

Attitudes and Knowledge in High School Science: An Empirical Test of a Theoretical Model of Correlations

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ABSTRACT

It has been discussed that emotional investment in the educational process generates positive cognitive outcomes. This correlation addresses a core tenet of the three learning domains, Cognitive, Affective, and Psycho-Motor where all three constitute separate areas of one single learning process. And as such, one would expect to be able to measure this correspondence between the three domains. This study attempts to test the hypothesis of a correlation between the cognitive and affective domains in a cohort of in-service science teachers. Specifically, we seek to assess whether the affective posture towards school sciences shows an association with their cognitive competence in biology, chemistry and physics. We used partial least square regression analysis to examine the data, and the results indicate a direct correlation between the affective and cognitive domains. Teachers who scored higher in cognitive tests for the three sciences also had a more positive attitude towards them. These findings provide strong empirical evidence in support of the theoretical principle that the three domains are separate but interconnected components of the educational process.

Keywords: Affective and Cognitive Domains, In-Service Teachers, Science Teacher Training.

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I. INTRODUCTION

Even though the affective domain issue in education was introduced more than a century ago, it was not until the publication of Bloom's taxonomy of educational objectives that it had attracted some academic interest (Bloom *et al.*, 1956; Bloom *et al.*, 1964; Savickiene, 2010). Most of the research, though, has focused on the cognitive side of the taxonomy. Some scholars, like Martin and Briggs, consider that this is an oversight and that the two domains can and should be integrated (1986). Yet, the tendency has continued to favour the cognitive domain. This research attempts to study the correlation between both domains in the context of in-service science teachers.

Attitudes and behaviours towards the natural environment have been studied in certain cultural settings during the last 40 years (Thompson & Mintzes, 2002). A reasonable assumption in Kraus's (1995) view, is that 'attitudes, in some way, guide, influence, direct, shape or predict behaviour'. It has been discussed that emotional investment in the educational process generates positive outcomes (Walls *et al.*, 2002; Shoffner, 2009; Bathgate & Schunn, 2017). The emotional environment that teachers provide, whether positive or negative, greatly influences the quality of education in the classroom. Sanchez' study about TIMSS results and trends in the Philippines serve to assess the significance of developing the affective domain of learners

(2019). Students' learning experiences may improve or deteriorate accordingly (Grauer, 2014; Knuver & Brandsma, 1993). The plausibility of this effect validates the significance of the affective domain in the teaching-learning continuum. Given the bidirectional nature of the educational process, a teacher's emotional involvement impacts not only the students' entire attitude towards learning but also the teacher's experience as an educator (Bathgate & Schunn, 2017; Jeong & González-Gómez, 2021). We have understood that a teacher who is highly motivated would generate a better academic result for his or her students, but also, for himself or herself.

This correlation posits a core tenet of the three learning domains, Cognitive, Affective, and Psycho-Motor proposed in 1956 and later partially revised in 2001 where all three constitute separate areas of one single learning process (Anderson *et al.*, 2001; Bloom *et al.*, 1964). As such, one would expect the existence of a measurable correlation between the three domains. The attitude towards a subject matter impacts the teacher's ability to master the discipline, conveys a positive attitude towards science, and therefore his or her becoming an effective teacher (Bell, 2016; Grauer, 2014; Walls *et al.*, 2002). This correspondence between affective and cognitive domains appear to play a significant role in teaching-learning dynamics (Baker, 2010; Lin *et al.*, 2021).

This study attempts to test the theoretical model of a correlation between the cognitive and affective domains in a cohort of in-service science teachers. Specifically, as a case study we seek to assess whether the affective posture towards school sciences shows an association with their cognitive competence in biology, chemistry, and physics.

II. METHODOLOGY

A. Research Design

To accomplish our goal, we developed a multi-layered instrument to assess teacher mastery of physics, chemistry and biology, as well as the affective attitude towards science and science education. The first 12-question section was aimed at collecting demographic information such as years of professional experience, academic degree (bachelor's, licenciante, master's degree), and name of university where they completed their teaching degree. The second section about disciplinary content was based on the Costa Rican national standards set by the Ministry of Public Education for grades 7th. through 11th. (Sevilla Solano *et al.*, 2012; Villalobos & Jiménez, 2012; Valverde *et al.*, 2012; Díaz *et al.*, 2012). And the third section, about the affective, was designed using Bloom's modified taxonomy (Anderson *et al.*, 2001; Anderson, 2005; Krathwohl & Anderson, 2010). Data were collected from August to October 2016 based on a three-section survey instrument.

