The Effects Of Full Studio Class On Pre-Service Teachers' Conceptual Understanding And Inquiry Skills

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ABSTRACT
This study aims to examine effects of full studio class on pre-service teachers' conceptual understanding and inquiry skills about Bernoulli Principle. The sample of the study consists of 51 first year pre-service primary science students of one education faculty in Turkey. General physics course was designed by using "Full Studio" approach which is known to be one of the active learning approaches. Course schedule, which involved active learning techniques and Bernoulli Principle, was implemented for four weeks. Single group pre test- post test weak experimental design, in which the same data collection instruments were applied to the same students before and after teaching, was used in this study. Data were collected by means of conceptual understanding test and inquiry skills scale. Additionally, semi-structured interviews were conducted with five students to explore their responses in the test and to reveal their ideas about teaching process before and after instruction. This study is a mixed methods research in which quantitative and qualitative data were collected concurrently. Students' responses to conceptual understanding test were analyzed by using rubrics which indicated changes in conceptual frameworks of students. Analysis results of data obtained from inquiry skills scale showed that students inquiry skills were improved and there was a statistically significant difference between the pre and post scales ($t=3.39$; $p<.05$). Interview data also supported the difference in students' inquiry skills. Suggestions were made for designing a full studio class and for whom to use active learning and full studio approaches.

INTRODUCTION
It has been reported that classes in which traditional teaching methods used are inadequate in promoting students' success in physics (Bernhard, 2000; Demirci & Çirkinoğlu, 2004; Thornton, 1987). It appears that misconceptions have been existed among students before traditional education and there has been a little change at the end of the course (Küçüközer, 2004; Candan, Türkmen & Çardak, 2006). Also studies indicate that the students in the traditional classroom have failed in tests involving conceptual questions even if they are successful in the tests containing numerical problems (Crouch & Mazur, 2001; Bernhard, 2000). There are many reasons why students fail in course. But teaching comes at the beginning of these reasons. In our schools, teacher-centered methods are often used in teaching science concepts and students have to memorize this information. In this case failure brings with it.

Studies show that active learning methods are more effective in learning physics concepts and increase the success more than traditional teaching methods (Gibson & Chase, 2002; Kalem & Fer, 2003; Minner, Levy & Century, 2010). Active learning has become one of the most interesting areas in recent years. Especially, in many developed countries such as USA, Germany, England, several projects have been prepared (Minner, Levy & Century, 2010). Also, the number of publications and research conducted on this subject are increasing day by day (Ün Açıkgöz, 2011). Active learning is a learning process in which a learner carries the responsibility of the learning process and has the opportunity to make decisions regarding various aspects of the learner and self-regulate the learning process. Furthermore, it is a learning process in which the learner is forced to use his/her mental abilities through complex educational tasks (Çeken, 2002). According to active learning approach, students make decisions about how to perform their own learning, how much they should learn and what is missing concerning their own learning. Teachers only guide their students and make some advices when students require and follow up the development of their students.

Active Learning Approaches in Physics Education

Many active learning curriculums, which are based on constructivism, have been developed. At a meeting at Tufts University, the participating physics education researchers reached an agreement on the following points (Bernhard, 2000):

- Questions that require qualitative reasoning and verbal explanation are essential
- Students need to participate in the process of constructing qualitative models that can help them understand relationships and differences among concepts.

- Certain conceptual difficulties are not overcome by traditional instruction
- Scientific reasoning skills must be expressly cultivated.
- Connections among concepts, formal representations, and the real world are often lacking after traditional instruction.
- Teaching by telling is an ineffective mode of instruction for most students. Students must be intellectually active to develop a functional understanding

In accordance with the decisions taken, radical decisions about physics education in America were made and a variety of active learning curriculums based on constructivism were developed. The principal aim of those curriculums is to engage students in active learning process and to ensure that students work in groups collaboratively (Bernhard, 2000; Minner, Levy & Century, 2010). Redish (2000), refers to these as "active engagement classes". They all have in common a focus on what it is the students actually do and on what the effect of that activity is.

Active learning approaches that are used in physics teaching have been presented in Table 1. Those approaches are applied in different forms (Bernhard, 2000; Şahin, 2007). While laboratories have been reorganized in some universities, arrangements have been made to active involvement of students in large classes in some universities. The most important revision is arranging group work, laboratory study and problem solving hours so that all these activities can be managed at the same time in a class.

