field only progresses as new questions are constantly generated and explored, and these foster the thinking process underlying all ideas which forces us to face convoluted contexts [44].

1.3.1 Pseudo-socratic teaching

In recent studies researchers [60,61] argue that *a teacher's "value-added"* (average test-score gained by their students on ACTs) makes the difference between achieving and non-achieving students, and a large difference in their income in adult life. We proposed that the *"value-added"* concept, although a good indicator of which classrooms should be investigated more closely, is not a good measure of teachers' performance. Value added measure should help to identify teachers who need more specific training to better helping the various kinds of students in their class. This is one of the key strengths of the Finnish education model [36]. Also, Ferguson and Ladd [62] contend that ACT scores exert a larger influence on student achievement than does student poverty level, class size and teaching experience combined. However, it is our belief that students' performances are mostly tied to their perception of their teachers. Further, researchers found that teachers seemed no more effective after undergoing the grueling certification process than before it [63]. Thus other factors are at work that impact students such as classroom comfortability, connectivity, organization and preparation, and the ability to engaging the critical thought process.

The conjecture of this paper is that many methodologies can work if blended with older teaching strategies and newer ones. We do deplore however, the lack of training of teachers in these methodologies, especially in higher education. In the Finnish model, teachers are all trained with the same methods [46], become flexible, and adapt to all new classrooms. Our focus is on the practitioners' training whom we believe need to gain teaching skills along research ones to be more efficient with students and thus educate them, equipped with more fundamental and solid bases.

Our proposed teaching paradigm associates various proven teaching methodologies and focuses on the practitioner to help them bridge all the learning modalities of the students by having these methodologies in their toolbox. Below is detailed the utility of tangible attributes such as organization, connection, and question asking; and what Goodwin [64] describes as intangible attributes such as belief in students' abilities, which must be the skills gained by practitioners to drive student success, and which are the pillars of the PST method.

Making good teachers implies teaching them to repudiate the belief that we must 'teach to the middle' because some students are going to fail anyway. There is an inherent loss of faith in some students' capabilities, especially those assumed to be low achievers [65]. The characteristic attitude about this group should be similar to teaching a child to ride a bicycle. There would be no significant accomplishment if the child already knew how to ride. The true noble challenge in education is equipping those students who entered the classroom challenged, helping them to grow and develop to ride off in the sunset.

Thus, an interactive classroom that facilitates optimal learning is one that sets synergistic elements reciprocally interacting with and mutually reinforcing each other such as a sense of comfort, connectivity, organization and preparedness, curiosity, and effective teaching approaches. The PST approach focuses on content and pedagogy giving practitioners a better toolbox to create a classroom that fosters a positive interaction between themselves and their students.

1.3.1.1 Comfortability

Comfortability pertains to professors' friendliness, availability, and approachableness in and outside the classroom. Comfortable students are happy and productive. What makes educators likable? Experience tells us that sharing personal stories with students allows them to see how they can relate to professors. As Rogers & Friedberg [66] point out, great teachers are authentic, open, and trust in their students in a way that allows them to feel comfortable in a safe class. Establishing this bond limits potential behavioral issues as professors appearing more human, down to earth, and understanding [67]. Using humor contributes to comfortability as well. Ice-breakers generally help but should be used without demeaning or discriminating. In being intentional in creating likability, it is important to maintain a position of authoritative figure without being authoritarian so as not to negatively impact the trust and control of the classroom. A first rule of thumb is, if over 70% of the students like their professor it will easily translate to the rest of the class influenced by the larger group.

1.3.1.2. Connectivity

For effective teaching to occur, teachers must be intentional in making a connection with the class. Psychologist Bruner [4] points out that good teaching involves the educational practitioner knowing their students' storyline. Instructors may check in, compliment, or make comments on current events. Comfortability and connectivity are interwoven processes. To achieve comfortability, professors must relate well with students and their likeability quotient should help foster the personal connection that students feel with their professors. Thus, good teachers should invest time in becoming familiar with those whom they teach and care about. As Goodwin [64] describes, we must believe that students can be learners, have abilities, and can be connected with. Connectivity is crucial because educational research has shown that students who have close, positive, and supportive relationships with their teachers attain higher levels of achievement than students with more conflicted relationships [68,69]. When students feel a personal connection to teachers, they will communicate freely and frequently. Consistent and ongoing communication develops relationships and ensures that students benefit from support and guidance [70]. In a nurtured relational context, students more likely trust a teacher, show more engagement in the academic content, display better classroom behavior, and achieve at higher academic levels, thus, contributing to a comfortable learning atmosphere. Teachers who experience close relationships with students have reported students less likely to avoid school, being more self-directed, cooperative, and engaged in learning [69,71]. Students also reported liking school more, experiencing less loneliness, and better performance on measures of academic performance and school readiness [69].

Connectivity is achieved when students experience their professors' humanity demonstrated when they do not allow themselves to be perceived as overly brilliant impressing who won't dare approach or challenge. Educators also show humanity when they know the names of their students even in large classes and feel comfortable making mistakes. Finally, students appreciate their questions being addressed rather than avoided, or at least professors coming back to them later when they had no answer. This communicates to the students that they are important.

Professors who foster positive relationships by connecting to their students create classroom environments that are more conducive to learning and meet students' developmental, emotional, and academic needs.

1.3.1.3 Organization and preparedness

Although comfortability and connectivity are essential elements, they must occur within an organized and prepared classroom. We recommend that educational practitioners adopt the Finnish principle that 'less is more'. This gives students opportunities to engage in the learning process more deeply unencumbered by boring and heavy lectures. Research has shown that lecturing is as effective as other instructional methods, such as discussion, in transmitting information, but less effective in promoting independent thought or developing students' thinking skills. As such, practitioners must try to share complex intellectual analyses, synthesize ideas, clarify controversial issues, or compare and contrast different points of view to engage and entice students' critical thinking [72]. When care is taken in carefully preparing to engaging and developing students' thinking processes, they are better able to deduce or make transitions to ideas that the practitioner has not yet lectured on.

Professors might rehearse their material to connect confidently and engage students into constructive discussion and learning. However, sometimes, the use of on-the-fly examples in problem solving may allow students to experience the practitioners' humanity as this spontaneous and organic process increases the probability of making mistakes. At times, this may look as unpreparedness, but when professors rehearse all examples, they fail to model how to recognize mistakes in problem solving and model the thought processes involved in fixing them. Without mistakes, practitioners may seem more robotic, and unaware of potential challenges students face in their thinking.

In preparing to teach, Christensen [73] suggests to list the topics that are important to include and estimate the amount of time required for covering them. By increasing the time estimation by 50% teachers allow time for students' questions and inevitable logistic slippages. Consider also students' attention span (between 10 and 20 minutes), after which students' concentration diminishes [74]. Thus, ongoing monitoring of students' responsiveness and body language must happen throughout. Strategies such as introducing humor, stories, or changing the pace every 15 minutes or so helps relieve monotony and recapture students' interest. Other helpful strategies include demonstrations, audiovisual aids, and giving problem-solving tasks or case studies for students to organize in groups.

Lecture preparation and presentation are crucial in conveying organization. As such, we recommend that lectures should start with the end in mind: the goals to reach should be highlighted at the beginning, and summarized at the end. This somehow appears to contradict fundamental principles of the Socratic method, but we propose that it can still be used in the context of lecture (see subsequent sections).

Although being well prepared implies planning lectures beforehand, one must still be fluid both in approach and delivery of content being able to change a plan spontaneously as class progresses. While teaching, the classroom context and dynamic must determine the approach which may require to stop a lecture because optimizing students' understanding might be, at a given point, more important than agenda. Thus, educators must be versed in various teaching methods and flexible enough to have the ability to engage the classroom in various ways.

1.3.1.4 Critical Thinking

As Knowles [75] explains, an effective teacher gives an active role to their students by engaging them in being committed to their learning, diagnosing what they do not know and need to know, and evaluating their own learning. This can only happen through true critical thinking skill development facilitated by class context. Academics give various definitions to critical thinking. However, in education, philosophy and psychology, the overall consensus seems to be that it includes: analyzing arguments, claims, or evidence, making inferences using inductive or deductive reasoning, judging or evaluating, and making decisions or solving problems [76-79]. Ennis [76] defines critical thinking as reasonable reflective thinking that focuses on deciding what to believe or do. This means that critical thinking must involve natural dispositions and acquired abilities. There is a challenge in distinguishing whether or not critical thinking is to be discipline specific. However, thinking helps to broaden the perspective of the learner beyond a discipline. Therefore, the goal of teaching is not just to present information and communicate knowledge, but also to shape and enhance the thinking ability of students beyond the subject at study [64]. We propose that critical thinking should depend on the learners' ability to utilize both dispositions and capabilities. Thus, educational practitioners must provide learners with a repertoire of thinking tools to use in effective ways. When students are able to think in more coherent ways, they can disseminate and apply knowledge to broader contexts, and can go even further to create or transcend knowledge.

