Influence of the epistemological beliefs on student success in basic Physics courses: An international comparison

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Abstract

The purpose of this study was to determine if the students' epistemological beliefs is a significant predictor for their final physics grades in introductory physics courses and to compare the epistemological beliefs of the students from two different institutions, Woodbury University, USA and SKR College for women, Andhra University, India. The study involved the analysis of students' course work for final grades, and pre and post interviews to elicit their epistemological beliefs on the structure of scientific knowledge, nature of knowing and learning, real-life applicability, evolving knowledge, and source of ability to learn. Statistical analysis indicated that there was strong correlation between the epistemological beliefs and the final physics grades. The regression analysis suggested an equation with epistemological beliefs as a predictor variable for the final physics grades. All the components of the epistemological beliefs evenly contributed to the final physics grades and the components evenly improved during the courses. The comparison between the students of SKR College, India and Woodbury University, USA suggests that the dependence of the final physics grades on the epistemological beliefs may not be influenced by the cultures. Independent samples t-test between epistemological belief scores of Woodbury University and SKR College students at the beginning and at the end of the course work indicated that Woodbury students had significantly higher epistemological beliefs. Paired samples t-test indicated that epistemological beliefs improved by the end of the course at both the institutions.

Keywords: Epistemological Beliefs, Influence of epistemological beliefs on grades, International comparision of epistemological beliefs.

Resumen

El propósito de este studio fue determinar si las creencias epistemológicas de los estudiantes es un factor predictivo importante para sus calificaciones finales de Física en los cursos introductorios de Física y para comparar las creencias epistemológicas de los estudiantes de dos instituciones diferentes, Universidad Woodbury, EE.UU y el Colegio para mujeres SKR, Universidad de Andhra, India. El estudio incluyó el análisis del trabajo de curso de los alumnos de los grados finales, y las pre y post entrevistas para conocer sus creencias epistemológicas sobre la estructura del conocimiento científico, la naturaleza del conocimiento y el aprendizaje, la aplicabilidad en la vida-real, el conocimieto en evolución y el origen de la capacidad para aprender. El análisis estadístico indicó que no había correlación entre las creencias epistemológicas y las calificaciones finales de Física. El análisis de regresión sugiere una ecuación con creencias epistemológicas como una variable de predicción para lo grados finales de Física. Todos los componentes de las creencias epistemológicas contribuyeron uniformemente a los grados finales de Física y los componentes cada uno mejorados durante los cursos. La comparación entre los estudiantes del Colegio SKR de la India y los de la Universidad Woodbury de EE.UU sugieren que la dependencia de las calificaciones finales de Física en las creencias epistemológicas no pueden ser influienciadas por las culturas. Muestras independientes t-test entre las puntuaciones de las creencias epistemológicas de la Universidad de Woodbury y los estudiantes del Colegio SKR en el inicio y al final del trabajo de curso indicaron que los estudiantes de Woodbury fueron significativamente más altos en las creencias epistomológicas. Muestras pareadas t-test indicaron que las creencias epistemológicas mejoraron al final del curso en las instituciones

Palabras clave: Creencias epistemológicas, Influencia de las creencias epistemológicas enlas calificaciones, Comparación internacional de las creencias epistemológicas.

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I. INTRODUCTION

Without going into the detailed philosophical meanings of justification, truth, beliefs, internal knowledge and external knowledge, Stanford Encyclopedia of Philosophy[1] describes *Knowledge* as justified true beliefs, and *Epistemology* as the study of knowledge and justified beliefs that are concerned with the nature of knowing and learning, structure, limitations, source and evolution of knowledge. Epistemological beliefs of individual students are called personal epistemologies. Obviously, the personal epistemologies are important for the instructors and for students. Instructors can design better instructional strategies to promote appropriate student learning based on the personal epistemologies. Understanding their own epistemologies helps students choose better learning strategies and perform better in the courses.

In general students' personal epistemologies influence their motivationto learn [2], affect choosing better learning strategies [3], impact learning outcomes [4], influence ability to integrate their understanding of concepts [5], and may affect the way they evaluate their learning [6, 7]. Discipline specific -epistemology shapes from more general epistemology discussed in papers like Hofer and Pintrich; Stodolsky, *et al*. [2]. Hofer and Pintrich's work also presented a review on women's way of knowing [2].

There is some research done on the correlations with the epistemological beliefs in specific disciplines. Specific clusters of epistemological beliefs correlate with grade point average [4] and with mathematical text comprehension [3].

In Physical sciences, certain epistemological beliefs correlate with integrated conceptual understanding in middle school [8]. In an introductory college biology course, Edmondson finds correlations between students' reported learning strategies and their epistemologies [9].

There is also a study on how immature beliefs affect students' ability to integrate their understanding of science concepts [10].