Table 1. Active learning approaches (Bernhard, 2000; Şahin, 2007)

Curricula	*Developer*
Traditional Format	
Discovery Labs	
Tools for Scientific Thinking	R. Thornton, Tufts University D. Sokoloff, Oregon University
Realtime Physics	R. Thornton, Tufts University D. Sokoloff, Oregon University P. Laws, Dickinson College
Socratic Dialogue Inducing (SDI) Lab.	R .Hake, Indiana University
Lecture Based Models	
Active Learning Physics System	Alan van Heuvelen, Ohio State University
Peer Instruction /Concept Tests	Eric Mazur, Harvard University
Interactive Lecture Demos (ILD)	R. Thornton, Tufts University D. Sokoloff, Oregon University
Recitation Based Models	
Co-operative Problem Solving	Ken and Pat Heller, Minnesota University
Tutorials in Introductory Physics	Lillian Mc. Dermott, Washington University
Mathematical Tutorials	E. Redish, Maryland University
Full Studio	
Physics by Inquiry	Lillian Mc. Dermott, Washington University
Workshop Physics	Priscilla Laws, Dickinson College
The Physics Studio	Jack Wilson, Rensselaer Polytechnic Institution
Scale Up	Beicner, North Carolina State University

Laboratory-based models are replaced with the traditional laboratory by a discovery type active learning laboratory. Recitation-based (problem-solving) models are replaced with the recitation in which an instructor solves problems for 1-2 hours by active learning activities guided by carefully designed worksheets such as a mini-lab in which the students carry out shorter guided discovery experiments and learn reasoning in groups. Lecture-based models retain scheduling of the lectures and are carried out in a lecture hall, but modify the activities carried out by the students. In the full studio classes, the teacher lectures only for short periods during the class. Instead most of student time is spent doing experimental activities in groups in designed experiments.

Full studio classes

In the full studio classes, the entire class time is taken up by periods in which the students actively engaged with exploring the physics using some laboratory equipment. Only a small fraction of the period may be spent with a teacher lecturing to the students. These classes tend to be more expensive, time, space and equipment required than the traditional lecture format (Redish, 2000).

Physics by Inquiry

One of the initial applications of Full Studio classes is Physics by Inquiry that has been designed by Lillian C. McDermott and her friends at the University of Washington. Their teaching was designed for the learning environments in which the main aim was exploring rather than memorizing and learning by inquiry rather than lecturing so as to ensure that students worked like their teachers (McDermott, 1996a; Redish, 2000). This class was fully equipped explorative laboratory. There was not a teacher and each topic was taught in the periods of two hours of two laboratory classes. Students worked in groups of two with simple materials and followed the worksheets given to be able to answer the questions posed in those periods. Those worksheets were prepared in a manner that each student understood the task and explained the mechanism of how a system worked with his/her predictions. When the system did not work, student's prediction ended with a cognitive conflict. Then, teachers, who were responsible to the group of 10-15 students, took over the control and helped them to find the correct explanation of the problem.

Workshop Physics

Workshop Physics, which was developed by Priscilla Laws at Dickinson College and used in physics education, was a successful learning approach. Theoretical, practical and laboratory classes were integrated rather than separating them. Aim of teaching, in which peer instruction was used, was to learn physics by doing physics. Each student was equipped with a computer and various experiment materials during teaching. Students were active in each class and used Workshop Physics Activity Guide that was written by Laws (1991). Computers were used almost in all experiments. This technique was reported to be quite succesfull in small groups (Knight, 2004).

Physics Studio

Physics Studio is a very similar technique to Workshop Physics and it has been developed by Jack Wilson at the Institute of Rensselaer Politechnic (Wilson, 1994). Separation of theoretical, application and laboratory classes was also removed. Classroom environment consists of studio computers and laboratory materials. More than one student can access a computer. Physics Studio is a more structured technique, can also be applied in large classrooms and puts more importance on problem solving than Workshop Physics (Knight, 2004).

Common goal of both Workshop Physics and Physics Studio is to present more qualitative world to students. Classrooms were equipped with computer materials. Each student group works with computer supported tools like Universal Lab Interface Box (ULI). Physics Studio classes mostly consist of periods of two hours in which students make observations with equipments provided and construct their mathematical models. Classroom has a common area where general presentations are made and each class ends with many teachers' brief presentation or classroom debate.

Scale-Up

The Scale Up (Student-Centered Active Learning Environment for Undergraduate Programs) project has been conducted by Beichner and his friends at the University of North Carolina State and shows that collaborative interactive computer based education can be managed in large classes (URL-1).

The importance of the study

In this study, classroom environment was designed on the basis of "Full Studio" approach under current circumstances. Separation of theoretical, practical and laboratory classes was removed. Arrangements were made to prepare a classroom atmosphere in which students could work in groups and they could conduct an experiment, carry out an investigation by using computers or browse textbooks and journals whenever they were required. This study is believed to contribute to the literature because of the full studio classes which were developed and applications made in abroad was adapted to our country for the first time by using active learning techniques.

