UTILIZING CONCEPT MAPS TO REMEDIATE PROSPECTIVE PHYSICS AND CHEMISTRY TEACHERS' DIFFICULTIES IN INORGANIC QUALITATIVE ANALYSIS

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ABSTRACT

Inorganic qualitative analysis remaining a difficult topic to learn and to teach influences the learner acquisitions. The study investigates utilizing concept maps to remediate prospective physics and chemistry teachers' understanding of inorganic qualitative analysis, via a pre-and post-intervention test methodology. Data were collected from the tests scores and the content analysis of responses. Results show a significant difference between the achieved scores, and a decrease of percentage responses located in 'incomprehension or unanswered' category. The gain scores are very pronounced for the "reagents and uses" basic (97.2%). This finding supports that the treatment may provide efficiency to remediate participants' difficulties. *[African Journal of Chemical Education—AJCE 11(2), July 2021]*

INTRODUCTION

Inorganic qualitative analysis (IQA) is one of the chemical subjects, which aims to identify a single compound [1] or to detect the ions in unknown composition substance [2]. It remains a practical method which is more rapid and less expensive, and constitutes one of the most essential academic knowledge in secondary school to build scientific concepts in chemistry.

Qualitative analysis courses have dual function [3-5]. Firstly, their teachings include several aspects that learners will be to developed, such as, understanding of concepts, acquisition of practical skills, and ability to identify ions. Secondly, they constitute a beginner in chemistry, leading to form a mental picture around which framework of theoretical principles may be built. Moreover, qualitative analysis teaching not only helps learners to improve their skills, but it is also a very effective tool to make teachers professional development.

Ions analysis induces among trainees in chemistry the development of practical, conceptual and thinking skills. Indeed, the practical work of qualitative analysis requires learners to carry out several experimental practices, such as, observation of chemical reactions, laboratory techniques and procedures, development of abilities to analysis, solve problems and interpret experimental results according to the theory rules [2, 6]. Also, this branch of science offers better opportunities to emphasize reactions and phenomenon's in analytic chemistry, for example, acid-base, oxidation-reduction, solubility product, precipitation, common ion, and complexation [7, 8]. Thus, the experimental practice of IQA promotes acquisition of the fundamental basic concepts of chemistry. Furthermore, introductory course in qualitative analysis provide improvements to enhance learning general chemistry and level of thinking [9]. Qualitative analysis course plays a vital role to strength students' understanding of chemistry [3], and increase the motivation and engagement of students. Highton have been reported that qualitative analysis constitutes an

excellent practice drill which increases student attraction toward the classroom activities. He added that this discipline can afford opportunities to students to developed orderly habits and to use the reasoning faculties [10].

On the other hand, Guy has described three possible reasons for teaching qualitative analysis [11]. Firstly, it allows to acquire the practical laboratory art, and the success is measured in the "number of unknowns" identified correctly. Secondly, this topic serves as a training ground for the writing and balancing of chemical reactions. In the end, the qualitative analysis subject offers an excellent place to highlight many of the fundamental principles of chemistry.

However, a growing number of studies have identified diverse learners' difficulties in teaching and learning IQA. Thus, students' skill acquisition is confronted to problems in understanding chemical concepts and reactions [12]. For examples, students are unable to relate the precipitation phenomenon to the low solubility of salts [13]. Sattsangi has been reported that the students cannot devise a logical approach to understand and write chemical equations [14]. De Jong et al. have shown difficulties and confusions when teachers exploit reactions involving redox concept [15].

Concerning the difficulties encountered by teachers, they range from factors related to science teaching to the content of scientific knowledge in IQA. Literature reports that pre-service teachers have alternative conceptions similar to those identified for students in several chemical areas [6]. In such situation, these alternative conceptions can be unwittingly transmitted to their learners, and often lead to inaccurate concepts that can influence considerably further learning on the subject [16]. Furthermore, Valanides reports that teachers' knowledge can enhance or limit students learning [17]. Therefore, the teachers need a lot of knowledge base for teaching [18]. Among the most important knowledge for teachers, theoretical and practical knowledge of

inorganic qualitative analysis has been a priority to ensure effectively the process of didactic transposition for the scholarly knowledge. Consequently, these difficulties referred to subject matter knowledge, require teacher remediation procedures aiming at correcting problems, especially for those do not meet minimum performance [19] and do not understand key concepts.

BACKGROUND, RESEARCH AIM AND QUESTIONS

Background

The Moroccan education system has not got specific importance to IQA topic [20-22]. All teaching-learning cycles from secondary school to university did not include explicitly in the formal content teaching programs the necessary subjects who learners need to know in order to understand IQA and to acquire good manual skills. In physic-chemistry classrooms, learning about IQA typically begins implicitly in collegial secondary education [20]. The primary teaching approach towards the identification of ions produced during the reactions of acid-base solutions with materials takes place in the 3^{th} grade chemistry courses (age range 12-15). However, practical work activities relating to it, occurs an important place to build chemical principles and concepts. The actions of acid (hydrochloric acid) and basic (sodium hydroxide) solutions on metals such as iron, copper, zinc and aluminium have been used for the development of several chemistry basics and conceptual understanding. During this dynamic process where learners contribute with their teachers to identify some cations and anions, they actively construct their own chemistry knowledge and/or skills.

However, the literature reports that the secondary prospective physics and chemistry teachers' (PPCTs) subject matter knowledge was problematic [23]. They are confronted to several difficulties, and do not correctly understand fundamental inorganic qualitative analysis basics,

probably associated with insufficient initial training. Thus, PPCTs are unable to explain the reactions between substances and reagents, and their practical knowledge shows little experimental skills in chemistry. Consequently, it would be uncertain that they will succeed their chemistry teaching. Remediation of PPCTs with learning disabilities constitutes an opportunity to provide them supplementary support. From the literature, studies on this area have rarely been carried out.