Andy diSessa's [11] "Toward an Epistemology of Physics" is profound work that introduces epistemological and ontological views in physics. Physics naïve people have naïve sense of mechanism or naïve physics knowledge or intuitive physics, which is formed due to the interchange with the real world. The naïve physics knowledge is not fully supported by the facts and truths and is often less coherent, less systematic, and less integrated. The physics experts' sense of mechanism or experts' knowledge is integrated, coherent and contain facts based truths. The epistemological claim is that this naive sense of mechanism through reorganization of its naïve knowledge elements evolves into expert scientific knowledge. The naïve knowledge elements are phenomenological in nature and hence called phenomenological primitives in short p-prims. P-prims themselves are behavioral or necessarily containbehavior, which serve an important role in explaining physical phenomena and are self-explanatory. If something happens, it happens "because that is the way things are". P-prims are intuitive equivalent of physical laws and explain other phenomena but they themselves are not explained within the knowledge system. P-prims are activated for cues and in turn these activated p-prims help activate other context-relevant knowledge elements called "active knowledge structure or active schema or network". P-prims are the nodes in the schema. Properties of p-prims and the naïve knowledge system change toward the scientific knowledge system. Initially, a rather large and relatively unstructured collection of p-prims exists in the naïve knowledge system. This large collection gets tuned toward expertise knowledge systems by enhancing or reducing the priority of some p-prims, changing the contexts of activation, and expanding or contracting, and assigning new roles in the developing physics knowledge system. The p-prims then can no longer be self-explanatory but for justification defer to much more complex knowledge structure, such as physics laws, which is the objective of the learning. This change in the function of p-prims from relatively isolated and self-explanatory entities to pieces of a complex knowledge system that has depth, breadth and integration is a substantial structural change in the naive or intuitive physics knowledge system. diSessa's ontological claim is that the physics naïve people either do not have "motion" as a basic category of thought or they have it placed in the wrong category of thoughts. Learning of this category must happen by acquisition of a new ontology or a major shift of category from ontology to another.

diSessa's naïve sense of mechanism explains students' knowledge (knowledge in pieces) and reasoning at coarse grain level, and accounts well for the patterns in the students' reasoning. These patterns are attributes of stable properties. Students often change their reasoning and ideas from moment-to-moment in a short time scale-they give one kind of reasoning invoking a naïve knowledge system containing certain kind of p-prims, in another moment they change the reasoning [12]. It is highly unlikely that students' knowledge structure progresses toward an expert knowledge structure within such a short time. This variability in reasoning and the use of multiple ideas on a short time scale, which is a dynamic property, is inexplicable using diSessa's framework. Hammer and Elby [12, 13, 14] explain by considering 'elements of cognitive function' as *resources or epistemological resources,* which are neutral, multi fold, diverse, and context sensitive in their activation. The *resources* are not declarative statements like *force cause motion* p-prim in diSessa's framework. The idea of "*resources*" leads to many fold knowledge system and *resources* are the elements the system.

The sources of these knowledge elements are agents such as teachers (knowledge as propagated stuff), self-constructed (knowledge as fabricated), self-creation (Knowledge as free creation), self-perceived (direct perception), retrieved from memory, and many more.

Physics education researchers have been looking at the impact of students' attitudes of learning physics, expectations, and influence of epistemological beliefs on their learning [15, 16, 17, 18, 19, 20]. David Hammer reports that some students see physics knowledge as weakly connected pieces to be learned separately and others see it as a highly coherent knowledge to be learned together [15]. Elby and Lising in a case study showed that students' epistemologcal beliefs about physics knowledge and learning physics could have a direct and causal influence on their learning and causal relation on their grades in physics courses. They suggest that explicitly attending students' epistemologies is important in teaching physics. Instructors and curriculum developers should make suitable changes to include students' epistemologies [16]. In an introductory college physics course, May and Etkina found from students' weekly written reflections, that students with high conceptual gains tend to show better articulated reflections on learning and sophisticated epistemologies than students with lower conceptual gains [19]. David Hammer studied how students' epistemological beliefs impact how they solve physics homework problems [15]. Dinal-Taganahanexplored the relationship between epistemological beliefs and conceptual understanding of force and motion in an introductory college physics course.She found that students with more mature epistemological beliefs achieved greater conceptual understanding on force and motion, and students in the active learning instruction class developed matured epistemological beliefs than the students in traditional instruction class [20].

Stathopoulou and Vosniadou [21] looked at the relationship between secondary school students' physics-related epistemological beliefs and physics conceptual understanding.

Regression analysis showed that beliefs about the Construction and Stability of physics knowledge and the Structure of physics knowledge were good predictors of physics understanding. They suggested that sophisticated physics-related epistemological beliefs are essential but not sufficient for physics understanding. Kortemeyer [22] reported correlations between the MPEX and measures of student learning (final exam, FCI, and course grade). Correlations between the score on the coherence cluster and the course grade percentage was r=0.36. Using correlation methods, Sahin found significant correlations of students' physics grades with expectations, attitudes, and epistemological beliefs. Stepwise linear regression revealed that only the effort cluster of MPEX was a significant predictor of physics grades [23].