Critical thinking involves three basics components: description, analysis and evaluation. Description invites students to ask 'what', 'when', 'who', where as analysis focuses on 'why' and 'how', and evaluation encourages students to think beyond the phenomenon by going deeper and asking 'what if.' When students ask questions, educators must take the time to listen, make eye contact, and respond in such a way that students feel valued. When educational practitioners create an environment that encourages students' comfort in asking even the most basic questions, this helps enhance their thinking. Therefore, good thinking is directly linked to learners' development of question asking which, with experience, ensures that learners can apply their thinking more broadly than in the specific discipline. This ability for broader application of thinking demonstrates that critical thinking is not bound to disciplines but rather transcends all learning contexts. Thus, one of the most effective ways to measure enhanced creative thinking is to look at outcomes vis-à-vis the learners' basic starting point.

Educators often spend significant effort and energy motivating students to use critical thinking. However, we believe that this approach often results in negative outcome due to a limited focus on more fundamental qualities for effective learning. We propose that one of the first qualities is curiosity. Research in the field of developmental psychology has outlined the importance of curiosity showing how it drives learning and problem solving abilities [80-83]. When students are curious, it is easier for them to engage in question asking. Consequently, the most fundamental asset to critical thinking involves asking questions at the most basic level driven by learners' curiosity. In the absence of curiosity and question-asking behaviors, less learning occurs which results in lower problem solving ability [84-87]. The crucial question is how to maintain a level of curiosity in our students of all ages to create the drive to be engaged in exploration and generate questions to fill in knowledge gaps. Some methods have been implemented in educational research to model question formulation to participants, which yielded significant positive results [88,84,83,89]. Educators must then be careful not to shut down any question, which could otherwise thwart students' desire to ask anything in class. Educators' goal must be to finding ways to awaken students' curiosity. We posit that teaching students through SMs sparks curiosity and helps acquire thinking and question-asking skills coupled with interactive and interesting teaching material to substantially improve thought processes and problem solving skills.

Our methodology so far outlines important relational components between critical thinking and the value of students' curiosity. Our model / approach enables the critical thought process of the learner to flourish. We believe that curious students are thinking students and that thinking students are a curious student.

1.4 Teaching Methodology

Coupled with these relational aspects must be pedagogical approaches that engage student learning. The PST model integrates several methodologies, i.e., Socratic Method, Concept-based instruction, Didactic, and Inquiry-based learning, to further tune professors into the world of their learners.

Some educators argue that one of the best ways that students learn is through the use of examples. We posit that this is fallacy, at least for most of the major disciplines, because examples are best used to reinforce an already learned concept. Our focus therefore, is on concept-based instruction. When educators use concept-based instruction, they match elements presented in real-life to foster creative thinking and give intellectual impetus to their students. Such bridging methods help students find links between concepts and deepen their understanding of what is taught. Exposure to concepts triggers the necessary curiosity that drives question-asking in students. Students perform best in learning environments where they embark on discoveries and construct knowledge. Such intellectual environments exist in what is called "three-dimensional concept-based curriculum models" [90] (Fig. 4). For Erikson [90] thinking can be represented in two- or three-dimensional models. The former focuses on facts and skills while the latter is concerned with concepts and principles but adds a complexity layer by using facts and skills as tools in the thinking process. When students are engaged in learning a new concept, they tend to ask more questions, improving the level of discussion. Therefore, educational practitioners should start by introducing students to a concept, awaken curiosity and then illustrate how the concept is used to solve a problem.

1.4.1 Determining baseline

Where to begin? First Practitioners must determine a class' baseline. Practitioners must meet students where they are by first assessing the level of the bottom quartile and designing a curriculum to reach it while engaging the top. For example, in a college introductory physics class, a Force Concept Inventory (FCI) test [92] is administered to help professors gain insight into how to adjust to the needs of the class. FCIs used in this manner help practitioners to best plan and design targeted goals. Depending on what FCIs indicate as the class' foundation, the practitioner can cover adapted content and go deeper into various topics. If the foundation is poor, then lecture style must be changed to establish and strengthen the foundation. Concept Inventory tests tend to be given the first day of class, which is problem since instruction plans have already been made, but we propose that giving it a few weeks before instruction (at registration for example) would allow the practitioner to make more informed decisions on instruction planning.

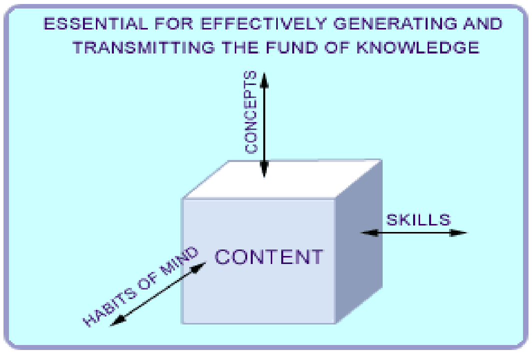

Fig. 4. Attributes necessary for both generating and effectively transmitting knowledge [91]

1.4.2 Implementing the method

Note first that the following suggestions will work as well in sciences as in other disciplines, problems either mathematical or philosophical demand the same basis, thinking. Fig. 5 shows how educators may start class, either from a Socratic or Didactive framework. Starting on didactive means beginning by using concepts to communicate content, which is the traditional lecture format [93]. The educator presents the concept to students for no more than 10 to 20 minutes in order to ensure that students' concentration is not exhausted [73]. One could start with familiar, real life examples and capture students' attention by asking a question or performing a demonstration where students are asked to give predictions first [94]. This brings the classroom to learn through inquiry, which we will discuss later.

A good demonstration often surprises students and draws them into speculating on what is happening, eliciting curiosity, and fostering engagement. Question asking is one of the most essential tool to enhance the critical though process [44]. At this point, the practitioner is ready to transition to explaining the related concepts and illustrate how to use them in problem solving. After the explanation of each concepts, the practitioner must give students time to process and ask questions. If there are no student-generated questions, then the instructor may ask one. With the introduction of questioning, we move from didactive teaching to Socratic teaching moving from Didactive teaching to Socratic teaching (Fig. 5).

This interplay of methods accomplishes what a number of researchers have shown to improve student problem solving abilities [85,86] and wanting to see more in teaching methodologies that bring the student to ask questions [87,84]. Elder and Paul [44] support this point saying, "[…] the statement that water boils at 100 degrees Centigrade is an answer to the question "At what temperature centigrade does water boil?" Every declarative statement in the textbook is an answer to a question." (p.2) Socratic teaching provides a pathway that sharpens students' thinking abilities which is the very idea illustrated above [49].

A Socratic approach first allows students to examine previously held beliefs and values in lieu of what has been presented in class. The PST method is thus called because of the strong interplay between didactive and Socratic teaching styles, this dynamic creates a very interactive class.

Before continuing, it is important to give an overview of Inquiry-Based teaching and its benefit to education since it can be incorporated into the PST method. John Dewey's reform of the educational system led to the first inquiry-based learning (IBL) methods used in the United States.IBL is, in essence, Socratic by nature and creates environments in which the Socratic Method can be used. "Inquiry is defined as a seeking for truth, information, or knowledge -- seeking information by questioning" [3].

With IBL students are asked to make predictions, observe phenomena and compare to predictions, explain their observations and predict again. This strategy shapes students' critical thinking abilities. Magnussen, Ishida, and Itano [95] have shown that in a "comparison of critical thinking test, scores for 228 students in their first and 257 in their last semester showed that those with the lowest scores initially benefitted most from IBL"(p.5). This indicates that Inquiry-Based teaching could be used to close the gap between the weakest and the strongest students. For Exline [96], school is less about collection of information than about how the knowledge is being used for which inquiry learning is a great tool. Inquiry is a tool for learners to discover where they lack information [94].