Research aim and questions

To enhance students, pre-service and in-service teachers acquisition in several chemistry topics concept maps, as a graphical tool for organizing and representing knowledge, have been found very effective [24-28]. Considering the importance of the foundation of IQA in chemistry, this study focused on trainees enrolled in the teacher qualification courses, aims to consider the efficacy of utilizing concept maps to remediate PPCT' understanding of IQA basics. The following research questions were investigated for this purpose: Are there statistically significant differences between the pre- and post-test scores? How does the concept maps can be used to help PPCTs understand inorganic qualitative analysis principles? What are the treatment effects toward IQA basics?

METHODOLOGY AND PROCEDURES

Participants

The participants in this study included a cohort of thirty-seven PPCTs (21 males and 16 females, aged from 22 to 39 years) who were in their first year of qualifying training at the Eastern Regional Center for Education and Training Jobs (ERCETJ, Morocco) and taking a physics and chemistry complementary training course (136 hours). All training modules content requires seven

months of full-time study and combines school-based of practice (120 hours). This course divided into two periods, includes activities in different subject areas relating to the teaching profession such as planning, management, pedagogic research, educational science, didactic, evaluation, legislation and job ethics, school life, and practice analysis and educational production workshops [29]. The participants possessing a licence's degree in chemistry or physics had undertaken at least three years of university studies. They have successfully passed a competitive recruitment organized by the Eastern Regional Academy of Education and Training. During the next school year 2020–2021, the research participants were assigned to classes within secondary schools and take the responsibility of teaching as teacher trainees. They should have abilities and skills to teach physics and chemistry disciplines in secondary collegial or qualifying schools.

Research procedure

Before starting this research, PPCTs were informed of the broad objective of the investigation was the study of utilizing concept maps as a remediation tool to enhance their knowledge. The importance of their participation has been highlighted. Two specific reasons motivate people to participate to this research. Firstly, the investigation offered them a good opportunity to expand their chemistry knowledge. Secondly, the use of concept maps as a tool for teaching helps participants to improve their classroom practices and optimize their acquisitions.

PPCTs participating in a research were informed of the procedure adopted involving an acquisition and evaluation strategies. They were aware that their test results do not influence their final chemistry assessment scores and collected data serve for scientific publishing reports. PPCTs were also informed that they could leave study at any time and reserve unconditional or absolute right of withdrawal without giving any reason.

In order to accomplish this scientific research, a pre- and post- intervention test methodology was employed. The research design including evaluation tests and concept maps studies were taken and carried out over four hours. The procedure was divided into three phases involving understanding development activity and evaluation performance (**Table 1**).

Table 1. Research design description.

Operations	Pre-test	Maps intervention	Post-test
Phase description	IQA achievement open-ended test	Maps-based learning	IQA achievement open-ended test
Duration	1h	2h	1h

First phase is a diagnostic evaluation conducted to determine PPCT trainees' level of knowledge before treatment using a pre- test lasting one hour. The second phase divided into two stages typically lasts two hour involved examination of concept maps. This activity aims to develop a better understanding of IQA principles including all methods and techniques used to identify ions. At the beginning stage, the PPCTs were briefed on the IQA theory, objectives and its importance in chemistry, and were encouraged to use supporting documentation to illustrate concepts related to this area. Then, the PPCTs divided into groups of three or four, were asked to examine studied maps and understand all concepts visualized. They were allowed to analyse and discuss the matter among themselves and to list the most misunderstood concepts in this field. During the last stage, at a round table involving participants, the components of maps were summarized and thoroughly re-explained. Otherwise, PPCTs were given detailed explanations and explanatory information about IQA. Questions raised by the participants were noted and immediately addressed. Also, the researcher made efforts to improve the quality of acquisitions and resolve any problems encountered by the participants who were having had difficulties. At the

end of maps treatment phase, the PPCTs were post-tested. They were given one hour to complete the knowledge post-test in order to evaluate their recent acquisitions. During this evaluation the participants were not permitted to use any support documents and no explanations have been given.

Instruments

The IQA tests used in this work as the pre and post-mapping were developed in two stages. The first stage involved a documentation review on the topic of IQA to determine the most important and minimum principles that PPCTs need to know. The use of all these basic concepts that covered the whole of the scientific area, allows elaborating the first master concept map (**Appendix A**). Otherwise, the participants are also invited to examine the literature concept map [30]. The second stage consists of the elaboration of knowledge judgement tools. Pre-and post-tests are constructed in similar ways using questions akin (**Appendix B**).

Master concept map

Four fundamental principles are essential for the study of qualitative analysis combining theory basis with practice skills and detailed chemical knowledge [7, 11, 31, 32]. The first principle reflects the practical experimental nature of this disciplinary field. It stipulates the acquisition of chemistry know-how relating to the operations and laboratory habits which are most often repeated. Therefore, the apparatus, tools, utensils and appropriate techniques used in manipulations, as well as the products resulting from them constitute the success factors in IQA. Knowledge of reagents, their functions and uses form the second principle. All reagents commonly used are divided into two groups. The general reagents serve for the classification of the most common ions based on the formation of precipitates. However, the specific reagents often provide

particular characteristics of the studied ions. According to the third principle, information's easily perceptible to senses such as sight and smell, collected through the actions of reagents on the simple allow to species identification nature with high certainty. Many types of reactions can highlight the existence of ions in solution. The most common are precipitation, complexation, oxidation-reduction and acid-base. As for the last principle, it's based on the design of systematic procedures which must be followed to complete analysis of inorganic samples such as metals, non-metallic solids and salts. For each simple, a systematic qualitative analysis involving physical properties and chemical reactions [30] must be carried out in order to identify constituents. Every analysis consists of several parts and typically starts with the preliminary tests, followed by the identification of ions after sample dissolution, and confirmatory tests cloture the process. Finally, through the concept maps treatment PPCTs develop their skills for each topic area previously cited.