The second section of the survey addressed the cognitive domain. The items were distributed to include the following cognitive dimensions: Remember, Understand, Apply, Analyse and Evaluate. The chemistry diagnostic test focused on Units I, II and III of the Ministry of Education (MEP) Chemistry Program. Units IV and V are covered in 11th grade (senior year in the local school system) and represent knowledge and skills that are more specific. It included all seven units of physics for 10th grade and the three units corresponding to 7th grade. The biology diagnostic test was based on the six units corresponding to 10th and 11th grades. It was strictly confined to the subject matter they have to teach. Participants were supposed to respond to specific questions, solve problems, and to reason and explain formulae.

The third section addressed the affective domain. These items were grouped in two sets: one to scale teacher perceptions on how much they like subjects such as sciences and mathematics, and the other to gauge teachers' perceptions on the level of difficulty or easiness that sciences and mathematics represent for them. The "likeness" sub-section set was made out of 55 items on a seven-step Likert-type scale. The "difficulty" sub-section set was made of 24 items, also on a seven-step Likert-type scale. Difficulty is an important affective measurement for it allows to infer a quantitative value to a personal judgement of one's capabilities and commitment, (Chesnut & Burley, 2015; Pierre & Oughton, 2007), in this case towards the three basic sciences.

All these questions are not about performance but rather about how they perceive and view sciences in their lives overall, including before they decided to take the science teacher career path.

The research instrument was tested for validity and reliability. First, for content validity, the instrument was test-applied using an independent group of seven fourth-year chemistry pre-service teachers from the School of Education at the University of Costa Rica. Since all three sections of the instrument follow the same organizational pattern, and validation is a matter of degree (Messick, 1987), testing the area of chemistry should provide us a good idea of the overall validity of the instrument. The test group indicated that they found the instrument to be easy to follow and to respond, and that all questions were relevant and appropriate. In addition, we proceeded to test analyse the data and found the results within our expectations, as can be seen in Table I.

The construct validity of the instrument was tested using discriminant and convergent validity utilizing principal component analysis (PCA)(Knaus, *et al.*, 2011; Taherdoost, 2018) with SPSS, v20. In this case, we measured the cognitive and affective sections from a small trial sample for chemistry and the first four secondary school teachers, as seen in Table I; and later with the entire dataset, corroborating the previous PCA results.

TABLE I: PRINCIPAL COMPONENT ANALYSIS, SPSS v20

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.603
Bartlett's Test of Sphericity	Approx. Chi-Square	338.610
	df	21
	Sig.	0.000

The overall Kaiser-Meyer-Olkin (KMO) measure was 0.603 being in the range of "mediocre," according to Kaiser's evaluation levels (Kaiser, 1974). However, considering that Bartlett's test of sphericity was statistically significant ($p < 0.0001$), it indicates that the data was highly factorizable; thus, increasing the validity of the construct.

The reliability of the instrument was tested using Cronbach's Alpha coefficient. This is considered the most appropriate measure of reliability when making use of Lickert scales (Taherdoost, 2018). The results indicated an acceptable and reliable coefficient of 0.620, as seen in Table II.

TABLE II: CRONBACH'S ALPHA RELIABILITY TEST USING SPSS, v20

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.620	0.788	56

According to the principal component analysis and the Cronbach's Alpha coefficient results, the results indicated that both the validity and the reliability were acceptable. Therefore, the instrument was not modified, and applied to the rest of the in-service science-teacher volunteers.

B. Research Environment and Participants

The instrument was administered to 109 out of all 112 active science teachers from 51 high schools, or secondary schools according to the local regulations (7th through 11th grade) in the South-western region of Costa Rica, which is mostly rural.

One teacher decided not to participate as she was about to retire, and the two others were not present at school when we administered the instrument. This represents a 97.32% of the entire science teaching staff of the region, which represents a reliable data set. This cohort included a range of teachers spanning from those working as the sole science faculty in small rural schools to larger urban institutions with more than 14 science teachers and 800 students. Some of the schools were inside Indigenous Territories (autonomous lands inhabited by native ethnic groups) with a total student population of no more than 50 pupils. All teachers were hired by the centralized processing system at the national Ministry of Education, with the exception of those in the 9 indigenous territories who were selected by each territory's council.

Out of the 109 informants, 57 were females, and 52 were males. Ten teachers did not hold any university degree at the time of the research (but were working towards a bachelor's degree), 45 had a bachelor's degree (B.A.), 49 had a "licentiate" degree (Lic., one additional year beyond the B.A.) and 5 had a Master's degree (M.A.). Seventy-one teachers received their highest degree from 14 different private universities and 38 from three public universities. The work experience of informants ranges from three months to thirty-two years, with an average of 11.5 years. Teachers without a bachelor's degree have an average of 7.9 years of service, while those with a master's degree have 20.5 years of service.