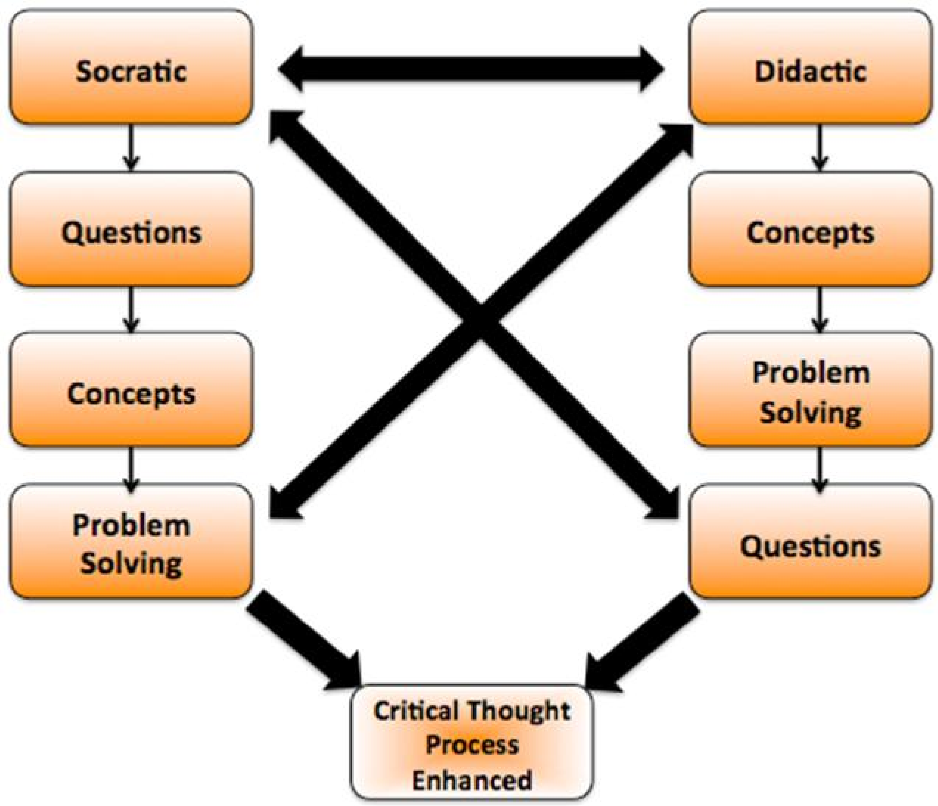

Fig. 5. Interplay between Socratic teaching and Didactic teaching to engage critical thinking

Schank [97] adds to that idea by showing that realizing that an information is needed basically opens the mind to be more curious about the fact and actively look for answers. Edelson and Gordin [94] point to positive aspects of inquiry-based teaching noting that "inquiry experiences can provide valuable opportunities for students to improve their understanding of both science content and scientific practices." However, they delineate five significant challenges to the implementation of IBL in classrooms:

- *Motivation.* For students to engage in meaningful learning inquiry they must be sufficiently motivated. The challenging and extended nature of inquiry requires a higher level of motivation in learners than is demanded by most traditional educational activities.
- *Accessibility of investigation techniques.* For students to engage in inquiry, they must know how to perform the tasks their investigation requires, understand the goals of these practices, and be able to interpret their results.
- *Background knowledge.* The formulation of research questions, the development of a research plan, the collection, analysis, and interpretation of data all require scientific knowledge. In designing inquiry-based learning, the challenge is providing opportunities for learners to both develop and apply that scientific understanding. Lacking this knowledge and the opportunity to develop it, makes students unable to complete meaningful investigations.
- *Management of extended activities.* To achieve the ultimate goal of open-ended inquiry, students must be able to organize and manage complex, extended activities. They would be otherwise unable to engage in open-ended inquiry or achieve the potential of IBL.
- *The practical constraints of the learning context.* The technologies and activities required by IBL must fit within the practical constraints of the learning environment, such as the restrictions imposed by available resources and fixed schedules. IBL is quite difficult to do in large lectures; however, it is possible as demonstrated by

Sokoloff and Thornton [93]. Technologies such as iPadapps allowing students to surf the web and use their smart RF responders makes it now possible. Fig. 6 illustrates a number of possible options in breaking down a class lecture. This strategy is flexible enough to allow all disciplines to benefit from it.

An important question is: can this combination offered by PST be accomplished in a 50-minutes lecture, and does it allow coverage of all needed content? As a reminder, the Finnish educational approach has shown that we can do more with less because the goal of teaching must be to teach how to fish so individuals may feed themselves. To integrate the PST approach, we will need to think effectively and select 75% of lecture materials that would be traditionally used. The amount of content one needs should depend on the class' baseline; and, as such, it is important to assess the needs of the class either on or prior to the first day of class. Important to this format is a balanced use of time. Sometimes, however, it can become necessary to allow the whole 50-minute to be Socratic. For example, in one introductory class, the topic of discussion was the rise of the earth's temperature. This took the whole class period in the form of a debate because it was a subject that students were passionate about both from the scientific and policy standpoints. We must not be afraid to become creative to keep our students engaged.

1.4.2.1 Clickers and demonstration in the classroom

The free response technology (FRT) or 'clickers' is one of the best ways to transition from did active to Socratic teaching. Clickers help verify students' understanding of concepts. After presenting a concept, especially after working an example problem, use FRT to ask questions about the concept. Preferably use multiple-choice questions format, giving about 30 seconds per questions. Possible results:

- > 75% correct. The professor or students show why the answer is correct, then the next question is presented.
- Below 60%, a hint is given and re-polling occurs.
- Below 40%, students discuss the problem in groups and then are re-polled. Afterward an explanation is given for the correct answer.

Sometimes after students chose their answer, ask them to elaborate in order to ask them more questions allowing them to reexamine their response. The question can be re-polled and the correct answer revealed. Further, if there are at least two close responses, the instructor may ask another question to help clarify the nuance in the thought process of the students. Students could *Think-Pair-Share* for about a minute in order to review the answer again with classmates and consolidate their understanding, then, the question can be re-polled. During the group discussion, the instructor should move around the lecture hall listening to various thought processes to see what direction to take next. The instructor at this point may ask follow up questions, ask for volunteers, or call students to work out a problem on the board. In this process class interaction is encouraged for other students to guide the student working problems on the board. Note that Fig. 5's breakdown may not always work, therefore, class dynamics should always dictate the next step. The professor's agenda should not be the priority, and vigilance is needed to see when to allow such engagement and when to move on to a new concept.

FRT can also effectively be combined with demonstrations for students to participate in the process which may take the form of an actual experimental setup, PHET application [98], or the like. One can then ask students to make predictions for the first 2-3 minutes of class. One student is called upon, followed with a vote of all students agreeing or not. The students are then asked for any other predictions, after thinking of new answers, another vote is taken to check students' agreement. The demonstration is performed or the PHET app is ran followed by a clicker question. With the use of PHET or other tools, students can be asked to run the application on their electronic devices.

Finally any methods should end with - *Just in Time Learning (JTL),* implemented in the University of California system. JTL allows for real time feedback and, in cases where students repeatedly ask similar questions, it offers a starting point for the next lecture. With JTL, students are asked to write down three things they have learned from that particular day's lecture or write questions they would like the instructor to answer during the upcoming class period for one extra credit point. Students can also ask questions or report on the three things learned after lecture using web-based technology such as Moodle, Canvass, or Blackboard etc. All these approaches help keep the class fully engaged.

1.4.2.2 The use of example problems in class

In addition to using FRT, using examples help engage students in learning. However, as mentioned earlier, examples must not be used at the expense of teaching concepts. In some disciplines, giving an example to illustrate a particular concept works quite effectively and can also serve to introduce concepts. Danger comes when examples are the only means capitalized on to teach how to confront particular problems. This may lead students to engage in rote memorization of specific answers rather than using thinking strategies, and thus, as soon as problems are presented in slightly different ways, fewer students can make the connection.