Inorganic qualitative analysis achievement test (IQAAT)

To measure the impact of concept maps examination on the PPCTs' knowledge, the IQAAT was developed according to established principles and literature reviews [31, 32]. The test-based protocol to collect data is a very popular strategy used to explore learners' conceptual understanding and enhance acquisition of concepts in chemistry education [33, 34]. The IQAAT is constructed on the basis of open-ended items frequently used in education as a measurement tools and possessing different advantages comparatively to multiple choice items [35]. This test administered on paper, included questions regarding the following sections: "experimental practice" (EP), "reagents and uses" (RU), "action of reagents" (AR), and "systematic procedures" (SP). It consists of fifteen items organized as follows: EP (1, 2, 3) ; RU (4, 5, 6,7, 8, 9) ; AR (10, 11,12) ; SP (13, 14,15). The IQAATs prepared using items akin were applied as pre- and post-tests

to determine whether there was a significant difference in terms of achievement scores before and after treatment [26]. PPCTs had asked to response direct questions about acquired knowledge based on the application of concept maps and to gauge whether they understand IQA key concepts. This type of item requires the learner to use their higher-level thinking skills [36], and remove possibilities to get answers by chance or through a process of elimination or even using corrective feedback [37]. Two experts in the field of chemistry education were asked for the validity and reliability of the evaluation instrument. They were requested to examine whether the scope of the two tests was sufficient to evaluate the concepts related to inorganic qualitative analysis. In addition, the experts were asked to control the similarity of items between the pre-and post-tests. According to their suggestions, three items were revised.

Data analysis

The responses given by the PPCTs to the pre- and post- intervention open-ended items were classified and using content analysis method. Answers have been categorized into five classes namely, "clear understanding" (CU), "partial understanding" (PU), "partial understanding with specific misconception" (PUSM), "specific misconception" (SM), and "incomprehension or unanswered" (IU). They were scored as four: CU, three: PU, two: PUSM, one: SM and 0: IU points, with the total possible points being 60 [33, 34]. The answer to each item was considered to be correctly answered if participant correctly responded to al parts of item. The reliability of the open-ended tests was established by a Cronbach alpha coefficient for 37 cases and 15 items [38]. Descriptive information like frequencies and percentages means and standard deviations of different coding categories were determined using excel 2010 software program. In all comparisons made in this work, results were considered to be statistically significant for $p < 0.05$.

The Wilcoxon test and t-test were employed to reveal whether or not there was a significant difference within the studied groups in terms of scores [39].

RESULTS AND DISCUSSION

This study involving classroom activity, embraces the effect of utilizing concept maps as a remedial measure to eliminate weaknesses or deficiencies that PPCT is known to have. Results presentation and their discussions include four sections, namely: statistical analysis of IQAAT, content analysis of IQAAT, overall gains and losses scores, and evolution of gains and losses versus IQA principles.

Statistical analysis of IQAAT

The PPCTs' pre- and post-test results are summarized in **Table 2**, while **Figure 1** presents the scores achieved by 37 participants. According to the calculated t-value of 11.26 (at the 0.05 level) higher than the table value of 2.02, the difference between the scores achieved before and after the didactic intervention were found to be statistically significant. Also, the result of the Wilcoxon test ($z = -5.258$, $z_{Table} = 1.96$, $p < 0.05$) shows a statistically significant change between the scores of two assessments in favor of the post-test. Furthermore, the Cronbach's alpha coefficients estimated for pre-and post-tests were closer, and found respectively as 0.6648 and 0.6655, indicating a moderate internal consistency [40].

Table 2. Statistical data of pre-and post-test changes, t-test and Wilcoxon test results ($p < 0.05$).

	Mean	Median	Mode	Min-Max	SD	Cronbach α	t	z
Pre-test	7.32	6.00	0.0	0-25	6.93	0.6648		
Post-test	19.57	20.00	25.0	4-40	7.56	0.6655	11.259	-5.258

From **Table 2**, it can be seen that the total mean mark of each of the two assessments was: pre-test--7.32; post-test--19.57, with a difference of 12.25 which was found to be significant and showing a remarkable effect of the intervention. Meanwhile, PPCTs scores range from 0 to 2

5 in the pre-test, while in the post-test they vary between 4 and 40. The standard deviation showing the spread of scores increases slightly of 0.63 in the post-test. This moderate change in advantage of the post-test indicates that the range in PPCTs' knowledge does not systematically change over the research activity. Others statistical quantities obtained for the post-test such as median and mode are higher than those recorded for the pre-test. Thus, the median values of pre-test and post-test were found to be 6 and 20 respectively. Also, the mode representing the number which is repeated the most in the set is higher in the post-test of 25 than the pre-test where a score of zero is achieved by six participants.

When looking at the scores achieved by PPCTs in tow tests (**Figure 1**), it is evident that the majority of them makes progress, but they had low scores providing an unsatisfactory level. Thus, 89.2% and 56.7% of PPCTs scored less than 20 marks in the pre-test and post-test respectively. For instance, these results can be due to very poor participants' prior knowledge and the acquisitions require probably more time than four hours devoted to this research activity.

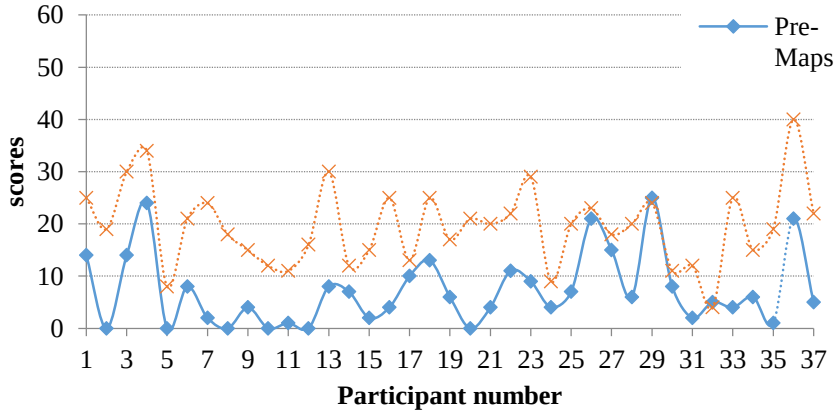

Figure 1. The pre- and post-test points scored by the participants.