In this paper, we examine and compare the epistemological beliefs of physics students of two institutions from two different countries USA and India. We investigate if the epistemological beliefs are predictors for the physics grades of students at each institution and both the institutions together. The students from these two institutions have different cultures and backgrounds. We also investigate if the physics grades depend more on one component of epistemological beliefs than any other component. We discussed in Section II, the data collection procedures, subjects' selection, and grading procedures; in Section III, the analysis of the data and discussion; and in Section IV, our conclusions.

II. DATA COLLECTION AND SELECTION OF THE SUBJECTS:

The details of data collection procedures and selection of the subjects at Woodbury University (Location 1) and at SKR College (Location 2) are presented in this section.

A. At Locations 1 (Woodbury) and 2 (SKR College):

Students at both the locations were pre-interviewed during the first week of the course and the post-interviewed after instruction before the final examinations. In the interviews, we asked the students at both the locations in pre and post interviews the same basic questions to elicit their personal epistemologies on the structure of the knowledge (axis 1), nature of learning (axis 2), real-life applicability (axis 3), evolution of the knowledge (axis 4), and their beliefs about the sources of ability to learn (axis 5.The basic questions and correct responses to those questions are presented in Appendix A. As our goal was to learn about the students' personal epistemologies, even though the basic questions were the same, the subsequent questions mostly depended on the individual responses. Depending on the epistemological content in the responses, duration of the interviews lasted from fifteen to sixty minutes and the final interviews took longer time than the initial interviews. We also asked students to give explicit examples to support their statements about their personal epistemologies, and to explain simple demos using their beliefs.

The interviews were audio taped, transcribed using hyper transcribe and the transcribed utterances were analyzed using hyper research. The responses were graded by two graders on each axis on 0-5 scale and later rescaled to 0-100.

Two graders independently graded interviews, discussed the discrepancies and took the average grade for each student.A detailed description of thecoding, scale used for grading, some typical examples of student utterencess with thescores are presented in Appendix B.In addition to the interview-data, we also looked for evidence in the student's submitted course worksuch as test papers, homework, projects, takehomes, etc.

The total epistemological scores were the average of the individual scores on each axis. The pre-interview grades are pre epistemological scores, represented as pre-scrs and post-interview grades are post epistemological scores, represented as post-scrs. The instructor at each location awarded the final course grades.

B. Location 1:

Bachelor of Architecture students take two series of college algebra and trigonometry based introductory physics courses. Most of the students did not take physics previously but some took science courses in high school. The students' ages ranged from 18-25. In fall 2008, thirty seven students enrolled in two sections but thirty students attended pre- and post - interviews, regularly attended classes, and submitted portfolios.

Method of Evaluation: The final course grade of a student was calculated based on a 0-100 scale from the student's portfolio and student-instructor interviews. The student-instructor interviews were conducted during the exam week after the final physics exam, which was a part of post-interviews. The portfolio included graded quizzes; in class work on simulations; three tests; homework assignments; laboratory experiments; self-reflections and grand reflections. Every week as a part of the homework, each student wrote his/her understanding on the concepts learned in that week and the connections of those concepts with the previously learned concepts. At the end of the course, each student wrote grand reflections to present the overall understanding of the concepts, principles, and relations among the concepts with application to daily life examples. The assessed activities include observing or visualizing the patterns in phenomena, recognizing the observed patterns with physical quantities, recording observations and explaining those observations, drawing the concept maps for events and explaining the connections, and learning problem solving skills.

C. Location 2:

The first year BSc physics course was taught for about 35 weeks and forty five students enrolled in the course. All the students took physics in high school (three years) and in intermediate (two years).The students' ages ranged from 18-25. Thirty-five students joined the course before the Pre interviews were conducted. Ten students joined after conducting the Pre interviews. These students were not included in the study. Five students out of thirty-five who were interviewed earlier left the institution as they obtained admission in professional courses. We were left with 30 students who attended both Pre & Post interviews.

At location 2 the interviews were conducted in the local language Telugu and hence the original transcriptions were in the same language. Then the transcribed utterances were translated into English.The english-translated version reflects almost the same meaning as the original version but the exact translation was not posible. A few scanned original Telugu transcriptions are also presented in Appendix B.

Method of Evaluation: Methods used at Location 2 were similar to that of at Location 1. The final course grade for a student was calculated on a 0-100 scale from the grades on experimental skills, which was from in class work, performance in theinterviews (called Viva Voce at Location 2) pertaining to the application of principles to the experiment, monthly exams, and final exams. Students were also assessed on deriving formulae, in addition to assessing on describing concepts and principles, and on problem solving skills. The final course grades were represented as course grades on the scale a 0-100. For proper organisation, retrieval and interpretation the data was coded. The *a priori* coding of the data done is described in detail in Appendix B.

III. ANALYSIS OF THE DATA AND DISCUSSION

The original data were collected through the interviews. The interview data was converted into scores on 0-5 scale using the basic rubrics described by EBAPS and also required the students give their own examples to support their epistemological statements, and required them to explain demos in the interviews using their personal understanding.

In the following paragraphs, we present the analysis of the data using statistical methods to appraise the influence of the epistemological beliefs on the physics grades.