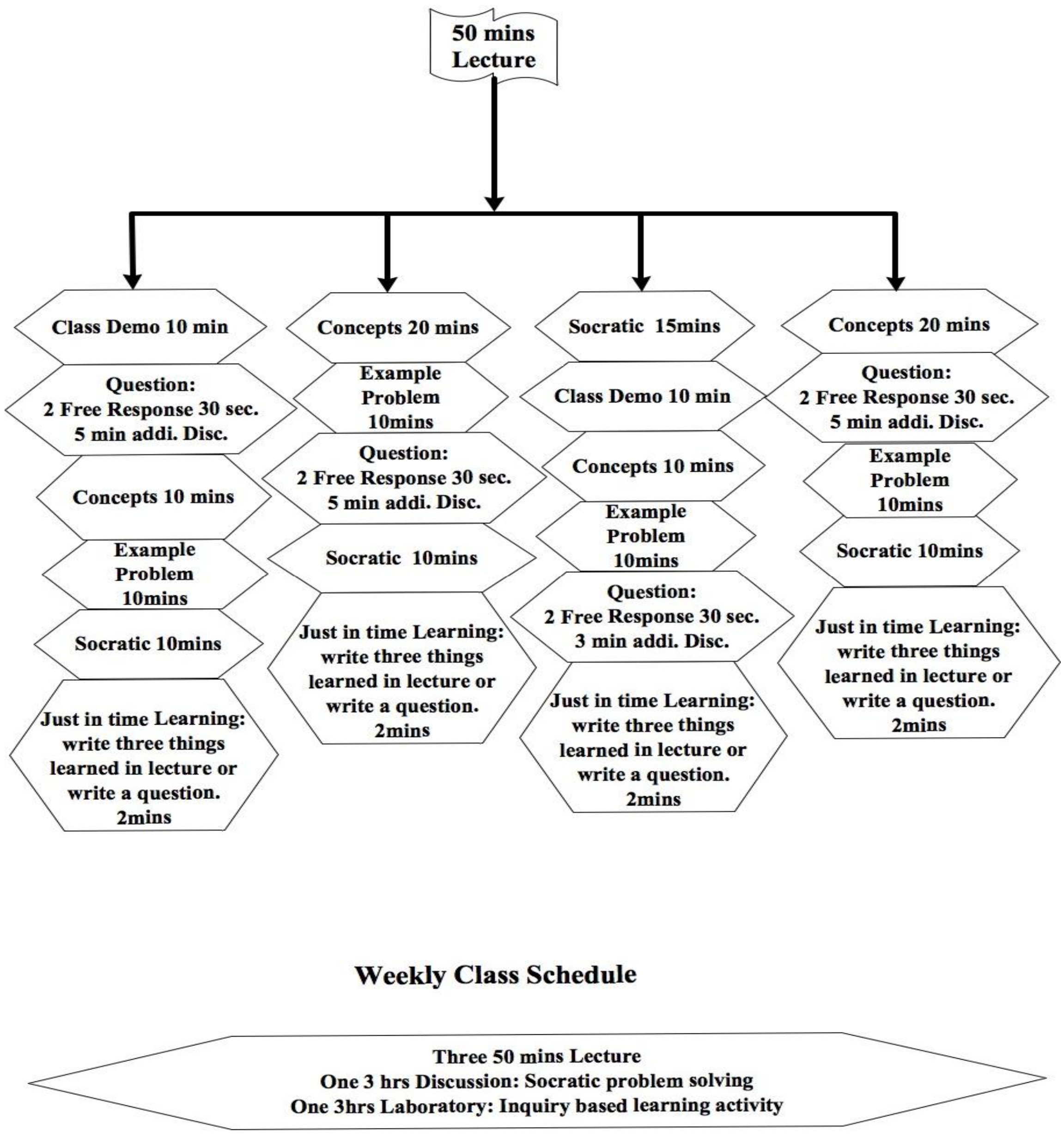

Fig. 6. Teaching breakdown options for a 50 minutes class session combine a didactive approach to a Socratic style

Although using examples may work in certain disciplines, the approach has limited effectiveness in many science and mathematics courses, which requires flexibility of thinking. It is our experience that often in physics and mathematics, professors use the whole class period to laboriously work out problems on the board; students generally understand the examples and reproduce the results, but only to a certain extent. Therefore, this method gives them a fish on the short term rather than teaching them how to fish for life. In order for one to teach problem solving through the use of examples, students must have some basic familiarity with the concepts involved or else they cannot efficiently deduce the concepts and use them to think and find solutions. Such skills require advance training in thinking. Thus, we propose that the practitioner teach through concepts, rather than by example and instead, use examples as tools to illustrate concepts.

Essential points:

- Concept illustrating examples should not take too much of class time unless vitally important
- Choose easily understandable examples for the weakest and move on to more complex problems
- Reinforce every concept by at least three example problems: #1 worked out completely in class, #2 sketched briefly and left for the students to complete, and #3 left undone expecting students to do it later. In the next class period, depending on the examples, clicker questions can be extracted from these examples revealing how well students learned.
- Provide group assignments to encourage students to work together by mixed level, ideally one strong, one weak, and two average ones.

1.4.2.3 Conceptual Teaching - An Example

In Appendix A we provide an example of classroom work and interactions that illustrates the merging of Socratic methods and Inquiry Based teaching strategies in the context of a physics class. It combines conversing with students while showing them how to use their thinking process to find new principles, and understand new concepts. Then from the inquiry, we ask students to draw upon what they have found to formulate concepts and/or formulae.

1.4.2.4 Homework

After dynamically using didactive, Socratic Methods, Concept-Based instruction and IBL, it is important to monitor and evaluate students' understanding. Homework plays is key in alerting educators about how students are learning and informing about any weakness or gaps in their understanding. Thus we argue against ideologies which contend that homework is ineffective [99]. Educators must chose between assigning too much work which may not give students opportunities for in-depth reflection on concepts versus too little limiting opportunities for practice. In science, for example, a professor may give 10 problems, each with five sub-questions. From experience, this results in homework becoming a tedious chore. Learning here is not achieved, because students have less time to critically think and their major concern becomes to just finish and get the work done for a grade. When assigning homework, the instructor must be intentional in assigning work directly related to instruction. Homework should start with simple concepts that easily illustrate the material covered and move to harder problems. As a good guideline we recommend those given Marzano and Pickering's suggestions [100, p78]. Further Cooper, Robinson, and Patall [101] did a comparison of homework assigned at an appropriate level versus no homework given, and found that students doing homework scored 23 percentile points higher on tests than the average students in a class in which homework was not assigned.

To stay with our science example, motivate students to complete homework by offering extra credit and slowly decreasing it over the course of the first half of the semester or quarter in order to prevent students from expecting and using extra credits to get by. After a certain period, only one extra credit or so is necessary per homework. The class must be so designed that the extra credit in homework represents no more than 2-3% of the overall grade with homework counting for no more than 10% of the class grade. Some disciplines will obviously require homework to weight more, especially in case of essays, or upper division courses.

Giving peer groups homework can be designed to maximize the academic performance of the lowest ability students and be very effective. We found that a group of four students works very well. The initial group can be selected using the FCI results described earlier such that (as much as possible) the group be composed of one high, two middle, and one low ability students [102]. Such suggested peered interactions have proven to have a positive effect on the learning ability of all the students in the group [102]. By convention, select the low and the high performance students such that they spread nearly equally over the first and third quadrant of a class (Fig. 7). The middle average is distributed about the mean, representing the remaining 50%, which is within one-standard deviation from the mean. When assessing students' performance, Stenberg, Grigorenko and Clinkenbeard [103] made justification for a half-standard deviation above and below the mean. In Fig. 7, 0.67 standard deviation covers 50%, which is the criterion we adopted for our proposed cutoff of the class FCI performance.

This can be applied to any class distribution, skewed or not toward high or low average students' performances. Once students are placed in these three quadrants according to their FCI average, the instructor can choose 1 low, 1 high and two average students to form groups (this obviously depends on how much students are in the class and in each categories). Such strategy allows to always have fairly even performance work groups allowing students to be challenged and supported in their learning. It is then up to the instructor to monitor and switch around the groups depending on how students fair with each other. In the event that the scores are not evenly distributed about the mean, using a cut-off of 60 to 75% for the mid-range group, and 75% as a minimum score for high ability students, form the groups by best judgment looking at mean, median and standard deviations. After the first test, students may be shuffled through groups to better reflect the categories in which they are temporarily in and the instruction should help to create a better distribution about the mean, especially in case where FCI scores were very scattered. Ideally, these groups should change reflecting the progress of the students. A total of six problems may be assigned to the class. We ask all students to attempt two problems and discuss them within their group, then the group leader disburses the four other problems among the students. Later each member must present their problem to the group showing them how to work out solutions. In a more general sense, we believe that every discipline can develop tests like the FCI. Some equivalents already exist such as 'needs assessment' tests. These are a window into students' initial understanding, and tools allowing instructors to know how students develop over the course of the instruction, and can help shaping instructors' preparation of the course.