Many studies conducted to improve students' understanding of physics. Most of these studies include mechanical (Candan, Türkmen & Çardak, 2006; Ünlü & Gök, 2007; Ünlüsoy, 2006) and electrical concepts (Küçüközer, 2004; Şekercioğlu, 2011). The number of studies on fluid mechanics is quite small compared to the concepts studied in previous researches. Studies which focus on the concept area of fluid mechanics chose one or two topics of fluid mechanics on the primary or secondary levels (Gazioğlu, 2006; Akpınar & Ergin, 2007; Çeken, 2002; Şahin & Çepni, 2011; Daşdemir & Doymuş, 2012). The topics considered are generally properties of liquids and gases, swimming, stinging, pressure and buoyancy. However, this study deals with Bernoulli Principle which is the last topic of fluid mechanics and the effects of full studio class on pre-service teachers' conceptual understanding and inquiry skills are investigated.

Teachers attempt to realize desired learning at schools and quality of education is directly proportional to the quality of teachers. Loverude, Gonzales and Nanes (2011) emphasize that attention should be paid not only to content knowledge but also to pedagogical subjects about the related content area in training teachers. In this study, it is aimed to help students acquire both content knowledge and pedagogical knowledge about teaching Bernoulli principle by presenting content knowledge with pedagogical content knowledge. Moreover, students' inquiry skills are aimed to be improved by designed teaching model.

THE STUDY

The aim of this study is to examine effects of full studio class on pre-service teachers' conceptual understanding and inquiry skills about Bernoulli principle. The sample of the study consists of 51 first year pre-service primary science students of one education faculty in Turkey.

Method and data collection tools

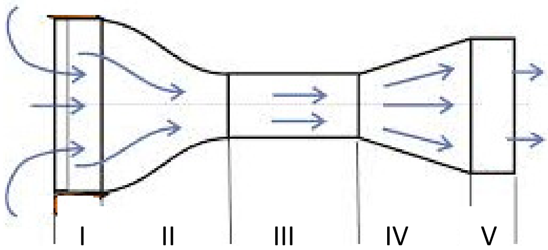
Teaching of Bernoulli principle, which utilized active learning techniques, was implemented for four weeks period in a class of which was designed according to "full studio" approach. In this study, single group pretest-posttest weak experimental design, in which the same data collection instruments were applied to the same students before and after teaching, was used. A conceptual understanding test that was developed by researchers, an inquiry skills scale that was developed by Aldan Karademir and Saracaloğlu (2013) and semi-structured interviews that were conducted with five students before and after teaching were used as data collection instruments.

This study is a mixed methods research in which qualitative and quantitative data were collected concurrently. Mixed methods research design is accepted as increasing the reliability and as reinforcing the validity of a study with qualitative and quantitative data. Qualitative data, which were obtained from the conceptual understanding test and semi-structured interviews, were examined by using rubrics whereas quantitative data, which were obtained from inquiry skills scale, were analyzed by using SPSS 14.0 software.

Conceptual understanding test

The conceptual understanding test was developed by researchers. First, a number of questions regarding the Bernoulli's principle were prepared. Then the questions were applied to another group of students and the responses were evaluated. Incomprehensible or difficult questions were removed from the first version of the test. The remaining questions were presented to the four experts in physics education area. Three of them were chosen to take part in the final version of the test as can be seen in Figure 1.

Question 1



The air flow, as shown in the figure above, is passed in a tube having different cross-sectional areas.

a. Do you think, the rate of air flow is different or remain same in the areas? (If you say different, please rank from major to minor) Please explain your reasoning.
Your answer:…..

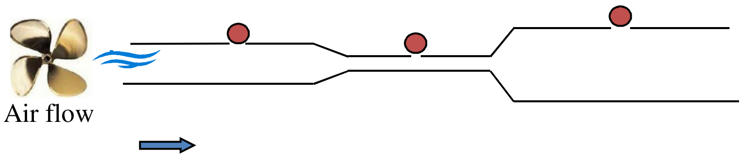
b. Do you think, the pressure that exerts to the walls of the tube, is different or remain same in the areas? If you say different, please rank from major to minor) Please explain your reasoning.
Your answer:……

Question 2

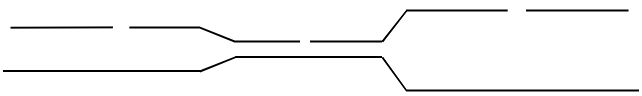
When a light breeze blowing, the smoke rises faster throughout the chimney. What do you think is the reason for this situation?

Your answer:…..

Question 3



There is a tube in the airflow as shown in the figure above. This tube was collapsed in some places and some parts were also enlarged. Three holes on the tube exist on different parts and ping-pong balls were put on those holes. When air starts to flow towards the tube it is known that balls remain stationary above the tube. How do you think positions of the balls over the tube will likely to be? Please explain your reasoning by displaying on the tube below.