Despite this, results argue strongly that the concept maps improve PPCTs ideas and knowledge-building ability in IQA. The magnitude between the pre- and post-test scores was moderate, ranging from a low value of 2 to high of 19 points. However, the concept maps were found to be ineffective to help advanced level chemistry of two participants to understand IQA, and there scores decreased slightly by 1 point. Hence the performance of the majority (94.59%) of PPCTs has undergone evolution and demonstrates the knowledge development of IQA prospective teachers.

Based on these findings, it is reasonable to conclude firstly that the PPCTs' performance in IQA has increased considerably after the treatment carried out. Therefore, the strategy-based concept maps improve PPCTs' achievement regarding the topic of IQA. On the other hand, the items of pre- and post-tests measure inorganic qualitative analysis success consistently [41].

Content analysis of IQAAT

Results presented in **Table 3** show that the frequency for the majority of responses in the IU category was higher than other categories (CU, PU, SMPU, SM) for the majority of participants in two tests. This proves that the PPCTs are facing difficulty in understanding IAQ concepts [23]. However, the IU category percentage for pre-test of 80.6% has declined substantially following intervention strategy. The percentage decrease of 37.8% obtained for "incomprehension or unanswered" answers, brought a remarkable improvement in the categories showing better acquisitions. Therefore, the adopted current way leads PPCTs to make statements showing fewer misconceptions and increase their abilities to give answers justifying sufficient knowledge.

Table 3. Total content analysis of items in the pre- and post-tests.

	CU		**PU**		**PUSM**		**SM**		IU	
	f	%	f	%	F	%	f	%	F	%
Pre-test	2	6.7	1	1.4	2	6.5	2	4.9	30	80.6
Post-test	5	12.6	5	14.2	5	14.2	3	8.8	19	50.1

Based on **Table 3**, fifteen PPCTs (41%) in the post-test gave answers in the CU, PU and SMPU categories, against only five participants (14.6%) before intervention answer in the similar categories. Concerning the percentage of the post-test PPCTs' responses in the CU category of 12.6% was higher than the percentage of pre-test PPCTs' responses in the same class of 6.7%. Also, the number of answers in the SM and CU categories given by PPCTs, it's doubles after they have finished the concept maps-based enhancing chemistry knowledge. Moreover, it can be seen that the PPCTs in the pre-test located in PU category had very low percentage of 1.4% compared to the participants in the post-test of 14.2%. These results agree with those previously presented in where the median and mean for the post-test scores were higher than those computed for the pre-test scores. This finding suggests that the PPCTs had gain a better understanding of the main topics in IQA following this remediation activity. The overall results demonstrate the effect of utilizing concept maps to enhance PPCTs' understanding of IQA content.

However, the relationship between the studied variable and the participant's acquisition according to IQA principles is another exploration option. **Table 4** presents the percentage distributions of PPCTs responses in the pre- and post-tests over the answers categories for the four principles and items.

Table 4. Percentage distributions of PPCTs in the pre- and post-tests for each item.

Principles	Items	Pre-maps % Distributions According To Categories					Post-maps % Distributions According To Categories				
		CU	**PU**	**PUSM**	**SM**	**IU**	**CU**	**PU**	**PUSM**	**SM**	**IU**
EP (t =	1	0	0	5.4	13.5	81.1	5.4	2.7	8.1	13.5	70.3
6.43, p	2	13.5	2.7	5.4	5.4	73.0	10.8	18.9	29.7	2.7	37.8
<.05))	3	5.4	10.8	13.5	8.1	62.2	10.8	43.2	35.1	2.7	8.1
Average		6.3	4.5	8.1	9.0	72.1	9.0	21.6	24.3	6.3	38.7
RU (t =	4	13.5	0.0	0.0	8.1	78.4	18.9	24.3	27.0	2.7	27.0
12.11, p	5	0.0	2.7	2.7	0.0	94.6	35.1	18.9	16.2	10.8	18.9
<.05))	6	0.0	0.0	8.1	0.0	91.9	35.1	2.7	10.8	2.7	48.6
	7	13.5	2.7	2.7	0.0	81.1	5.4	16.2	13.5	8.1	56.8
	8	8.1	0.0	2.7	0.0	89.2	2.7	0.0	0.0	10.8	86.5
	9	2.7	2.7	8.1	8.1	78.4	32.4	29.7	10.8	0.0	27.0
Average		6.3	1.4	4.1	2.7	85.6	21.6	15.3	13.1	5.9	44.1
AR (t =	10	37.8	0.0	2.7	2.7	56.8	8.1	16.2	13.5	10.8	51.4
0.21, p	11	0.0	0.0	24.3	5.4	70.3	2.7	10.8	5.4	32.4	48.6
<.05))	12	0.0	0.0	13.5	8.1	78.4	0.0	2.7	16.2	13.5	67.6
Average		12.6	0.0	13.5	5.4	68.5	3.6	9.9	11.7	18.9	55.9
SP (t =	13	2.7	0.0	0.0	5.4	91.9	13.5	5.4	16.2	10.8	54.1
3.56, p	14	2.7	0.0	0.0	0.0	97.3	5.4	18.9	10.8	2.7	62.2
<.05)	15	0.0	0.0	8.1	8.1	83.8	2.7	2.7	0.0	8.1	86.5
Average		1.8	0.0	2.7	4.5	91.0	7.2	9.0	9.0	7.2	67.6