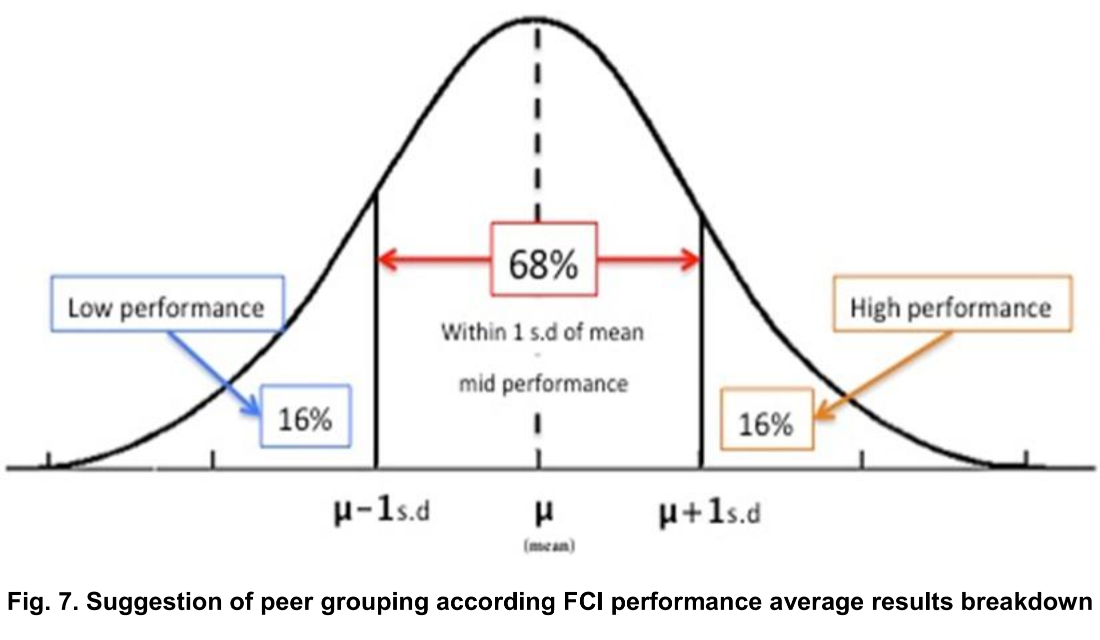

Fig. 7. Suggestion of peer grouping according FCI performance average results breakdown

1.4.2.5 Testing

Testing methods are as important as educators' teaching methodology. Tests should never be about grade, but indicators of: 1.) How well students understand concepts, whether the gap between weakest and strongest students is shrinking, and how well students' thinking skills are improving; 2.) The teacher's own instructional effectiveness, whether instructional and curricular decisions need modification, and how well their instructional intentions are instituted. Over the years we experimented with a simple testing method:

- Give a test review similarly formatted as the actual test, a training tool for the true test helping with understanding the concepts, enhancing motivation, and helping students transition to solving problems they never saw.
- Include a few problems from the review test and giveit 24 hours before the test date. Encourage students to work independently without assistance.
- Write the test with the weakest student in mind.
- When a test averages less than 60%, give students the choice to redo the problems or questions missed, and turn it back in within 24 hours for a third of the points. Any question re-done must have side annotations explaining why the answer they now chose is correct (students work independently but may consult the professor if they become confused). The rational is that a curve is not given blindly but students must earn it.
- A test average below 40% indicates that the problem is with the test because a majority of the class failed. Reassess the weaknesses in communicating the material, address it, and retest.

The goal is to enhance students' motivation and not to demoralize them as did previous curve structures [104]. Testing becomes a pedagogical tool with which students learn while practicing, and their grades are not inflated as a result of the instructor's poor performance in relating to the students and communicating the material ineffectively.

2. METHODS

2.1 Exams and FCI Tests

We administered a course-specific FCI over the span of 5 years at the beginning and end of the course. Four exams allowed for a broader check for understanding of the course content and a comprehensive finals were given over the course of the semester or quarter (exams formats detailed below). Students' demographics were not gathered at the time but according to limited information, the groups tested were representative of a small private university and a Californian public university with a majority of Hispanic, Asian, and Caucasian groups and a smaller African American representation. Male and female were on average equally represented, ages ranged between 17 and 45 years old, and their socio-economic status was representative of Southern and Central California demographics. Classes sizes ranged from 30 to 110 students with a retention rate above 95%.

All exams were administered in class for 50 minutes, except for the final exams, which were 2hrs comprehensive exams. The exams sections were broken down into the following categories to check overall acquisition of the concepts taught while using PST (Appendix B). Every test was vetted by a teaching assistant to ensure that the course content aligned with the instructional objectives. Students were given the opportunity to challenge their results if they believed the tests items to not reflect class content. We found in end of year class review survey data that 78% of students reported that the exams' content was a fair reflection of the class content. Test grading was checked both by the instructors and the teaching assistants. All students' responses were examined against each of the following criterion. Section A (*testing detailed knowledge and understanding of learned concept and principles, and effectiveness in thinking through simple concepts*) contained 15 multiple-choice responses (45 pt). When constructing multiple choice (MC) we followed the preparation outline by Burton, Sudweeks, Merril and Wood [105]. MC allows teachers to test broad sample of course content in a given amount of testing and allows access to test validity [105]. Further, well-written MC items compare favorably with other test item types on the issue of reliability and are less susceptible to guessing, producing more reliable result [105]. The reliability of the MC was tested using Chronbach alpha averaged across five years showing that the test is well constructed (60 items, α = .85). Section B (*understanding and effective exploration of concepts relevant to the material, and effective use of concepts to thinking through questions*) contained two Short answer responses (15 pt). Finally, section C (*assessed understanding of the* *concepts to problem solve, use of visualization techniques to show understanding of physical situation, observed mathematical rigor set up, and problem solving*) contained two long answer responses (40 pt). Final Exam: sixty MC questions (70 pts), four short answer questions (40 pt), and eight long answers from which students are asked to complete six (90 pt).

Students' raw scores were compared across years and courses to track their progress under the PST method when implemented by practitioners along with our four pillarsfora successful classroom. Group A represents years 1 thru 5 of Calculus-based physics and Mechanics, Group B represents years 1 thru 5 of Electromagnetics, and Group C represents years 1 thru 5 of Modern physics and Optics.

2.2 The survey

The data was gathered from students' class reviews in two calculus-based classes in 2013. End of year evaluations are electronically collected by the school at the end of the semester and sent to professors. Comments were carefully screened for expressions of class and academic experience reflecting each of the four PST principles: Connectivity (one-on-one contact, availability, authenticity, nurturance), Comfortability (Professors' openness, humor, and personality, ease of communication in the classroom), Preparedness and organization (flexibility, lecture format, method, pre-class background preparation), and Critical thinking (students feeling invited and shown how to ask, ponder, think and grapple with problems). We took the frequencies of appearance of comments corresponding to each category and summed them over the amount of students in the classroom to get a percentage of students expressing freely what they experienced while being taught under these four principles (Table 1). Aside free comments, a number of questions were asked which also covered the four principles (Appendix C).

3. RESULTS AND DISCUSSION

3.1 RESULTS

Analyses revolved around the study of performance gaps and how they are reduced under PST pedagogies, and focuses on students' experiences with the method.

3.1.1 The exams and FCI Assessments

Analyses of variance were performed to assess Calculus-based physics class exam average and final exam averages of Group A (years 1 thru 5 of and Mechanics), Group B (years 1 thru 5 of Electromagnetics), and Group C (years 1 thru 5 of Modern physics and Optics), compared over of 5 years. There was a statistically non-significant difference between the three groups (Group A: $F(3,84,) = 1.121$, $p = .345$, Group B: $F(3,72) = 0.241$, $p = 0.867$, Group C: $F(3,68) = 1.282$, $p = .228$). A similar finding is observed for the final exams over the same period. Fig. 8 shows the exams' averages over the 5 years staying above 70%.

Correlations analyses were also done to look at associations between the final exams and the final FCIs which showed a statistically significant correlation ($r = .54$, $p = .011$) indicative of the robustness of the test and methodology.