A scattered plot from the original data for final physics grades versus post epistemological scores, is shown in Fig. 1a. Two outliers were identified at the bottom right quadrant of the graph from both locations, one was from Location 1 (represented by red oval) and the other one was from Location 2 (represented by blue triangle). The outlier from Location 1 had a low final course grade even though the student had a relatively high epistemological score. Further investigation showed that the student completed only 50% of the final test and did not turn in the portfolio that contained the entire course work. The outlier from Location 2 also had relatively high epistemological score and low course grade. The student did not do well in the examinations and failed to turn in the assignments. In a personal communication with the instructor, the student mentioned that her father was terminally ill and facing financial problems. The school records showed that the student failed in all the other courses as well. As we know the reasons for their poor performance in the course both outliers were removed to get better understanding of the relationship between epistemological beliefs and final course grade. The scattered plot without the outliers is shown in Fig. 1b. After removing the two outliers, we calculated Pearson correlations between the post epistemological scores and the course grade. The correlation value for Location 1 was $r=0.575$, $p<0.001$ and for Location 2 it was $r=0.807$, $p<0.001$. The correlation value for both the locations combined was $r = 0.852$, $p<0.001$. The correlation values infer that there was a moderate to strong positive correlation for individual locations and strong correlation when the data from both locations was combined. The positive correlation reveals that low values of epistemological beliefs are associated with low course grades and high values of epistemological beliefs are associated with high course grades. We can identify in the scatter plot, two clusters, one predominantly with higher values mostly from Woodbury students and another cluster associated with lower values from SKR College.

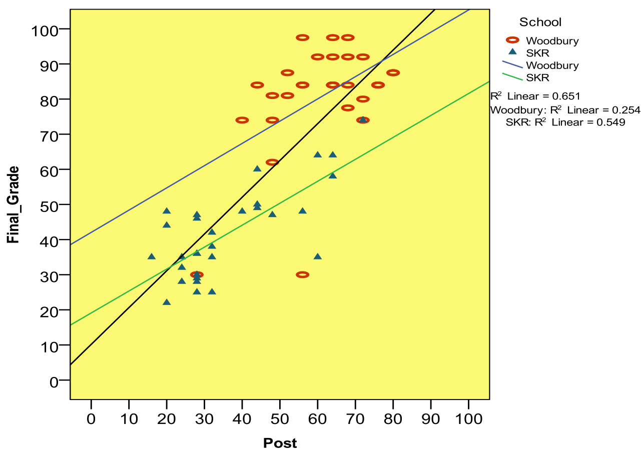

FIGURE 1a. Scatter plot Final Course grades (Final Grade) versus Post epistemological scores (Post).

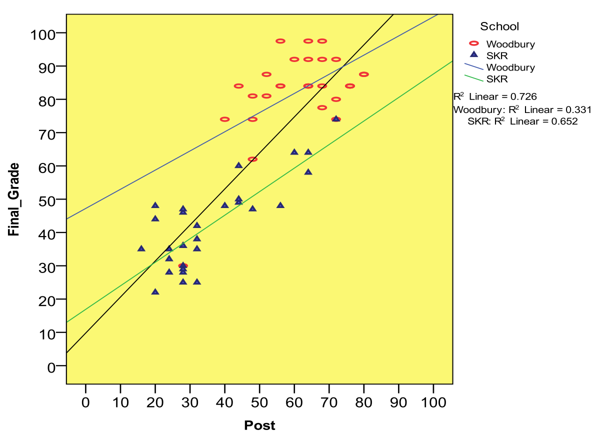

FIGURE 1b. Without outliers at lower-right quadrant.

TABLE I. Pearson correlation coefficients for Location 1, Location 2 and for both the locations combined.

	r	R^2	p-value
Location 1	0.575	0.331	0.001
Location 2	0.808	0.652	<0.001
Combined	0.852	0.726	<0.001

Regression analysis was carried out using SPSS by selecting post epistemological scores as the independent variable (Predictor) and final course grades as the dependent variable for each of the schools as well as both combined.

A summary of simple regression analysis is shown in Table II. Eq. 1 represents the linear regression for the combined data. Eq. 2 represents the linear regression for Location 1 and Eq. 3 for Location 2.

Final Physics Grade =1.082 * Epistemological beliefs score + 9.790 (1)

Final Physics Grade = 0.576 * Epistemological beliefs score + 47.218 (2) (2)

Final Physics Grade = 0.707 * Epistemological beliefs score + 16.911 (3)

TABLE II. Summary of regression analysis for final course grades versus epistemological beliefs.