Results show for the "experimental practice" principle a decrease of answers in the IU (72.1%) and SM (9.0%) categories in the pre-test comparatively with than those obtained for the post-test respectively of 38.7% and 6.3%. While the number of responses in the categories justifying an acquisition (CU, PU, PUSM), it has undergone significant increase in the post-test. Thus, six participants (16.2%) have successfully proposed the appropriate solvent for particular compound used in IQA and two of them gave answers in the CU category to the question 1. Unfortunately, the percentage of responses in IU category remains very high (70.3%) in the post-test. Regarding the question 2, the percentages of answers in the PU (18.9%) and PUSM (29.7%) categories were higher in post-test than the pres-test respectively of 2.7% and 5.4%, whereas the percentages of answers in SM (2.7%) and IU (37.8%) groups were lower compared to the pre-test scores. Therefore, the PPCTs knowledge about the effect of solid form on dissolution has been

found to be developed. Responses collected to a question 3 are very marked for the EP principle. Indeed, sixteen (43.2%) and four (10.8%) participants in the post-test gave answers respectively in the PU and CU categories, whereas the number of responses does not exceed in the pre-test six (16.2%) PPCTs for the similar groups.

Also, the number of answers in the IU category decreased significantly (twenty, 54.1%) in the post-test following the use of concept maps. This finding indicates that the intervention activity improved PPCTs' sound understanding of the crystallization and precipitation processes.

According to the "reagents and uses" results, a majority of PPCTs (85.6%) gives answers in the IU category in the pre-test. After the treatment, it was observed that the percentage of answers in this class decreased significantly (44.1%), while the number of responses in the CU (8 : 21.6%), PU (6: 15.3%) and PUSM (5: 13.1%) was higher in the post-test than the pre-test. For the questions 1-9, the percentage of answers in the IU category range from 78.4% to 94.6% in the pre-test, whereas in the post-test, it's vary between 18.9% 56.8% except for the question 8 showing a high value of 86.5%. In this last question whose answers are classified especially in SM and IU categories in the post-test, the PPCTs are enabling to choose the general reagent using to detect group 2 anions, probably due to memory problems [42]. Otherwise, the number of answers in the CU category for questions 4, 5, 6 and 9 was higher in the post-test respectively of seven (18.9%), thirteen (35.1%), thirteen (35.1%) and twelve (32.4%) than for the pre-test. They correctly wrote the formula of lime water reagent $Ca(OH)_2$; and they correctly response to questions, linked to the knowledge that they have never be acquired, in particular, the general reagent and flame test colour. As well, it can be seen that a minority of participants had a lower percentage (5.4%) of answers in the CU category for question 7 in the post-test. This result can be linked to the short time devoted to this activity which did not examine thoroughly the characterization of ions in each

group using specific reagents. Also, results show that the percentage of answers in the CU category for the questions 7 (13.5%) and 8 (8.1%) in the pre-test are higher than those obtained in the post-test, in connection with the PPCT-preparation courses during the training [20].

The percentage distributions of PPCTs in the pre-and post-tests recorded for the "action of the reagents" principle does not lead globally to single effect**.** Indeed, the percentage of answers in IU (55.9%) category in the post-test is lower compared to the pre-test of 68.5%; and the number of answers in PU (4: 9.9%) class is higher than its homologue in the pre-test. While in the post-test the CU and SMPU categories have been decreased of 9% and 1.8% respectively; and the SM category has increased of 13.1% after treatment. In detail, comparison between frequencies of answers for questions 10, 11 and 12 gives moderate results. An increase in percentage of answers in PU in the pre-test rose to high values ranging from 2.7% to 16.2% after treatment due to partial ability of trainees to interpret the experiment phenomenon leading to write chemical equations. Also, the frequencies of answers in IU category ranging in the post-test from 56.8% to 78.4% were lower than those recorded before treatment varying between 51.4% and 67.6%, indicating a decrease of IU responses. However, results obtained for the SM category does not support the previous statement established for PU and IU categories. This situation indicates that PPCTs had difficulty to elaborate chemical equations which requiring a content knowledge that learners have studied in different chemistry topics [30, 43]. Therefore, it seems in the case of the "action of the reagents" that the examined concept maps didn’t allow to significant changes on scientific participants’ knowledge.

Examination results from "systematic procedure" part provide exhaustively significant effect of concept maps. The percentages of answers in CU, PU and PUSM categories have been increased of 5.4%, 9.0% and 6.3% respectively; while the frequency of responses in IU category has been

dropped from 34 (91.0%) to 25 (67.6%). Minutely, the majority of PPCTs gave answers in the IU category to questions 13-15 requiring systematic procedures to identify metallic compounds, pure mineral salts and metal oxides. After the concept maps activity, the increases of the percentages of responses in the CU and PU categories are moderate. In the post-test 5.4%, 18.9% and 2.7% of answers respectively to questions 13, 14 and 15 are located in the PU category; simultaneously 13.5%, 5.4% and 2.7% are classed in the CU category. This indicates that these participants reached correct conceptions through the concept maps and were able to perform systematic analysis of unknown simples. However, the percentage of answers in SM category after the concept maps increases slightly of 5.4% and 2.7% respectively for questions 13 and 14; and remains unchanged for question 15. The treatment showed that PPCTs had difficulty to identify unknown ions which would require probably further strategy based on experimental practices.

Overall gains and losses

For assessing knowledge and learning, the literature refers to the gain–loss approach as a formal model using pre-test and post-test steps [44]. The score differences between the two evaluation situations can be seen in **Figure 2**, which shows the overall gains or losses (post-test score minus pre-test score) realized by each participant in all principles at the closing activity. The calculated quantity revealed some interesting results regarding with how PPCTs use knowledge acquired from an examination of concept maps. Differences above zero indicate the PPCT did better in the post-test. Quantities extending below zero show that the PPCT did better in the pres-test principle.