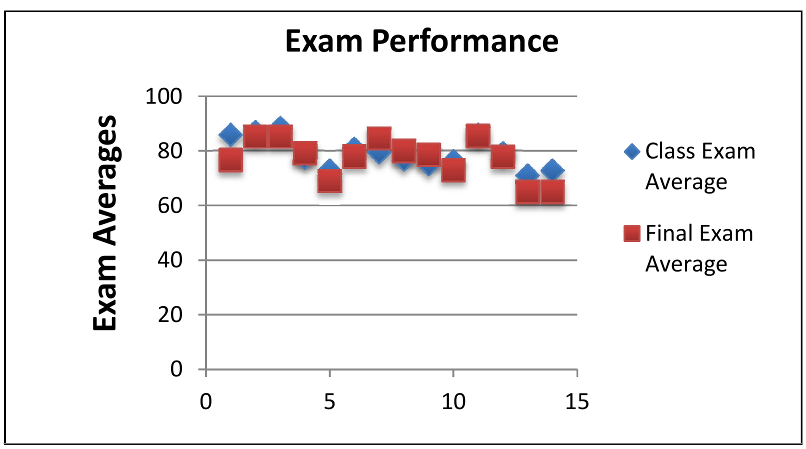

Fig. 8. Students' exam performance in introductory Physics for three quarters over a 5 years period (on the x-axis are represented the years in quarters)

The next step involved assessing how the gap between weaker and stronger students evolved as the PST method was implemented. Fig. 9 shows the gap closing between the weaker students in the class compared with the strongest as we implemented the PST method. Results showed a significant difference between FCI scores before and after instruction with students' performance showing improvement after instruction r = .460, p = .005, FCI 1 (M = 10, SD = 4.5) and FCI2 (M = 15.35, SD = 6.72).

As indicated earlier, the class average was always near 70% which is shown by all exams final grades in a given quarter (Fig. 10), ranging between 34-25 percentage points.

3.1.2 The survey

Table 1 shows a comparison between students' two modes of evaluation responses (online free voluntary comments and survey) showing their experience with the characteristics of the four PST concepts of teaching, after a semester of implementation of it in physics classes. The data is in percent of comments per class fitting under these 4 pillars.

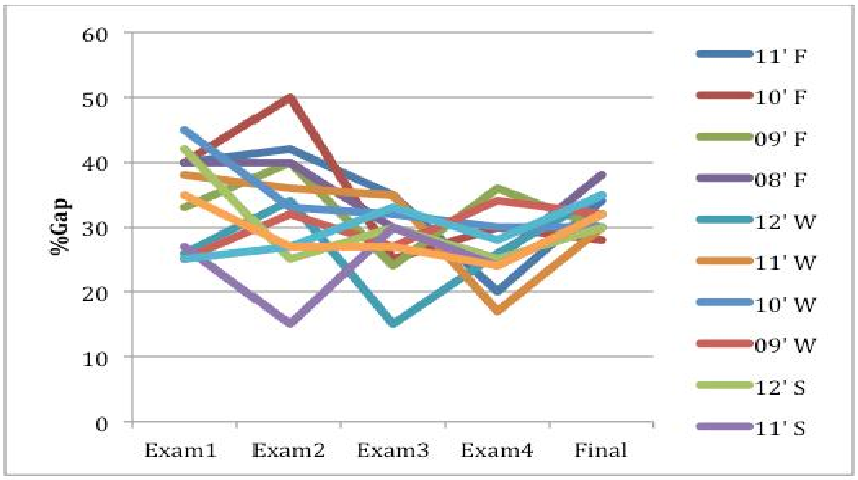

Fig. 9. Average percentage gap between the weakest and strongest students in the class
S= Spring, W=Winter and F=Fall

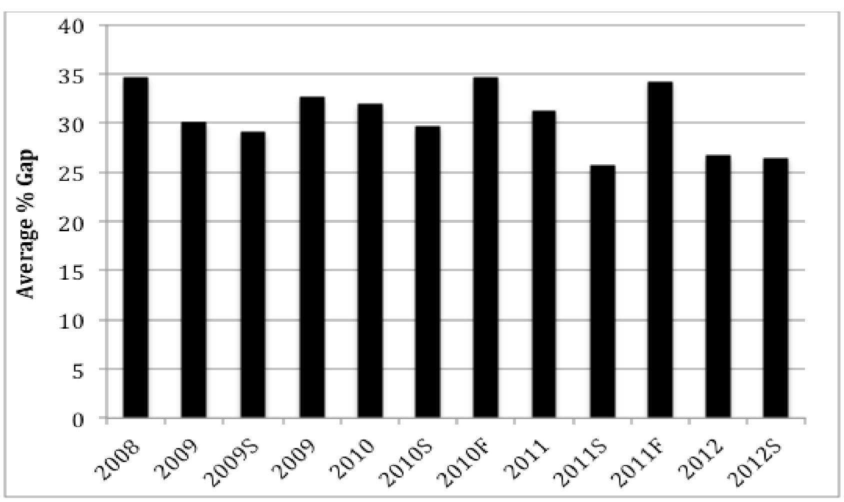

Fig. 10. Exam percentage gap average for all exams in a given quarter including final exam

Table 1. Comparison of students' evaluation reviews

PST concepts	Open-ended comments	Survey responses
Comfortability	71%	93%
Connectivity	75%	91%
Organization and preparedness	48%	74%
Critical thinking	40%	79%

% = percent of comments per class corresponding to the 4 pillars of PST

The results indicate that what students considered the most important and which fostered their sense of success was similar between what they were asked to evaluate and their authentic experience. Simple frequencies on the amount of time students mentioned positive comments about the homework given showed that 78% of students reported that homework and tests were effective in their preparation and that all tests and assignments given reflected the lectures. Also, more than 90% of students reported that one-on-one interactions with the instructor helped their success in the class, and finally, a similar percentage agreed that peer-to-peer work was very effective in their understanding of the subject matter.

The findings reported in this section show that using FCI as a marker for progress allows practitioners to track progress and are valid tools to assess knowledge at any point during instruction. It demonstrates that implementing the PST method was indeed a driver for both better performance and performance gap shrinking. Finally, the survey data shows that students appreciated the instruction style and benefitted from its philosophy.

3.2 Discussion

The Pseudo-Socratic Method combines Socratic teaching centered on student-friendly question asking training, Didactive teaching, Inquiry Based Learning, and distinct teaching strategies including grouping, testing, homework strategies, and specific practitioner's attitudes toward students. It shows how to create an interactive atmosphere conducive to learning, and improve students' participation and performance in the classroom. The goal of this paper was to describe current educational challenges, and give an example of an educational system that worked (the "Finnish way") inactively reducing performance gaps (the smallest in the world). We compared it to existing known teaching trends and showed how PST can fit in the world of education and contribute to students' success. The argumentation revolved as well around the idea that more teaching training is needed for professors and teachers in credential programs and graduate school to be better prepared to manage classes successfully.

We then provided a thorough description of what each tenet of the method looks like and how to implement PST in educational settings. Analyses of the grades performance and gaps demonstrated that students, after receiving PST teaching, had maintained a good average, and that gaps between weakest and strongest students had reduced. A survey of the students revealed that they were satisfied with the classes and had positively benefitted from the effects of the 4 pillars of PST (Comfortability, Connectivity, Preparedness & Critical Thinking), which made their learning of the material more interesting and efficient. The consistency of the results between exams and FCI did show the validity of the FCI as a test of pre and post knowledge and grouping strategy. Pre-FCI tests results showed more variance of scores than post-FCI tests, which shows that after a thorough PST work in the classroom, the classroom averages, wherever students started, tends to diminish and cluster above 70% (Fig. 8). FCI in PST allows to assess performances, prepare groups that will help each student to grow, and track progress to flexibly structure methodology and address the needs of the class.

The classes observed were ethnically diverse which seems to indicate that PST would work well to close the gap in spite of the social disparity, which Milner [14] showed to be one of the primary reasons for the students' achievement gaps. Although we did not do a gap study comparing gaps between the PST approach and those from alternative approaches, we found it interesting that the average gap between students decreased consistently over the five periods as the PST was implemented. This was expected since Magnussen [95] demonstrated that IBL approaches dramatically increases the performance of weaker students.

Some caveats will warrant further study to replicate our PST method's results such as the fact that the created groups did not account for the influence of ethnicity or race on students' performance, nor did we specifically investigate the impact this grouping strategy had on reducing the performance gap in the class. Further, though the preliminary data indicates that PST works well in the classroom to increase student performance and decrease gaps, more research on diverse and larger data sets from diverse populations and programs are needed to confirm the trend.

4. CONCLUSION

The purpose of this essay was to formulate the basis for a blended teaching approach by shifting the teaching landscape. We intended to open the conversation on the fact that constant new trendy methods may not be necessary for better learning. Some existing methods can be united, adapted, and shifted to offer optimal learning environments and make more informed and efficient instructors. The failure of our educational system in providing the same quality of education for all can be attributed, in part, to negligence in training teachers, especially in higher education, in ways that would allow them to: adapt easily to their classes, be flexible with their agenda, engage in discussions and questions, use technology, be approachable and use constructive teaching strategies. As educators and researchers propose interventions and solutions to educational challenges we must also acknowledge that achievement gaps may be linked to many social causal factors. Now when the focus is on test taking as a solution, too much emphasis is placed on remedying achievement gaps through standardization. This has negatively impacted creativity and gave place to unhealthy trends such as grade inflation and loss of important courses within curricula to give more space to national test taking-focused classes. In reality, it may be that reducing other systematic and structural gaps existing in education would improve achievement without resulting in such drastic measures [6].