Variable	B	SE (B)	β	t	Sig (p)	R^2
Epistemological beliefs (Combined data)	1.082	0.089	0.852	12.177	<0.001	0.726
Epistemological beliefs (Location 1)	0.576	0.157	0.575	3.656	0.001	0.331
Epistemological beliefs (Location 2)	0.707	0.099	0.808	7.116	<0.001	0.652

The value of R^2 (t=12.177, Beta=0.852, p-value <0.001) for Eq. 1 (combined) suggests that 72.6% of the variance in the final physics grades can be predicted from the epistemological beliefs. The value of R^2 (t=3.656, Beta=0.575, p-value <0.001) for Eq. 2 (Location 1) indicates that the model explains only 33.1% and the value of R^2 (t=7.116, Beta=0.808, p-value <0.001) for Eq. 3 (Location 2) explains 65.3% of the variance.

Statistical parameters of pre-post epistemological scores and final course grades for both locations are presented in Table III. Significant pre-post epistemological score differences were found for both locations (Location-1 Woodbury Pre-score mean=36.9, SD=12.2; Post-score mean= 61.5, SD=12.7 and Location-2 SKR mean=20.3, SD=11.9; Post-score mean=35.7, SD=15.1). The data indicate that students at Location 1 started with better epistemological beliefs and by the end of the course, they developed better epistemological beliefs than students at Location 2 did.

As the students at Location 1 had better epistemological beliefs than the students at Location 2, students at Location 1 did better in the course grades than students at Location 2. Also, the dispersion is consistent at both locations, since values of standard deviation, range and interquartile range were similar for both locations.

TABLE III. Mean scores (0-100), standard deviation, maximum, minimum, median, range and interquatile range for pre epistemic scores (pre-scrs), post epistemic scores (post-scrs) and Final course grade (Final Grade) for both locations.

	Mean	S. d.	Max	Min	Me dian	Range	Inter quartile Range
Pre-scrs of Location 1 Students	36.9	12.2	60.0	16.0	36.0	44.0	20.0
Post-scrs Location 1 Students	61.5	12.7	80.0	28.0	64	52.0	20.0
Final-Grade of Location 1 Students	82.6	12.7	97.5	30.0	84.0	67.5	9.25
Pre-scrs of Location 2 Students	20.3	11.9	52.0	4.0	16.0	48.0	16.0
Post-scrs Location 2 Students	35.7	15.1	72.0	16.0	28.0	56.0	18.0
Final-Grade of Location2 Students	42.2	13.2	74.0	22.0	42.0	52.0	17.5

A paired samples t-test was performed for each school individually to compare the pre and post epistemological beliefs. There was a significant difference between the pre-post epistemological scores as shown in Table IV, implying that the instruction in both institutions had improved significantly the student's epistemological beliefs ($t= -16.139$, $p<0.001$) for Location 1 and for Location 2 ($t= -13.020$, p-values <0.001).

TABLE IV. Paired samples t-test to compare means of pre-post epistemological beliefs after course work.

	t	Sig. p-value
Pre-Post scrs Location 1	-16.139	<0.001
Pre-Post scrs Location 2	-13.060	<0.001

Independent samples t-test to compare the means of students from Location 1 and from Location 2 for pre-scrs, post-scrs and final course grades, showed that pre epistemological scores, post epistemological scores and the course grades of students from Location 1 students are higher and significantly different from those of Location 2. The scores of the two schools are shown in Table III and the statistical significance, p-values, in Table V.

The pre-epistemological beliefs were already different at the beginning of the course, and continued to be different at the end of the course work. Even though there was improvement in the epistemological beliefs at both locations, the improvement was not enough to bring the post beliefs of both groups of students to the same level.

TABLE V. Independent samples t-test between Location 1 and Location 2.

	t	Sig. p-value
Pre-scrs_Location 2 / Pre-scrs_Location 1	5.269	<0.001
Post-scrs_Location 2 / Post-scrs_Location1	7.033	<0.001
Final grades_Location 2 / Final grades_Location 1	11.867	<0.001

The fact that Location 1 students started the course with already a high level of epistemological beliefs in comparison with their counterparts at Location 2 (mean 36.9 versus 20.3) seems to have contributed to a higher performance in the course. In addition, a much narrower spread in the final course score for Location 1 was observed, resulting in a cluster at the higher values of epistemological beliefs scores and higher course grades. In part this might explain the low correlation between Post-epistemological beliefs and Final physics grades.

We ran an ANOVA to investigate if one axis contributed more to the final grades than any other axis. The output of the ANOVA applied to all axes which is presented in Table VI shows that there is no significant difference between the means of each axis (epistemological components) since the p-value is well above $p>0.05$. Hence, we could accept the null hypothesis –there is no significant difference between the means of pre-post epistemological belief components represented by each axis in both locations. Consequently, all axes have evenly contributed to the performance of the students in the course.

TABLE VI. One-way ANOVA significance test for comparison between components of epistemological beliefs for both the locations.