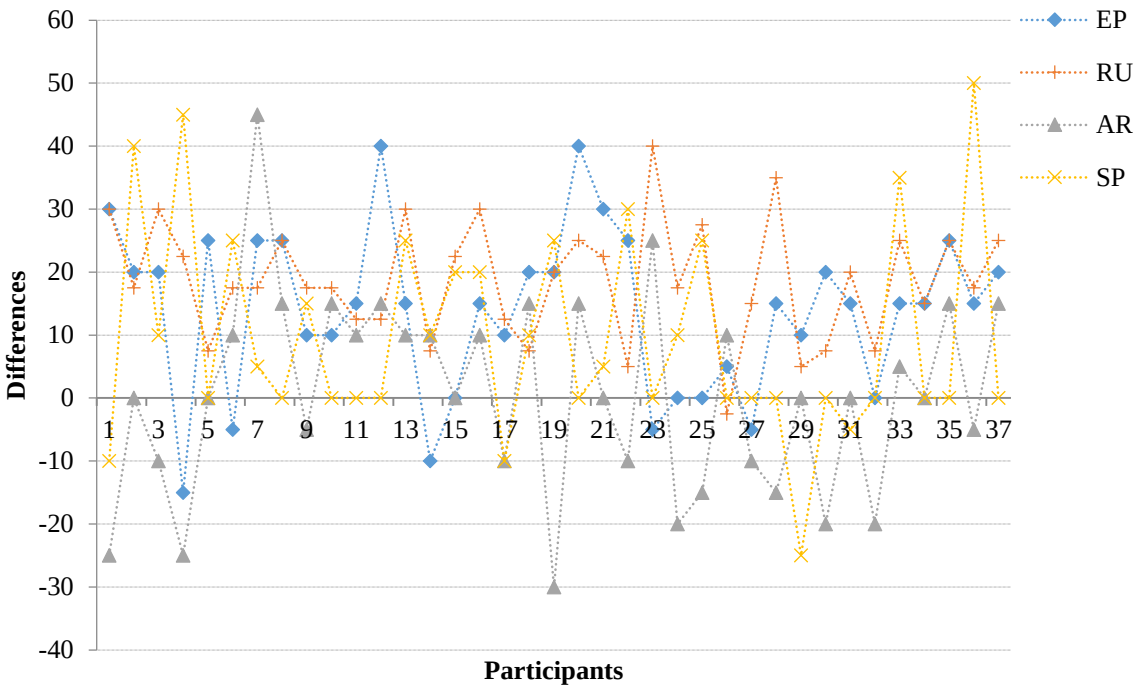

Figure 2. Differences between pre-and-post test scores for each participant.

Results prove large individual differences among the PPCTs, but in general, the majority of the participants did better to enhance their IQA performances. Three cases can be distinguished as follows according to the difference signs. Score differences firstly superior to zero suggested that PPCTs did better in post-test principle. They gain knowledge through the examination of concept maps leading to enhance trainees' understanding of IQA [25]. Studied learning objects have the potential capability to modify the IQA knowledge of PPCTs. The biggest gain of 50 points has been achieved by participant 36 in SP, followed by PPCT 7 who has progressed within 45 points in AR. Also, participants 20 and 23 have obtained a gain of 40 points respectively in EP and RU. The second case induces negative quantities reflecting that participants are not made adequate progress. The search activity has lead to the *opposite effect, linking probably to* decreased knowledge base [45]. The smallest differences were -30(AR), -25(SP) -15(EP), -2.5(RU) points, scored respectively by the participants 19, 29, 4 and 26. In the latter case, differences equal to zero

show a lack of improvement in the participants' knowledge. It's noted that no participant has achieved this value in RU. For the other principles, losses are classified following the order based on the frequency SP(15) > AR(7) > EP(4) > RU(0). For these participants the didactic interventions is ineffective to support their learning and should have opportunity for supplementary teaching sessions in order to correct their problems.

Evolution of gains and losses versus IQA principles

Figure 3 presents distributions of percentage of gains, losses and no evolution after the concept maps activity according to EP, RU, AR and SP principles.

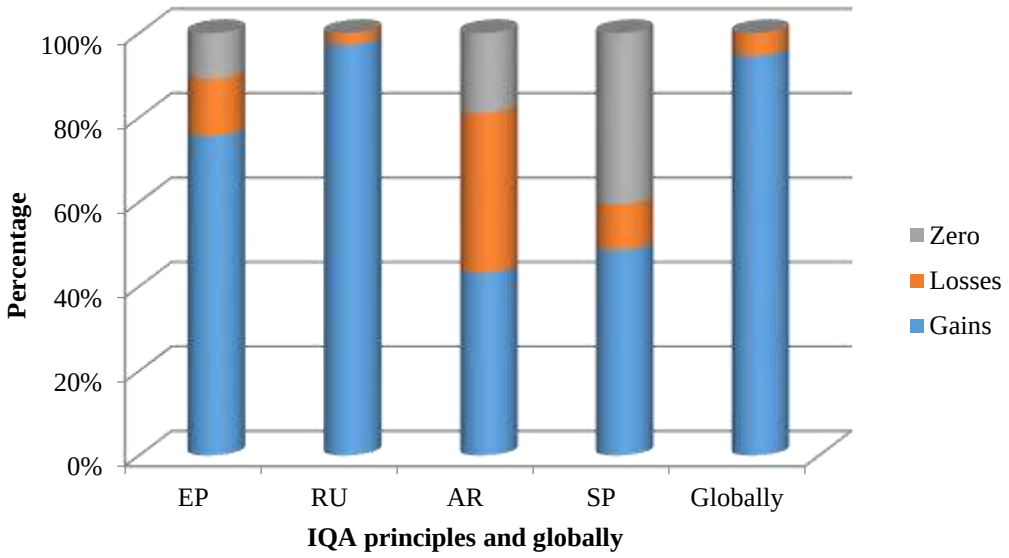

Figure 3. Percentage distributions of gains and losses versus EP, RU, AR and SP.