Your answer:…..

Figure 1. The questions in the conceptual understanding test

Inquiry skills scale

In this study, Inquiry Skills Scale, which was developed by Aldan Karademir and Saracaloğlu (2013), was used in order to question students' inquiry skills. The scale was applied to 425 pre-service teachers studying at the departments of primary science, primary teaching, and primary social studies. The scale which was constructed as a five points likert type, consisted of three factors and 14 items. According to the exploratory factor analysis that was conducted by the authors, these factors were named as ''Getting information'', "Checking information'' and ''Confidence'' (Table 2). Each sub-factor's Cronbach's alpha reliability coefficient was calculated as .76, .66 and .82 respectively. The whole scale's reliability coefficient was .82.

Table 2. Examples of the statements in the scale

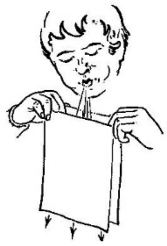
Statements	***Concerned factor***
I can distinguish what information I need to learn.	Getting information
I try different solutions when answering a question	Checking information
I say without hesitation what I think about the topics discussed in class.	Confidence

The interview form

The interview form, which was prepared by the researchers, consists of two parts in a semi-structured format. In the first part of the interview form, there are conceptual questions about the Bernoulli Principle. Some preliminary trial interviews were conducted to decide on which of the questions had to be used. Different from the questions of Conceptual Understanding Test, two different questions were included in the interviews. Other questions were designed for each individual student based on the related student's responses given to the conceptual understanding test. The second part of the interview form includes the pre-service teachers' opinions on the use of inquiry skills and teaching process. Figure 2 shows some sample questions from the interview form.

Question 1
Is there a relationship between flow rate and pressure of a fluid? How do you explain?

Question 2
What do you expect to happen when it is blowed out between two papers as illustrated in the figure? Why ?



Question 3
Do you say that everyone could easily tell what she/he thought in this course?

Figure 2. Some sample questions from the interview form

Preparation of the learning environment and teaching process

In this study, the classroom was organized as a full studio class and active learning techniques were used. In full studio classes, the discrimination among theory lesson, laboratory and recitation lessons are eliminated. Therefore, the learning environment was organized as follows:

- Four hours of lectures and two hours of laboratory course were given as a total of six hours per week.

- The classroom was divided into two groups. Then each group was divided into heterogeneous groups in their own four or five people. The students' university entrance scores were important for the creation of the groups.
- The discrimination among theory lesson, laboratory and recitation lessons were eliminated and because of this reason, teaching of the topic was decided to be processed in the laboratory.
- Laboratory was prepared in accordance with the full studio. Much as possible, computers were established in the laboratory and internet connections were made. There was a computer available to each group. In addition, students could use the library, stationery or try corner whenever they wanted as can be seen in Figure 3.

Figure 3. The full studio classroom

- ‘Energy Conservation and Bernoulli's principle’ was chosen as the topic of teaching. However, active learning techniques in the designed lesson plans were applied from the beginning of the ‘Fluid Mechanics’ unit in the full studio classroom in order to ensure that students get used to the classroom environment. Time plan for teaching of the unit was presented in Table 3 on a weekly basis and teaching of the whole unit lasted for four weeks.
- Tests and scales were applied and semi-structured interviews were conducted before and after teaching.

Tablo 3. Time plan for teaching

Lesson	*Subject*	*Lesson*	*Subject*
Week 1 Lesson 1	What is fluid?, General characteristics of the fluids, Density	**Week 3 Lesson 1**	Viscosity, fluid resistance
Week 1 Lesson 2	Pressure , Hydrostatic pressure , Pressure Gases	**Week 3 Lesson 2**	Ideal fluids, Flow lines, Rate Continuity equation
Week 1 Lesson 3	Pascal principle	**Week 3 Lesson 3**	Energy conservation Bernoulli’s equation
Week 2 Lesson 1	Buoyancy	**Week 4 Lesson 1**	Applications of Bernoulli's equation
Week 2 Lesson 2	Swimming - Sinking - Hanging , Archimedes Principle	**Week 4 Lesson 2**	Rate measurement, Venturi tube
Week 2 Lesson 3	Surface tension, Capillary , Adhesion , Cohesion		

FINDINGS

Findings from Conceptual Understanding Test and Interviews

In this part, students’ responses to conceptual understanding test and interview questions about Bernoulli’s principle were presented. Students were asked to respond those questions before and after teaching. Firstly, students’ responses were allocated to two broad categories in terms of being scientifically acceptable or unacceptable during the analysis. Thereafter, responses were grouped hierarchically in sub-categories in terms of the elements involved in each response. Below, students’ responses were presented question by question.