C. Data Analysis

The data were analysed using partial least square regression analysis (PLS), in InfoStat (Di Rienzo *et al.*, 2017) as this is one of the best tools in inferential statistics for evaluating educational models (Lin *et al.*, 2021). Our primary hypothesis was that the affective domain is associated with the cognitive domain. The cognitive data include the score per teacher. The affective data consist of Set 1 (A1) for like/dislike, whereupon a higher score indicates a greater positive attitude towards that subject and Set 2 (A2) for difficulty/easiness values, whereupon higher scores indicate that a specific subject is perceived as more difficult. The analysis also includes demographic data on level of academic degree, type of institution (private or public), and number of years of service as variables that may also explain the results of the affective and cognitive tests.

III. RESULTS

Our results show that teachers with higher scores in the cognitive tests for biology, physics and chemistry also typically have a more positive assessment of affective data in A1 (Fig. 1), which measures whether they like that subject or not. For example, results of the PLS indicate that performing better in cognitive tests in physics, CogPhys, (as seen by larger values in the x axis, Fig. 1) is associated with performing better in A1Phys.

Similar results are observed for chemistry and even better for biology. This can be observed as both CogBio and A1Bio are very close together in Fig. 1. In this type of analysis and graphics, correlations can be explained as positive between variables when the lines run within ca. 45°

of each other. But they can be correlated as negative when they run in opposite directions, or alternatively there can be no correlation if the angle between the two lines representing the variables is ca. 90°.

Therefore, the pattern of correlation between cognitive results and affective data A2, which measures whether they find that subject difficult or not, is not consistent among the three sciences, though. In biology, higher scores on cognitive tests are associated with higher values of A2Bio, indicating that those that do better also find this topic more difficult, yet for chemistry higher grades in the cognitive test are associated with lower values of A2 (i.e., teachers that do better in cognitive tests find this topic easier), and there is no correlation between results of A2Phys and cognitive tests in physics, CogPhys, as seen in Fig. 1.

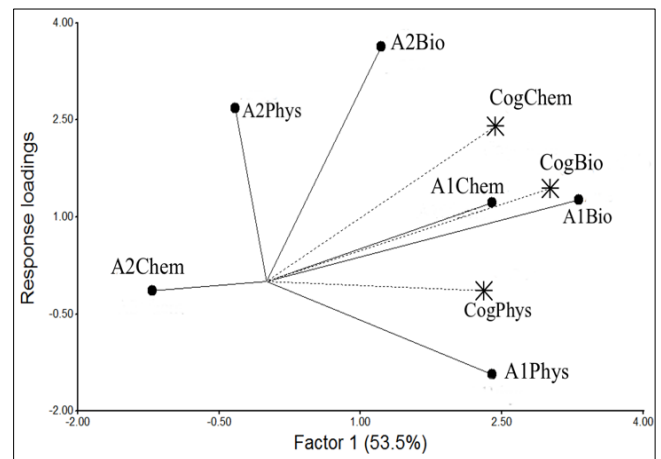


Fig. 1. Biplot showing the correlation between cognitive (Cog) tests in chemistry (Chem), physics (Phys) and biology (Bio), and affective dimensions A1 and A2 for all three sciences. Results are based on the Partial Least Squares analysis, and higher values for each variable are represented by larger values of Factor 1.

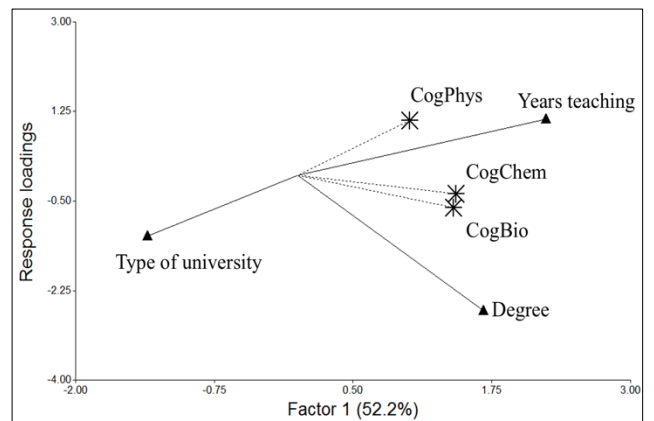


Fig. 2. Biplot showing the correlation between cognitive (Cog) tests in chemistry (Chem), physics (Phys) and biology (Bio), and academic degree (higher degrees are represented by higher values of Factor 1), years of teaching experience, and type of university (higher values represent private universities, and lower values public ones). Results are based on the Partial Least Squares analysis.