Results show that 94.6% of PPCTs' have scored an overall gain, and performances depend on the examined areas in where gains are generally loom larger than losses. Indeed, the "reagents and uses" results are more attractive then those obtained for the other cases. Thus, 97.3% of PPCTs made progress and scores varies between 5 and 40 points. The remediation strategy has been

proved to be very efficient to discover general and specific reagents used in qualitative analysis. After a simple lecture of the studied maps describing IQA reagents, followed by an examination of the key concepts, the degree of understanding has been much promoted. Both general and specific reagents have received particular attention by participants which allowed them to answer correctly the questions relating to this principle.

Overall gains obtained by 75.7% of participants for the "experimental practice" range from 5-40 points (**Figure 2**), suggesting that concept maps have produced meaningful changes. Utilizing concept mapping promotes motivation and encourages participants to use their previous practice knowledge that have coming into a program. However, the only exception to this trend is the performance of 14.7% of the participants, which showed losses on the experimental practice post-test part. Otherwise, four (10.8%) PPCTs participating in this study show stable knowledge. In this case, utilizing concept maps induces differences on the basis of IQA experimental practices. Remedial activity allows participants to develop their technical skills in handling. Globally, results suggest that the use of concept maps improve practical skills acquisition.

The "action of the reagents" inducing analysis and interpretation of experimental results has been recorded moderate changes. Half of the participants (43.2%) positively improve their scores in the post-test compared to the pre-test, a few PPCTs score the same on the two tests (18.9%), and other participants scored higher on the pre-test than on the post-test (37.9%). The minimum value of decreased score reached 30 points. These participants scoring negatively are not able to elaborate some usual chemical reaction equation. The concept maps allowed for them to mobilize a large number of skills [46] in various fields, in particular, the interpretation of reaction results in chemistry. This activity did not improve the knowledge of these PPCT, but it contributed to

identify their specific difficulties in terms of abilities to explain experimental observations based upon knowledge of acid/base chemistry, redox chemistry and solubility [2, 31].

The participants' performances are average at the level of the "systematic procedure" involving a series of tests in a systematic manner depending on the unknown simple. Most of the participants (48.6%) were very successful to response better in the post-test than the pre-test, against 10.8% of PPCTs have shown knowledge loss. Therefore, concept maps have important role to remediate difficulties related to IQA experimental procedures. They had helped PPCTs to construct their own understanding and knowledge on the practical process for identifying ions. However, the treatment was not sufficient for several participants (40.5%) to accumulate knowledge and their scores revel unchanged in the post-test. They need probably practical acquisition to acquire an accurate knowledge of the systematic procedure.

CONCLUSION

This study involved a process including concept maps examination and two assessment steps, aimed to investigate the effect of the didactic intervention to remediate prospective physics and chemistry teachers understanding of qualitative inorganic analysis.

According to the t-test (11.26, $p < 0.05$) and Wilcoxon test ($z = -5.258$, $p < 0.05$) results, differences between the IQAAT pre-test and post-test scores were found to be statistically significant in favor of the post-test scores. The achieved results show that the majority of PPSTs made progress after the application.

From the content analysis of IQAAT, it can be seen that the percentage of responses (80.6%) in the category of "incomprehension or unanswered" for PPCTs in the pre-test has declined substantially after the concept maps intervention than the percentage of responses (50.1%) in the

same category in the post-test, brought a remarkable improvement in the categories showing better acquisitions. Meanwhile, the percentages of responses in "clear understanding", "partial understanding" and "partial understanding with specific misconception" categories in the post-test were higher than the values obtained in the pre-test for the similar categories with variations respectively of 5.9%, 12.8% and 7.7%.

According to "experimental practice" and "reagents and uses" principles, the number of responses in these categories has undergone significant increase after intervention in the post-test. However, the action of concept maps does not lead to single effect in the case of the "action of the reagents" principle. PPCTs had several difficulties to elaborate chemical equations leading to identify unknown compound which would require probably further strategy based on experimental practices.

Regarding the score differences between the post-test and pre-test using gain–loss approach, results show that the majority of PPCTs (94.59%) had score differences above zero and did better to enhance their inorganic qualitative analysis performances. They gain knowledge through the examination of concept maps which have the potential capability to modify their IQA knowledge's. Furthermore, the gain and loss changes depend strongly on the nature of principles in where gains are generally loom larger than losses. The "reagents and uses" results are more attractive than those obtained for the other cases. The percentage of gains of 97.3% was very higher than the results obtained for "experimental practice", "systematic procedures" and "action of reagents" of 75.7%, 48.6% and 43.2% respectively.

Briefly, it was found from the study that the concept maps-based remediation strategy in the topic of inorganic qualitative analysis helps PPCTs' to solve problems and reduce their difficulties related to subject matter knowledge. Thus, the shortcomings and weaknesses cumulated during the

initial teacher training courses can be addressed using this method. However, the chemistry curriculum development involving concept map studies remains a challenge to improve the quality of education system.

DISCLOSURE STATEMENT

The author declares no conflicts of interest.