PST is designed to enhance students' motivation by combining several methodologies and intentionally test students' knowledge using methods that do not demoralize them as previous curve structures have done. We have demonstrated that testing, within this framework, becomes a pedagogical tool with which students learn by doing. PST is a construct that focuses primarily on the practitioners' educational and personal ability to connect and have a constructive relationship with students. This relationship may mitigates the disparity in the achievement gap in ethnically diverse community. The success of the practitioners is due to a high ability to deliver content, through the use various pedagogies while having high expectations for their students' success. PST requires practitioners to be well trained in pedagogies development and implementation. Although content knowledge is an essential educator's quality [106], teachers who also possess strong pedagogical content knowledge are more effective than those with content knowledge alone [107]. Thus PST's focus is to train practitioners in various pedagogical methodologies (having both content knowledge and knowledge of how to teach their subject areas), and have the know-how to work in diverse communities with a strong belief in students' success.

The major difference in this approach is that it gives emphasis to the practitioner's role in reducing the divide between the weakest and the strongest students in the class, and between themselves and the overall class by finding ways to connect with the learners. The practitioner must create an environment that is comfortable, safe, and engaging to the learner and then bring various methodologies and technologies through the Socratic framework to inspire and motivate students to formulate questions and be stimulated to learn. Experiencing with a combined form of known educational pedagogies gave birth to a model that has been tested and proven efficient.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX A

This lecture was developed for 120 minutes and must be modify t for a 50minutes class session.

This section shows Socratic/Inquiry Based teaching evolving into a didactive process.

Objectives

Understand how Newton's first law works in every situation
Write Newton's 2nd law using appropriate units for mass, force, and acceleration
Apply Newton's 2nd law to problems involving a body in constant acceleration.!

Demonstration: PHET demo cart pushed with friction and another without friction.!

Newton's 1st Law ~ *Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.*

Q *= instructor's question;* ***A*** *= students' answers;* ***S*** *= Statement*

Q*: What was different in these two scenarios?*
A*: The cart with friction stopped after it was pushed but the cart without friction, never stopped.*
S*: Sometimes this law is called the Law of inertia, the tendency to resist motion. In the demo, friction and applied force are external forces. In both situations the blocks sat until a force was applied. Once moving, it would continue until an external force was applied.*
Q*: Can you provide examples of Newton's 1st Law?*
A*: A book on a table will not move without an outside force; A car going in a curve would continue to go in a straight line if there was not an external force applied to follow the curve's path.*

CLICKERS
A book is lying at rest on a table. The book will remain there at rest because:
a) there is a net force but the book has too much inertia
b) there are no forces acting on it at all
c) it does move, but too slowly to be seen
d) there is no net force on the book
e) there is a net force, but the book is too heavy to move

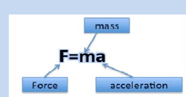
Demonstration: Applying a force to an empty cart.

Q: *What is the result of the applied force?*
A: The *cart will move with a certain speed.*
Q: *What will happen now if we apply about the same force to a cart filled with stuff?*
A: *It won't move, or it would move but at a slower speed.*

Demonstration: The cart is pushed.

Q: *What did you observe, and what can be concluded about both situations?*
A: *The cart moved slower in the second situation because it had more mass.*
The greater the mass, the slower the speed under the same force.
Q: *From the fact that the cart travelled slower, what can you say about the motion?*
A: *Change in motion is smaller in the second situation*
Q: *What does this mean?*
A: *It means that the second cart had a smaller acceleration.*
Q: *Is there a relation then between the mass of the cart and acceleration?*
A: mass is inversely proportional to acceleration.
Q: *Observe when I applied a force to the cart that it went from rest to some velocity.*
What can we conclude about force and motion?
A: *Force causes motion.*

Concept: An object under force will experience acceleration, or to create a force an object must accelerate. Newton's 2nd law posits that the acceleration of an object is directly proportional to the net force acting on it, and it is represented as follows: !∑! =ma. Units for force: !! (! ")! (! /! !) = ! (!)



Solving problems

Engineers at the Johnson Space Center must determine the net force needed for a rocket to achieve an acceleration of 70 m/s². If the mass of the rocket is 45,000 kg, how much net force must the rocket develop?

Solution

F = ?
M = 45,000 kg
A = 70 m/s²

$$F = ma = 45{,}000\text{ kg} * 70\,\frac{\text{m}}{s^2} = 3.15\times10^6 N$$

A hockey player accelerates a puck (m = 0.167 kg) from rest to a velocity of 50 m/s in 0.0121 sec. Determine the acceleration of the puck and the force applied by the hockey stick to the puck. Neglect resistance forces.

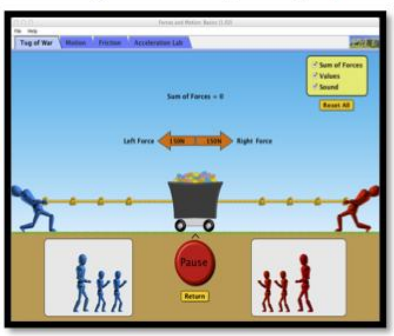
Solution
The force acting on the puck is constant which means that acceleration is also constant. Apply kinematics rules learned in previous chapters to find acceleration and use Newton's Law to find force. Please carry this out at home.

CLICKERS
An object is accelerating at a constant rate in a certain direction. What can be said about the force(s) (if any) acting on it?

a) The forces (if any) that act on the object add up to zero.
b) The force(s) that act on the object add up to a (non-zero) net force.
c) (Nothing can be determined about the forces acting on the object.)
d) (I'm lost, and don't know how to answer this.)

Net Force

Demonstration: Using the PHET tug-a-war program to understand net force.

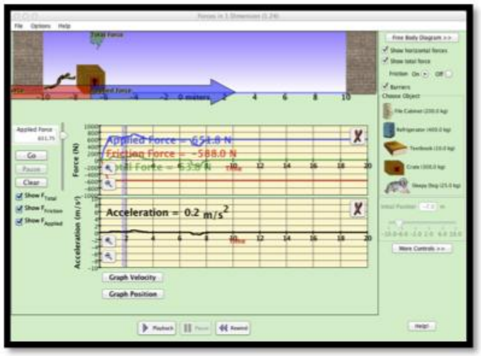


Q: *What did you observe when the red and blue ma\en pulled on the cart with the same force?*
A: *The cart did not move.*
Q: *Why so?*
A: *The forces in this are equal and opposite.*
S: *This is correct: the sum of the forces add to zero.*
Q: *What will happen when I add an extra red who will pull with half the force?*
A: *The cart will move to the right.*
Q: *Why do you think this occurred?*
A: *The forces are equal and opposite and the sum of the forces on the right is greater than that on left.*
S: *This is correct, as you saw the total for the man to the right is 200N and to left is 150N*

$$200N - 150\,N = 50N$$

Concept: As Newton's 2nd law tells us, an object under a force will experience acceleration, or to create a force an object must accelerate. It is represented as follows: $\sum F = ma$; Further $\sum F = 0$ when the men pull with equal and opposite forces such that the cart did not move. We can say that the cart is in static equilibrium.

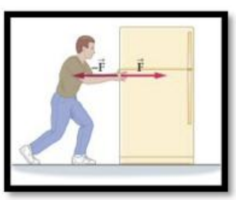
Demonstration: PHET demo of man pushing a crate.



Q: *As the men push on the crate how many forces do you observe in the horizontal and what are they?*
A: *Two forces. One is the applied and the other is friction.*
S: *Correct. The force acts in the* ***opposite*** *direction to motion. If a car needs to stop at a stop sign, it slows down because of the friction between the brakes and the wheels.*
Q: *What did you observe as the applied force increases?*
A: *The frictional force gets increasingly bigger until the crate is moving, then decreases.*
S: *Correct. This happens because the applied force must overcome the opposing force, which we will refer to as static* ***friction****. Once we get an object going, by Newton's 1st law it will continue to move. If there were no opposing forces, there would be no need for a force to keep it going. Therefore, once friction is overcome, opposing forces fall which makes the crate accelerate according to Newton 2nd Law. This frictional force is referred to as* ***kinetic friction****.*
Q: *Predict what will happen as I let the get object going and apply a force that is equal to the opposing force.*
A: *It will stop!!! It will continue to move but at a constant speed.*
S: *Observe that it continues move with constant velocity. This means that the net force is zero and as such the object is not accelerating. This is referred to as* ***dynamic equilibrium.***
S: *This graph shows the acceleration and net force is zero while applied and opposing force is equal and oppose.*

CLICKERS
Suppose you give a 10 Newton push to Nicki on skis (she weighs half as much as Ryan), how much will she accelerate?
a) half as much as Ryan; b) the same as Ryan; c) twice as much as Ryan; d) infinite

Visual Demo: A man pushing very large box.