	Axis	Mean	F	Sig (p-value)
Post-scrs_Location 2	1	36.00	.403	0.806
	2	38.00		
	3	36.67		
	4	33.33		
	5	38.67		
Post-scrs_Location 1	1	62.67	.466	0.761
	2	58.67		
	3	62.00		
	4	60.00		
	5	63.33		

IV. CONCLUSIONS

In this paper, we looked at the epistemological beliefs of students of two culturally different institutions (Location 1 and Location 2) from two different countries (USA and India). Statistical analysis showed that the students at Location 1 started the course with relatively higher epistemological beliefs and their epistemological beliefs by the end of the course were also relatively higher, when compared with those of students at Location 2. As the beliefs were higher the final physics grades of students at Location 1 were also higher. There was a statistically significant improvement in the epistemological beliefs of the students at both the institutions by the end of the courses, indicating that the instruction impacted the epistemological beliefs. Similar instructional methods were used at both the institutions. The main components of the instruction was eliciting prior knowledge by various methods; observing the most common p-prims in the prior knowledge; helping students reorganize the prior knowledge through discussions, reasoning, problem solving, giving plenty of time for reflections, etc., as well as formative assessment for evaluation and correction.

The moderate to strong positive Pearson correlation values for individual locations and both the locations together indicate that the epistemological beliefs have a linear relationship with the physics grades. One-way ANOVA showed that all five components of epistemological beliefs: *about the structure of the knowledge, nature of knowing and learning, application of the knowledge, evolution of the knowledge, and about the source of the ability to learn* evenly influenced the final grades. The regression equations indicate that the physics grades depended upon the epistemological beliefs. The better the epistemological beliefs the better the physics grades. Location 2 students had lower epistemological beliefs and their course grades were also low, and the Location 1 students had higher beliefs and they had higher course grades. In both the cases, the course grades depended on the belief scores. The fact that the course grades depended on the beliefs at two culturally different locations infers that this dependence may be independent of the cultures. Majority of students at Location 1 were Hispanics in USA and the majority of the students at Location 2 were from backward classes in India. These two groups are completely from different cultures but both the groups are first generation college students. This was the first physics course for the majority of the students at Location 1. All the students at Location 2 took physics for a total of five years in high school, and in intermediate (two years) colleges. The students of Location 1 had better initial beliefs than those of students at Location 2, even though the latter students took five years of physics. Possible reasons could be that the students at Location 1 may be from a group of youngsters who had opportunities to reflect upon real world examples. In general, while growing the youngsters in USA have more chances of being exposed to technology such as automobiles, electronic equipment and working with dads or friends in garages. The upbringing in the USA focuses more on problem solving and self-independence; the examination system and learning environment emphasizes more on problem solving than theoretical derivations and definitions.

While the students at Location 2, may be from a group who has hardly had chances to reflect upon the real world examples; the school and college education in this area focuses more on repetition and memorization than on reflecting upon work. The focus of the instruction is to pass the common final examinations that is based on writing definitions and deriving equations. We recommend further investigations at larger level involving more institutions and more countries to see if the grades depend on epistemological beliefs and culturally independent. Furthermore, it will be interesting to see if the teachers' epistemological beliefs and expectations affect students' epistemological beliefs. We are currently in the process of studying the epistemological beliefs and expectations of the teachers from the surrounding Rajahmundry area. The results will be reported elsewhere.

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APPENDIX A

The basic questions we asked the students in the interview and correct responses to the questionsare presented in this appendix.

Axis 1: Structure of physics knowledge. Is physics knowledge a bunch of weakly connected pieces without much structure and consisting mainly of facts and formulae? Or is it a coherent, conceptual, highly-structured, unified whole?

Correct response: Physics knowledge is a coherent, conceptual, highly-structured, unified whole. Formulae have meaning and those are quantitative representation of concepts.

Axis 2: Nature of knowing and learning. Does learning physics consist mainly of absorbing information? Or, does it rely crucially on constructing one's own understanding by working through the material actively, by relating new material to prior experiences, intuitions, and knowledge, and by reflecting upon and monitoring one's understanding?

Correct response: Learning physics relies crucially on constructing one's own understanding by working through the material actively, by relating new material to prior experiences, intuitions, and knowledge, and by reflecting upon and monitoring one's understanding.

Axis 3: Real-life applicability: Are physics knowledge and scientific ways of thinking applicable only in restricted spheres, such as a classroom or laboratory? Or, does physics apply more generally to real life?

Correct response: Physics knowledge and scientific ways of thinking are applicable in real life and not restricted to the classroom or the laboratory.

Axis 4: Evolving knowledge. Is the physics knowledge absolute where the knowledge does not change and it evolves based on mere opinions? Or it evolves as a result of the evidence-based reasoning?

Correct response: Physics is not set in stone. It evolves continuously with evidence based reasoning.

Axis 5: Source of ability to learn. Is being good at physics a matter of fixed natural ability? Or, can most people become better at learning physics if they work hard and use good learning strategies?

Correct response: Being good at physics is not just a matter of fixed natural ability, but most people can become better at learning (and doing) physics by hard work.

APPENDIX B

The codingused, some examples of the excerpts with scores, and copies of some examples of thetranscribed telugu-utterances are presented in this Appendix.