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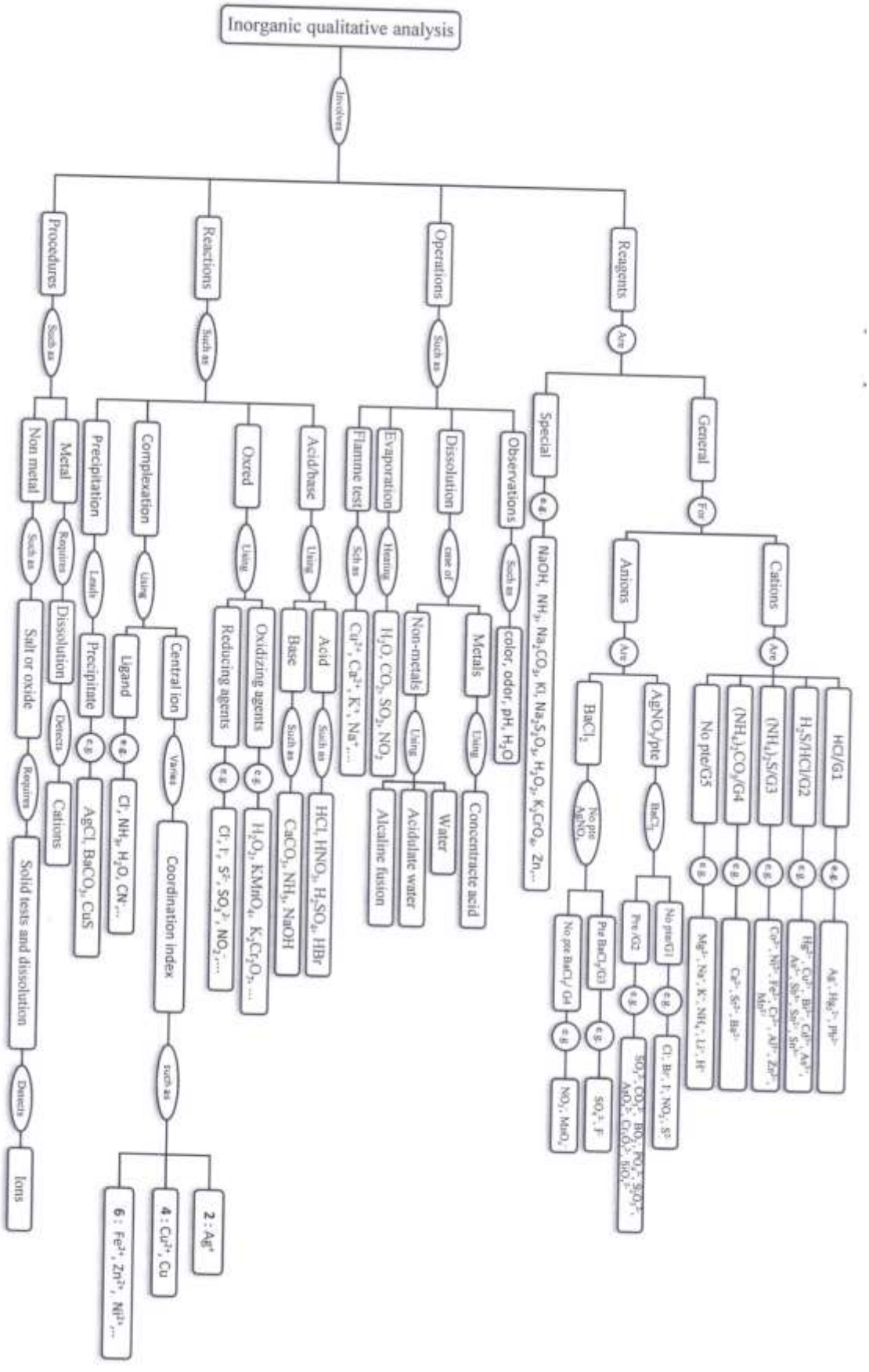
Appendix A: Constructed concept map



Appendix B: Examples of items in the pre-and post-tests

Pre-test	Post-test
1. Suggest the appropriate solvent for iron, $AgNO_3$, $CaCO_3$, $BaSO_4$ and $NiCl_2$? 2. Does the form of copper (shape, sheet, powder, wool) influence the dissolution? Explain? 3. What are the differences between crystallization and precipitation?	1. Suggest the appropriate solvent for Al, $Cu(NO_3)_2$, $BaCO_3$, $PbSO_4$, $FeCl_2$ and SiO_2? 2. Sodium chloride comes from sea salt and rock salt. Compare their dissolution in water? Explain? 3. Which operation among crystallization and precipitation is more used in IQA?
4.What is the reagent to be used to detect carbon dioxide gas? 5. Define general reagent? 6. Give general reagent to detect group 2 cations? 7. Explain the usefulness of sodium hydroxide solution to distinguish between Fe^{3+} and Zn^{2+} in group 3 cations? 8. Suggest an adequate test to detect Cl^-, Br^- and I^- belonging to group 1 anions? 9. Schematize the assembly to examine the ion flame colouration?	4. Give the name and formula of reagent used to detect carbon dioxide gas? 5. What does general reagent mean? 6. Give general reagent to detect group 3 cations? 7. Explain the usefulness of ammonium hydroxide solution to distinguish between Al^{3+} and Cr^{3+} in group 2 cations? 8. Suggest an adequate test to detect CO_3^{2-}, PO_4^{3-} and $S_2O_3^{2-}$belonging to group 2 anions? 9. Explain the flame colouration test basis?
10. A metallic copper plate is immersed in silver nitrate solution, leading to the formation of a shiny compound and the solution turns blue. Write the chemical equation? 11. Reaction between potassium iodide and mercury (II) chloride solutions gives a precipitate of HgI_2, soluble in excess of reagent. Write chemical equations?	10. A drop of mercury (I) nitrate solution is deposited on the metallic copper plate, leading to the formation of a graycolor amalgam. Write the chemical equation? 11. Addition of ammonia solution dropwise to a silver nitrate solution gives a precipitate of Ag_2O, soluble in excess of reagent. Write chemical equations?

12. The anion $S_2O_3^{2-}$ is precipitated with barium chloride, and discoloured with iodine solution. Write chemical equations?	12. The anion $Cr_2O_7^{2-}$ is precipitated with silver nitrate. It undergoes reduction with hydrogen sulphide and leads to the formation of sulfur. Write chemical equations?
13. Suggest a procedure to identify metallic compounds? 14. Describe briefly the steps required to identify salts? 15. Describe how metals oxides can be analyzed qualitatively?	13. Explain a procedure to identify metallic compounds? 14. What is the correct order of tests to identify salts: HCl, effect of water, $BaCl_2$, pH, flame colouration, NaOH, colour, H_2S/HCl? 15. Propose a procedure to identify oxides?