When analysing cognitive results based on demographic data, we found that more years of teaching experience were associated with higher scores in the cognitive tests for physics, and to a lesser extent to chemistry and finally biology (Fig. 2). A higher academic degree is associated with higher scores for chemistry and biology, but not in physics. Finally, the type of university (i.e., lower values represent public universities, and higher values represent

private ones) is negatively correlated with results in cognitive tests primarily for physics, but also with chemistry and biology, albeit to a lesser extent (Fig. 2). This means that results of cognitive tests for teachers in public universities were generally higher than those of teachers that attended private universities, and the correlation seems to be stronger for physics, as shown in Fig. 2 where “Type of university” is directly opposite to “CogPhys.”

We found that years of teaching was a poor predictor of most affective results except A1 in biology and A2 in chemistry, and to a lesser extent A2 in biology, as there seems to be a weak negative correlation (Fig. 3); thus, fewer years of teaching are correlated with more positive assessments of biology, and also with greater difficulties in understanding these subjects. The degree earned was negatively correlated with A2 in physics, and positively correlated with A1 in all sciences. Therefore, teachers with higher academic degrees also appear to like all topics more than teachers with lower degrees, and a higher degree also decreases the level of perceived difficulty in physics. Finally, the type of university (i.e., private or public) is positively correlated with the affective domain A2, primarily in physics but also in biology and chemistry, and negatively correlated with A1 (Fig. 3). These results indicate that teachers that graduated from private universities perceive a greater difficulty with, and greater dislike for, all three sciences.

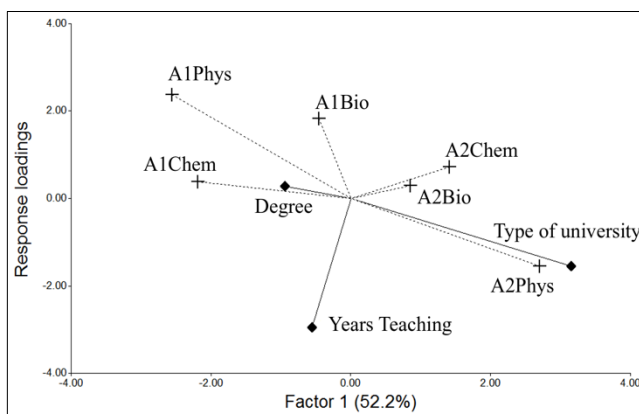


Fig. 3. Biplot showing the correlation between affective results A1 and A2 in chemistry (Chem), physics (Phys) and biology (Bio), and academic degree (higher degrees are represented by higher values of Factor 1), years of teaching, and type of university (higher values represent private universities, and lower values public ones). Results are based on the Partial Least Squares analysis.

IV. DISCUSSION

In order to assess the hypothesis of a correlation between the cognitive and the affective domains we tested a cohort of rural teachers in both affective response and cognitive proficiency in and about three science disciplines. Specifically, we sought to gauge whether the affective posture towards school sciences shows an association with their cognitive competence in biology, chemistry and physics. The data collected and analysed using inferential statistics suggest that there is a clear correlation between the cognitive and affective domains.

Cognitive knowledge (mastery) of the subject matter is associated with a more positive disposition, or enjoyment,

(A1) towards the subject, whether it is biology, chemistry, or physics.

On the other hand, mastery is associated differently with a perception of difficulty for the three disciplines. Mastery is associated with greater difficulty (A2) in biology, lower perception of difficulty in chemistry and no association in the case of physics. Overall, the correlation between cognitive data and perception of difficulty is not as strong as for liking or disliking. These findings, however, provide empirical evidence that both enjoyment and perception of difficulty together correlate to cognitive mastery. This means that it is difficult to learn that which is not appealing as it undermines self-efficacy (Betz & Hackett, 1986; Chesnut & Burley, 2015; Yada *et al.*, 2017). This is important because career choices in science education may be better mediated when these two aspects of the affective domain are taken into account.