Coding used:
Coding was done according to the following format
X-Yn/As-t [l-m]
Where,
X => Pre interview (PRI) or Post interview (POI)
Yn=> School and student.
As-t=>Axis t-relevant utterances found in Axis s-utterances.
[l-m]=>Location of the relevant utterances in the original transcript, from line number lto line numer m.
And
Instructor comments are presented in the format {*italics*}

Scale for scoring the relevant utterances:
The scoring was done on the 0-5 Likert Scale**.**

5 –Correct response with proper explanation in at least one or more than one examples.

4 –Correct response with ¾ of proper explanation in at least one or more than one examples.

3 –Correct response with ½ of proper explanation in at least one or more than one examples.

2 –Correct response with ¼ of proper explanation in at least one example.

1 –Correct response but no explanation.

0 – Irrelevant (or) No response.

Scores are summed across axes to arrive at a total (or summated) score.

Some typical examples and excerpts from interviews:

Example 1: PRI-R1/A1 [l53-l56]

Pre Interview Score: 1{*Correct response but no explanation*}.

{*The student was asked to read the statement of Axis 1, then the below questions were asked*}.

53. Int: Is there any relation between all the concepts which you have learned? ...
54. R1: Yes sir, … there is a relation between the concepts
55. Int: Do you ever think of the relations….
56. R1: No sir

{*Since the student did not explain the relation, hence the score was 1*}.

POI-R1/A1 [l45–l58; l77-l82];

Post Interview Score: 2 {*Correct response with ¼ of proper explanation in at least one example*}.

45. Int: Read Axis 1 statement.
46. R1: Is physics and chemistry knowledge a bunch of weakly connected pieces without much structure and consisting mainly of facts and formulas? Or is it a coherent, conceptual, highly-structured, unified whole?
47. Int: What is your opinión?
48. R1: There is a relation between each and every concept.
49. Int: Could you tell me examples?
50. R1: … in simple harmonic oscillator, … we can say that velocity, acceleration etc. This same case arises in the compound pendulum also.
51. Int: So the velocity that appears in compound pendulum and simple pendulum is equal… Is there any connection?
52. R1: There is a connection.
53. Int: What is that connection?
54. R1: If velocity increases displacement also increases. {*which is not true}.*
55. Int: What is related with acceleration?
56. R1: Velocity is related to acceleration.
57. Int: ..you studied all these in mechanics also.
58. R1: Yes.

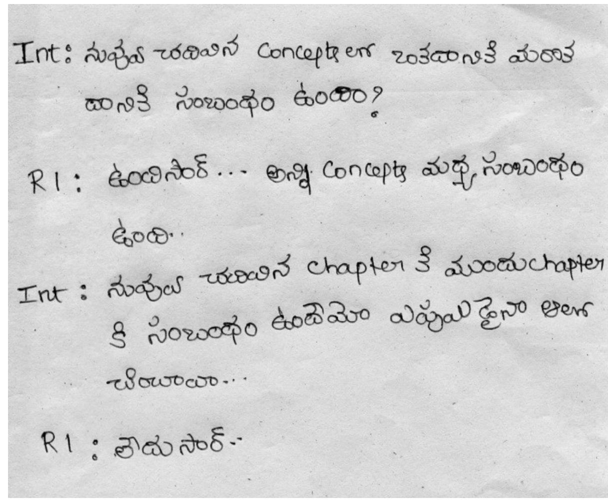
And

77. Int: …..what is the relation between displacement and velocity and what is the relation between the acceleration and displacement?
78. R1: There is relation among those.
79. Int: What is that?
80. R1: …. According to the definition the change in the displacement is called…velocity
81. Int: and, what else
82. R1: …. change in… velocity is called acceleration.

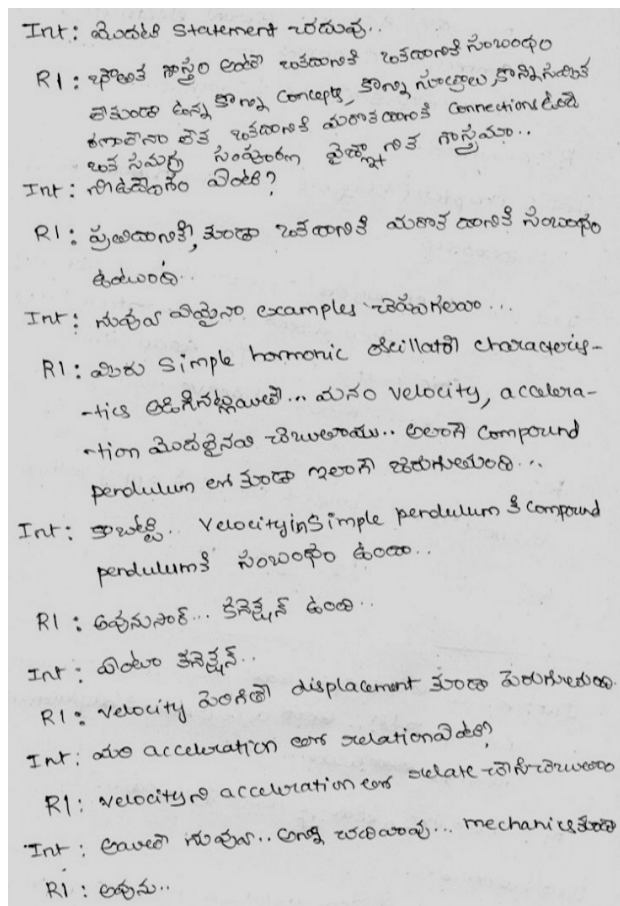
{*The student could not explain the difference between the relations among the velocity, displacement and acceleration in mechanic and the relation between the displacement, velocity and acceleration in simple harmonic motion. The explanation given for the relation between the velocity and the displacement in simple harmonic motion was also not correct.Hence score was 2***}**.