The Findings for Question 1

In the case of question 1, it was asked whether the velocity of air changes or not through different regions as shown in Figure 1. Teacher candidates' responses to this question in the pre and post-tests are given in Table 4 in comparison.

Table 4. Responses of students to question 1, part a.

TYPE OF ANSWER			PRE TEST		POST TEST	
			N	EXAMPLE ANSWERS	N	EXAMPLE ANSWERS
SCIENTIFICALLY ACCEPTABLE ANSWER	CORRECT ANSWER	Correct sequencing-Correct explanation	3	• How much cross-sectional area decreases, speed increases.	23	• According to $A_1.v_1=A_2.\ v_2$ equation, narrower cross-sectional area, increases fluid flow rate. • Fluid flow rate should be fixed. Speed of the fluid must be increased in a narrowed channel compared to the speed at a large channel.
	PARTIALLY CORRECT ANSWER	Correct sequencing – Partially correct explanation	-	-	1	• When we put a boat in front of the air flow in the ping-pong ball experiment, the ball was faster than previous. I sort of think about it.
		Wrong sequencing-Correct explanation	10	• In large areas, speed decrease and progresses more slowly. But in a narrow place, the same amount of air has to pass, so flow quickly.	13	• Greater the cross-sectional area, less the speed for air flow.
		No sequencing-Correct explanation	2	• There is more in the area III. Because in the cross-sectional area III, air is much more compressed. So gas rate increases.	-	-

		No sequencing-Partially correct explanation	1	• It is different. Because the structure and shape of the pipe is different.	-	-
		Wrong sequencing-Partially correct explanation	9	• Because of the length / area / width is different.	-	-
		Correct sequencing – Irrelevant explanation	-	-	1	• Static pressure is the pressure that fluid makes the side surface and it is inversely proportional to dynamic pressure.
		Correct sequencing – No explanation	3	-	2	-
SCIENTIFICALLY UNACCEPTABLE ANSWER	WRONG ANSWER	Wrong sequencing-Wrong explanation	12	• The speed of the air flow does not depend on the area. Therefore it remains the same. • It is the same. Because gases are distributed homogeneously. • Airflow needs larger areas to pass more quickly / Air stream is compressed in narrow areas. • Because the pressures are different. It is due to the cross-sectional areas.	6	• As cross sectional area is decreased, the amount of air passing through the tube increases and accelerates it immensely. • The speed of the airflow varies. Because the pressures applied to the wall in the numbered regions change.
		Wrong sequencing – No explanation	4	-	-	-
		No sequencing-Wrong explanation	1	• I would say normally area III is the fastest. However, pressure of air does not change as in the case of the experiment we did water. When we do try narrowing path of water, its pressure is increased but it is not the same for air and narrowing the path of air does not change the result.	-	-
		Correct sequencing - Wrong explanation	2	• The speed of air flow varies depending on sections. Because the pressure of the air flow increases in narrowed sections.	3	• Flow lines are much where the cross-sectional area decreases.
UNCODEABLE		Sequencing and explanation irrelevant	3	• III>IV>II>V>I Field II is narrowed and closed and has maximum air pressure. In field IV air pressure is too high because it takes the pressure from both narrow spaces because it is in a closed area, though both have less pressure accordingly.	2	• I>II>IV>V>III Rate is increased in area III.
UNANSWERED		No response	1	-	-	-
Total			**51**		**51**	

Considering the answers given in Table 4, the number of respondents, who gave correct answer, was three and twenty-three in the pre and post tests respectively.These students argue that the speed of the airflow increases as the cross-sectional area is decreased. In the post test, it was found that students made explanations using flow rate concept or continuity equation in line with that expected of teachers.

Partially correct answers category consists of seven subcategories that are named in line with the responses of teachers as correct sequencing-partially correct explanation, wrong sequencing-correct explanation, no sequencing-correct explanation, no sequencing-partially correct explanation, wrong sequencing-partially correct explanation, correct sequencing-irrelevant explanation and correct sequencing-no explanation. In this category, it seems that more students responded especially in the subcategory of wrong sequencing-correct explanation. This situation is valid in both the pre and post-tests.

Scientifically unacceptable responses of students have grouped in four subcategories. These are labeled as wrong sequencing-wrong explanation, wrong sequencing-no explanation, no sequencing-wrong explanation and correct sequencing-wrong explanation. The number of students, who made wrong sequencing-wrong explanation, was twelve and six in the pre and post tests respectively.

When students' scientifically unacceptable responses were examined it was found that some students assert the notions of 'flow rate of air was not related to cross sectional area' or 'as the cross sectional area was decreased the amount of air would be increased'. On the contrary, some students reasoned that air flow would go faster as the cross sectional area was increased. Student 48 explained his opinion on this topic in the interview before teaching as follows:

> *Air flow spreads much in wide regions and it progresses more comfortable, its speed increases and its pressure is reduced. However, speed decreases and pressure increases in the third region due to the narrowed area.*

Response of the same student in the post test was coded in the wrong sequencing-correct explanation category. Below some part of the dialogue after teaching between student 48 and the researcher was presented.