Q: *Is the man experiencing a force from the box?*
A: *Yes the picture show there is a force pushing back on him.*

Concept: To every action there is an equal and opposite reaction.

Concept taught: Newton's 3rd Law

Example Problems used to reinforce this concept:

Suppose that the magnitude of the force is F = 36 N. If the mass of the spacecraft is 5,000 kg and the mass of the astronaut is 92 kg, what are the accelerations?

Solution

Force on the spacecraft $\sum \vec{F} = \vec{F}$=36N

Force on the astronaut $\sum \vec{F} = -\vec{F} = -36$

By Newton second law $\sum \vec{F} = m\vec{a}$ then we have

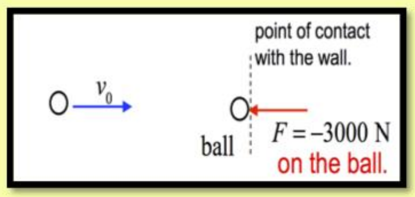
$a_s = \frac{F}{m} = \frac{36N}{5000kg} = 0.0072m/s^2; a_A = \frac{-F}{m} = \frac{-36N}{72kg} = 0.5m/s^2$

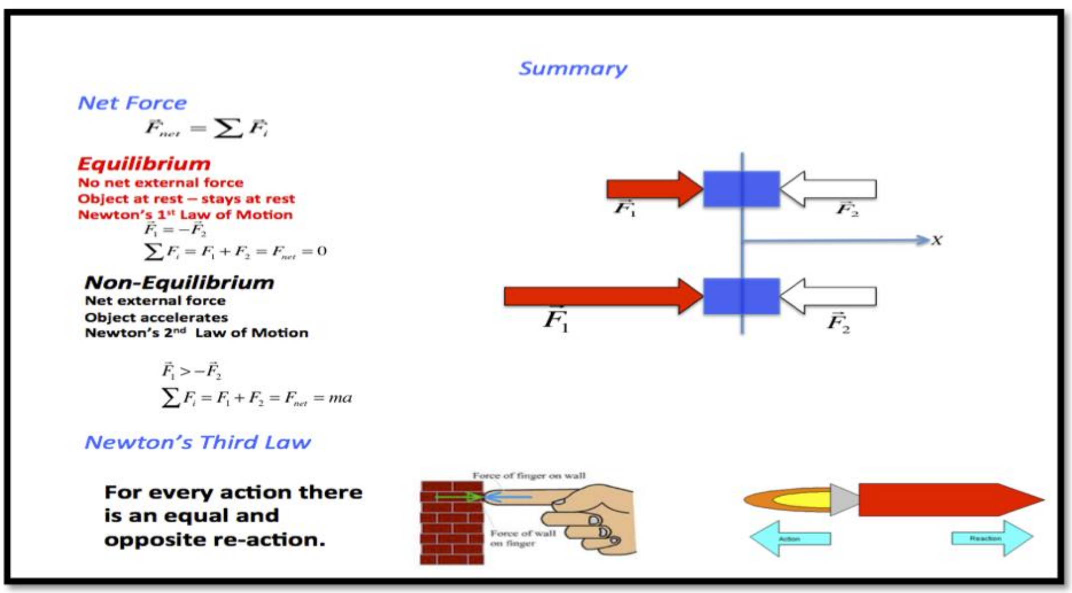
***S:** These two forces do not have a Net Force = 0. +**F** acts on the spacecraft, –**F** acts on the astronaut. To use the Net force and Newton's 2nd law, all the forces being summed must act on the same object.*

CLICKERS

A ball heads horizontally toward a wall. While in contact with the wall, the wall applies a force, *F* = −3000 N on the ball, as shown. At the same time, the ball must apply what force on the wall?

a) *F*=−3000N
b) *F*=+3000N
c) *F*=0N
d) *F*=60N
e) A ball cannot make a force.





Appendix B

Example Test Questions

Multiple Choice Question Types

____ A rectangular wooden board has the dimensions 132 cm × 36.5 cm × 7.2 cm. Its volume expressed correctly is [3]

A. 34690 cm^3
B. 0.346×10^8 cm^3
C. 34.6×10^2 cm
D. 3.5×10^4 cm^3
E. none of the above

____ Two friends, Tim and Tina, throw two balls from the top of a high tower at exactly the same moment. Tim drops the ball vertically downward, while Tina throws her ball horizontally at 6.0 m/s. Which ball reaches the ground first?[3]

A. Both reach at the same time
B. Tim's ball reaches first
C. Tina's ball reaches first
D. Cannot be determined

____ A small airplane, starting from rest, takes 30 seconds to reach its takeoff speed of 60 m/s. Its average acceleration is:[3]

A. 9.81 m/s^2
B. 2 m/s^2
C. 4 m/s^2
D. 1 m/s^2
E. none of the above

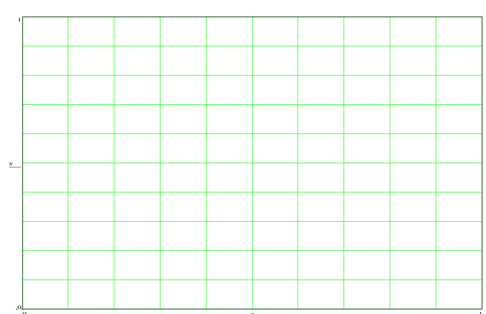
Short Answer Question Type

In the grid provided to the right, show how to add the following vectors (**A, B, C**) using the tail-to-tip method. Obtain the resultant **R** in component form, and also give the magnitude and angle of the resultant. [10pts]

A = (4, 3)
B = (-2, 3)
C = (6 @ 60° N of E)
$\mathbf{R}_x$= __________ $\mathbf{R}_y$ = _____________

Magnitude of **R** = ________________

Angle of **R** from+*x*-axis= ______________



Example of Long Answer Question.

Superman is jogging alongside the railroad tracks on the outskirts of Metropolis at 80 km/h. He overtakes the caboose of a 300-m-long freight train traveling at 50 km/h. At that moment he begins to accelerate at +12 m/s^2. [15]

a. How long does Superman take to pass the train?
b. How far will the train have traveled before Superman passes the locomotive?
c. What distance does Superman travel in this time?

APPENDIX C

Excerpt example of Survey and Open-ended response from students' professor and class evaluation.

2.1) This instructor was effective overall.

2.2) The instructor's explanations were clear.

2.3) In this class, I was treated with respect.

2.4) Materials used in this course (text, readings, notes, websites, etc.) were useful.

2.5) Assigned work was valuable to my learning.

2.6) This class was well organized.

2.7) I knew what was expected of me in this class.

2.8) The instructor was well prepared for class.

2.9) There was sufficient time in class for questions and discussion.

2.10) The instructor displayed enthusiasm for the subject matter.

2.11) Methods of evaluation in this course were fair.

2.12) Feedback on my work was valuable to my learning.

2.13) The instructor was available for consultation outside class.

2.14) I learned a great deal in this course.

Based on our 4 principles we counted the number of comments made per students in their responses: Connectivity in yellow (one-on-one contact, availability, authenticity, nurturance), Comfortability in pink (Professors' openness, humor, and personality, ease of communication in the classroom), Preparedness and organization in blue (flexibility, lecture format, method, pre-class background preparation), and Critical thinking in green (students feeling invited and shown how to ask, ponder, think and grapple with problems).

Example of free responses from which we also extracted terms relating to our 4 principles.

3.1) What do you like most about the course and instructor?

- -extra office hours
  -really opened up to students
  -never late to class
  -cared about students

- Concepts are well covered and the instructor is available outside of class. The tests are a good length so far and questions in class are usually answered.

- I liked how our professor actually taught us how to think about the question, and understand the concepts that are involved. I also liked how he wanted up to learn on our own to gain an understanding and then go and apply it or ask him for help. I also liked how he told us

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1172&id=21&aid=9349