Telugu Transcriptions:

PRI-R1/A1 [l53-l62];



POI-R1/A1 [l45–l58; l77–l86];



Example 2: PRI-W7/A1 [l16-l20]

Pre Interview Score: 2 {*Correct response with ¼ of proper explanation in at least one example*}.

16. W7: Structure of scientific knowledge, is physics and chemistry knowledge a bunch of weakly connected pieces without much structure and consisting mainly of facts and formulas? Or is it a coherent, conceptual, highly-structured, unified whole?
17. Int: What do you think…?
18. W7: .... I think it's the second one
19. Int: Which is?
20. W7: … It is a coherent, conceptual, highly-structured unified whole…because there is everything together and things connecting to everything each other ...

{*When asked for an example, the student didnot give any***}**.

POI-W7/A1 [l102-l112; l11-l14];

Post Interview Score: 3 {*Correct response with ½ of proper explanation in at least one or more than one examples}.*

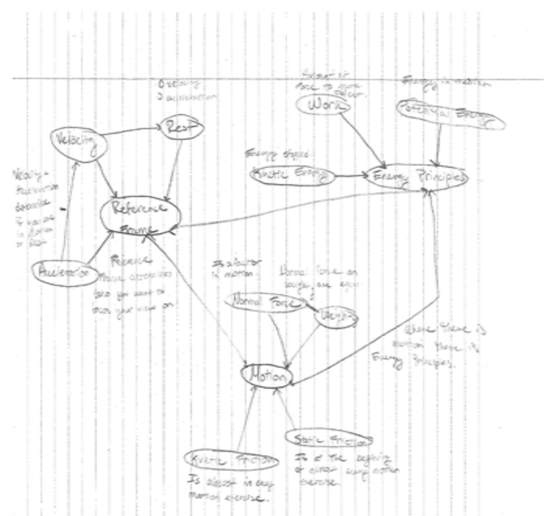
102. W7: …Is physics and chemistry knowledge a bunch of weakly connected pieces without much structure and consisting mainly of facts and formulas? ......
103. Int: ..you also had the same question in the begining of this semester. What do you think about these now?
104. W7: I dont know what I answered before but I would say it is coherent conceptually highly structured unified whole
105. Int: Have you really experienced during this semester?
106. W7: Yes
107. Int: You agree with that now. But what are those bunch of formulas? {*pointing to the basic formulas the student wrote in his Project work*}.
108. W7: The formulas are ways of calculating after you have understood the problem and all the events and subevents things that go into the actual event and you realise what kind of formula we should use and certain details you need to know before you can use.
109. Int: Do these formulas have any meaning? {*pointing to those equations*}.
110. W7: Yes
111. Int: What is use of these formulas?
112. W7: The formulas calculate in maths what you understood in the mind about the event in numbers.

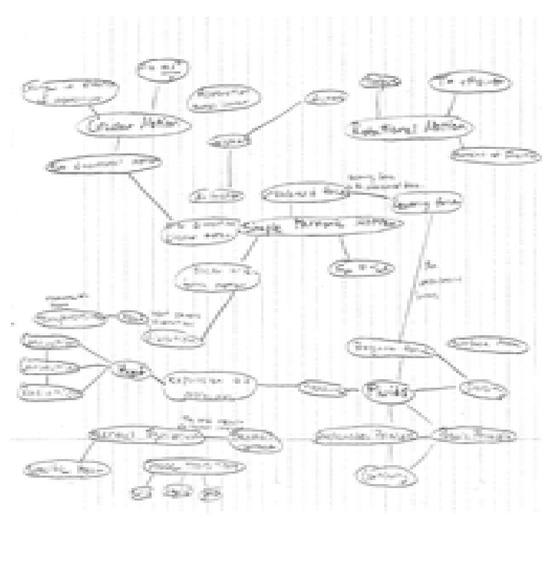
And

11. Int: Is there any relation between different physics concepts?
12. W7: Yes….I observed in my Project…
13. Int.What was the Project about?
14. W7: My Project work was aboutHockey…there is a lot of physics involved whenwe observe the game…

{The student explained the relation between various physicsal quantities in his Project}.

{The student drew concept maps showing connection between the physical quantities learned in the course. This was one of the homework activities for the students}.





{The student showed enough evidence in the Project and the concept maps. How ever he could not explain the meaning and use of the equations. Hence score is 3}.