> Interviewer: Are you sure about your response?
> Student 48: No, not about the sequence. But cross-sectional area is inversely proportional to speed.
> Interviewer: Ok. Do you want to reorder?
> Student 48: Yes. III is the largest; IV, V, II and I come in order.

In the pre-interview, student 50 revealed her ideas about question 1 as follows:

> Student 50: More current passes through large areas, it would be so much speed.
> Interviewer: Do you think that the amount of air passing through the area of I and II is different from each other?
> Student 50: It is the same for both, because both are integrated. Then it is pointless. It is faster in area III.
> Interviewer: So, in part II cross-sectional area is narrowed. Does this change anything?
> Student 50: Of course, the air must enter to the area II faster.

Considering dialogue held with student 50, it seems that she does not have a clear idea and makes a different explanation in her every answer. A dialog from post interview with the same student is presented below.

> Student 50: Because the cross-sectional area is narrowed speed is maximum in area III.
> Interviewer: Ok. What is the reason for this?
> Student 50: The same amount of air has been forced to pass through the narrowed area.
> Interviewer: What if we use water instead of air? Does the result change?
> Student 50: No, nothing is changed. It is also a kind of fluid.

When uncodeable responses are examined, two and three students' responses fall into this group in the pre and post tests respectively. The reason for coding responses in this category is that there is inconsistency between the statements made and the rankings given. For example, area III was considered the last in the rankings, while it was reasoned that speed was higher in area III than the others. One student left the question unanswered in the pre test.

In part b of question 1, it was asked whether the air pressure on the walls of the pipe in different regions would change as shown in Figure 1. Responses given by teacher candidates to this question in the pre and post tests are presented comparatively in the Table 5.

Table 5. Responses of students to question 1, part b.

TYPE OF ANSWER			PRE TEST		POST TEST	
			N	EXAMPLE ANSWERS	N	EXAMPLE ANSWERS
SCIENTIFICALLY ACCEPTABLE ANSWER	CORRECT ANSWER	Correct sequencing - Correct explanation	-	-	13	• Where the speed of air flow is reduced, static pressure increased and dynamic pressure decreased. As the speed increases the pressure made to wall decreases. • Static pressure + dynamic pressure + height dependent pressure = constant. The flow of the fluid is constant. Speed of the fluid in a narrowed region should increase to get a constant flow rate. The height is equal in every part of the tube, so it is ineffective. Then the static pressure decreases as the speed increases.
	PARTIALLY CORRECT ANSWER	Correct sequencing - Partially correct explanation	1	• Pressure is low in tight areas, because speed is high. But in wide areas, pressure is high.	3	• Static pressure is inversely proportional to the dynamic pressure. • Static pressure increases as the wall of the pipe increases.
		Wrong sequencing-Correct explanation	-	-	6	• Bernoulli equation says that pressure decreases according to whatever speed increases. • Pressure on the wall of the pipe made by the airflow and static pressure is inversely proportional to speed.
		No sequencing-Correct explanation	-	-	1	• When we narrowed the cross-sectional area of the pipe wall, it reduces the air pressure and also the static pressure.
		No sequencing-Partially correct explanation	3	• It changes because areas are different.	-	-
		Wrong sequencing-Partially correct explanation	4	• Speeds /cross sectional areas are different. • How much the region is greater, pressure is greater too.	1	• Smaller the cross-sectional area less the pressure applied to surface.
		True sequencing-No explanation	-	-	4	-
SCIENTIFICALLY UNACCEPTABLE ANSWER	WRONG ANSWER	Wrong sequencing-Wrong explanation	28	• Same in all areas. Because it is only the force applied to the wall. So everywhere is the wall of the pipe. • In large areas, pressure is high. In tight/small areas, pressure is low because of the jamming. • There is more pressure in areas with increased speed	19	• It is same in all areas. Because the wall of the pipe is the same everywhere, so the pressure doesn't change. • Pressure will be more in the narrow area. Because the number of molecules will increase. The pressure is inversely proportional to the surface area. Pressure on the wall of the pipe is reduced as surface area is growed. • Pressure on the wall of the pipe is increased where airflow is strong.
		Wrong sequencing-No explanation	12	-	3	-
		No sequencing-Wrong explanation	2	• As the cross-sectional area of the pipe decreases, the pressure increases.	-	-
		Correct sequencing-Wrong explanation	-	-	1	• Makes more pressure because more air molecules are found in large areas.
UNCODEABLE		Sequencing and explanation irrelevant	1	• It is directly proportional to the cross-sectional area. More pressure is exerted in smaller cross sectional areas. This is observed the most in area III.	-	-
Total			**51**		**51**	

When students' responses were examined, none of the students gave correct answer (correct sequencing-correct explanation) in the pre test while thirteen students responded in this category in the post test. Students basically responded that the narrower the cross sectional area, the bigger the speed of the air flow which would increase dynamic pressure and decrease static pressure on the walls of the tube.