On an additional related observation, mastery of the subject matter was also associated with other variables, including years of service, type of university, and academic degree; these variables may also explain the association of mastery with A1 and A2. For example, years of service is associated with better mastery of the subject in physics and less in biology and chemistry, whereas a higher academic degree is associated with better proficiency in biology and chemistry but not in physics. It is worth remembering these data are cross-sectional. This evidence may show general changes in pre-service training over the years with teachers who graduated a longer time ago having better training in physics than more recent graduates. As underscored below, teachers whose degree came from a public university performed better in the content tests. Since private university programs are newer than those from public universities, one could presume teachers with more years of service represent public institutions to a higher extent. Thus, consistency of trends for years of service and type of university is mutually validating. Another reading of this observation is that while knowledge in biology and chemistry is solidified through formal learning, in the case of physics years of service is more relevant for mastery of the subject matter. Thus, for this cohort of teachers' physics would be learned more through teaching (preparing and reviewing) than by earning additional academic degrees. This speaks of the different natures of the three sciences and of the particularities associated with learning and teaching each subject, for instance the level of abstraction necessary to master each of them (Bucat, 2004; Sandi-Urena, 2018).

We also found that training in a private university is associated with both a perception of greater difficulty and a lesser disposition towards the three subjects, biology, chemistry and physics. That is, teachers holding degrees from private universities in Costa Rica have a lesser liking for the three sciences and find them more difficult than those who graduated from public universities. Data indicated that private university training is associated with less mastery of the subject, especially in physics. This is consistent with other findings regarding private higher education in Costa Rica (Levy, 2015; P.E.N., 2019).

A better disposition towards the three subjects is also associated with higher academic degrees. Holding higher degrees may contribute to teachers' self-efficacy beliefs,

that is, judgments of their capabilities to successfully attain a goal (Bandura, 1986). In turn, higher self-efficacy beliefs are associated with higher motivation, persistence, and improved performance (Jungert & Rosander, 2010; Zimmerman & Lebeau, 2000). These observations stress the significance of sound pre-service training, especially for cohorts that may be relatively isolated in rural areas and with little access to professional development opportunities. Years of service do not make up for initial university training (except for physics). Achieving competence in a subject is harder to attain when the perception of difficulty is greater because it undermines self-efficacy (Betz & Hackett, 1986; Yada *et al.*, 2017).

We observed that the perception of difficulty for physics is less dependent on years of service. Contrary to that, biology and chemistry were perceived more difficult by teachers with more years of service than those less experienced. As above, this suggests changes in the overall perception of the sciences as teaching programs evolve, especially with the continuous emerging of newer teacher formation programs in private universities.

V. CONCLUSION

As a case study we wanted to test the hypothesis of a correlation between the cognitive and the affective domains, as originally proposed in Bloom's Taxonomy (Bloom *et al.*, 1956; Bloom *et al.*, 1964). We also support our position based on a reasonable assumption in Kraus's (1995) view, that 'attitudes, in some way, guide, influence, direct, shape or predict behaviour and capacities. Thus, we specifically sought to gauge whether the affective posture towards school sciences shows an association with their cognitive competence in biology, chemistry, and physics. For this purpose, we sampled a cohort of in-service science teachers from several rural communities, in Southwestern Costa Rica.

The data were analysed using partial least square regression analysis (PLS), in InfoStat (Di Rienzo *et al.*, 2017), as this is one of the best tools in inferential statistics for evaluating educational models (Lin *et al.*, 2021; Sellin, 1995). The results suggest that the affective domain has a correlation, or direct relationship, with the cognitive domain. Teachers with higher scores in the cognitive tests for biology, physics and chemistry also typically have a more positive attitude towards the three sciences (A1 in Fig. 1).

We also observed that mastery of the subject matter was also associated with other variables, including years of service, type of university, and academic degree, which may also explain the association of mastery with A1 and A2. These associations, however, do not interfere with the core analysis of the correlation between Affective postures and Cognitive competence. Since this correspondence between affective and cognitive domains appear to play a significant role in the teaching-learning dynamics, as suggested by Baker (2010) and Lin *et al.* (2021), we can deduce that the affective domain could serve as a predictor for cognitive competency and self-efficacy expectancies with respect to both content and career fulfilment.

Therefore, we can conclude that these relationships and correlations serve as evidence and a strong support for the theoretical principle that the three domains of the educational objectives (cognitive, affective and psycho motor) actually constitute separate elements of a unified and interconnected process.

Even though our sampled population was not that large, it is worth noting that it represented almost all in-service science teachers (109 out of 112) from the 51 schools included in this study. This sample size is equivalent to a similar study conducted in Hong Kong (Lin *et al.*, 2021). And from the statistical standpoint the results are valid, reliable and accurate, as proved by Cronback's Alpha and the KMO and Barlett's tests. Thus, we would expect that with larger sample populations similar results of valid correlations between the Affective and Cognitive domains can be found.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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