Partially correct answers were allocated to six subcategories which were labelled as correct sequencing-partially correct description, wrong sequencing–correct explanation, no sequencing-correct explanation, no sequencing-partially correct explanation, wrong sequencing–partially correct explanation and correct sequencing-no explanation. Responses in this category lack the enough explanation about the relationships between the concepts of cross sectional area, speed, static pressure and dynamic pressure. Additionally, more students gave responses belong to wrong sequencing-partially correct explanation and wrong sequencing-correct explanation subcategories in the pre and post test respectively.

Scientifically unacceptable responses were divided into four subcategories that were labelled as wrong sequencing-wrong explanation, wrong sequencing-no explanation, no sequencing-wrong explanation and correct sequencing-wrong explanation. 28 students made wrong sequencing-wrong explanation in the pre test while 19 students still responded in this category in the post test. When the responses were examined it was found that students mainly used the concept of 'pressure' without mentioning static and dynamic pressure in their responses. Moreover, the idea of 'increasing the speed also increases the pressure' was frequently used by the students. It is known that dynamic pressure increases with the speed of the fluid but students have to concentrate on the walls of the tube to be able to explain the pressure which is called static pressure and decreases with increasing speed of the fluid. Student 48 explained the situation in the post interview as can be seen below.

> "Where the speed is high, dynamic pressure increases and static pressure decreases.Static pressure is higher in a larger area. It influences the wall of the tube more than the case of small area. We can get the reason of this from Bernoulli's equation"

One student gave an uncodeable response in which inconsistency emerged between the explanation given and the sequence made in the pre test. None of the students left blank this question in both the pre and post tests.

The Findings for Question 2

The reason for the fume's rising up faster through a chimney in a windy day was asked in the second question as can be seen in Figure 1. Students' responses to this question in the pre and post tests were presented in Table 6.

As can be seen in Table 6, only one student made a scientifically correct explanation that was correct sequencing and correct explanation in the pre test while twenty nine students gave such a response in the post test. Students who gave a correct explanation argued that the pressure at the upper end of the chimney was decreased due to wind blowed above the chimney. Moreover, they were aware that pressure inside the chimney was higher than the pressure outside the chimney that was thought to be the reason of the faster movement of the fume inside the chimney from the higher pressure to the lower pressure.

Table 6. Responses of students to question 2

TYPE OF ANSWER		PRE TEST N	PRE TEST EXAMPLE ANSWERS	POST TEST N	POST TEST EXAMPLE ANSWERS
SCIENTIFICALLY ACCEPTABLE ANSWER	CORRECT ANSWER	1	• The smoke in the chimney rises faster when lower air pressure exists inside the house than the air pressure outside in windy weather.	29	• There would be increase in the rate of the speed because the wind blows. As speed increases, the pressure decreases. The upper part of the chimney is the low pressure region while the fireplace becomes the region of high pressure. Direction of flow is towards the low pressure from the high pressure region. Smoke rises faster through the chimney for this reason. I reached this idea from the Bernoulli equation.
	PARTIALLY CORRECT ANSWER	5	• Pressure difference occurs. • Gas pressure drops on the chimney so it rises faster.	8	• The pressure in the air affects the smoke. Therefore pressure applied to the smoke is much greater inside the house as the wind blows and the smoke rises faster. • As the pressure difference is much, smoke moves faster.
SCIENTIFICALLY UNACCEPTABLE ANSWER	WRONG ANSWER	43	• The air has a frictional force; this slows down the rate of rise of smoke. But when the wind blows slightly it helps smoke to move up and the smoke rises faster. • Smoke starts to rise/disperse/mix faster upwards to air with the help of the wind. An air exchange/flow occurs. • It is reverse with blowing speed of the wind and it rises faster through the chimney when a light wind blowing. When the speed of the wind increases, the smoke will be stuck in the chimney and it will drown into the chimney. • The suction power / thrust of the wind or more streams can be the reason of it. • Wind direction is clearer at a time to go to smoke and fumes cannot withstand the impact of large wind speed and rises with him. • The blowing wind can cause a circulation in the mouth of chimney. • Wind speeds of / takes out the smoke.	14	• The low pressure inside the house wants to mix more quickly with high pressure outside the house. The wind sets up a balance as a factor here. • Wind creates high pressure at the top of the chimney. Smoke goes from low pressure towards high pressure. • Because when the wind blows, breaks down his smoke and prevents it to be risen. But smoke rises faster in light winds due to be comfortable. • Because smoke is scattered under the influence of air flow that is created by the wind and rises quickly through the chimney.
UNCODEABLE	Irrelevant answers	2	• Because air pressure is applied and weather takes away all the smoke. • The opposite may be the case, I cannot explain.	-	-
		Total	**51**	**Total**	**51**

Five and eight students responded partially correct answers in the pre and post tests respectively. Those students were also aware that pressure difference existed but they did not mention the effect of the speed of the wind or in which regions high and low pressures would have been occurred.

43 students' responses coded as scientifically unacceptable in the pre test and 14 students continued to reason in the same category in the post test. It has been revealed that different ideas emerged in this category and students mainly used the notions of friction, the effect of wind and repulsive force without referring the concept of pressure in their answers to the pre test.

Students ideas about the same concept were tried to be probed by asking a question in different context in the interviews conducted as can be seen in Figure 2. Students were asked to hold two A4 size papers parallel to each other in a vertical dimension. Then, they were asked to anticipate what would happen if s/he blowed between the papers. Students 46, 47 and 48 responded in the pre interviews as follows:

> Student 46: I expect two papers to be separated.
> Student 47: I guess they move apart.
> Student 48: They may repel each other.

When it was blown between two papers it was observed that papers came closer that was contrary to the students' predictions. As a result of this trial, student 46 made such an explanation in the pre interview:

> "Let's consider the narrow region in the first question. We can get inspiration from there. Air speed is decreasing towards the bottom of the paper. But it is probably irrelevant."

Student 47 tried to explain the situation as follows:

> "I guess, air pressure causes this phenomenon.The pressure is much where we blow."

Student 49 explained the same situation in post interviews as follows:

> "It is due to the pressure. We increase the speed of air and decrease the pressure between the papers when we blow. The pressure outside the papers is higher than the pressure between the papers. Papers stick to each other since the external pressure is higher than the internal pressure."

All five students answered both the chimney and blowing papers questions correctly in the post interviews. Finally, two students made irrelevant explanations in the pre test and coded as uncodeable.

The Findings for Question 3

In the case of question 3, it was asked when the air flew, how the balls' position would likely to be as shown in Figure 1. Teacher candidates' responses to this question in the pre and post-tests are given in Table 7 in comparison.

Table 7. Responses of students to question 3

TYPE OF ANSWER			PRE TEST		POST TEST	
			N	EXAMPLE ANSWERS	N	EXAMPLE ANSWERS
SCIENTIFICALLY ACCEPTABLE ANSWER	CORRECT ANSWER	Correct presentation - Correct explanation	1	• As the width of the tube decreases, speed of air increases and pressure decreases. That's why the ball does not raise much.	18	• The speed increases when the cross-sectional area is narrowed. According to Bernoulli's equation, dynamic pressure increases as the speed increases. In order to remain energy constant static pressure must be decreased. In narrow cross sectional area the ball rises less due to low pressure.
	PARTIALLY CORRECT ANSWER	Correct presentation – Partially correct explanation	-	-	8	• Static pressure is reduced and dynamic pressure is increased in places where cross-sectional areas are small. • Reduced static pressure exists on the periphery of the narrow wall. Therefore, air outlet is the least at the wall of the narrow place.
		Wrong presentation – correct explanation	-	-	1	• Static pressure decreases as the speed of air increases. More pressure will be applied on the large wall surface area and the ball will go higher than the other cases.
		No presentation - Partially correct explanation	-	-	1	• Static pressure is inversely proportional to speed. Thus, the ping-pong ball rises more in the thick part of the pipe.
		Wrong presentation - Partially correct explanation	-	-	2	• The velocity of air entering into the tube will be greater and causes more dynamic pressure. But here is the static pressure which is exerted on the pipe wall. Narrowed places will increase speed.
		Correct presentation – No explanation	-	-	1	

SCIENTIFICALLY UNACCEPTABLE ANSWER	WRONG ANSWER	Wrong presentation – Wrong explanation	44	• The airflow removes harder in narrow places and the ball more gets up. But in wide areas, the air flows more comfortable, so the ball does not get up much. • Location on the tube is inversely proportional to the width of the tube. Air pressure is increased when the tube is narrowed and position of the ball on the tube will increase. • (They rise equal) When the air flow close up the balls, balls begins to rise upwards. • It is about the sizes of the holes.	18	• Airflow increases as the cross-sectional area is decreased. Thus, static pressure / pressure is also increased. Static pressure / pressure is greater where the height is maximum. • The first ball cannot jump upwards due to pressure created by the air stream when air flows inwardly into deadlock and starts to rotate. Other two balls jump up with the impact of the stream. • Because it will come up more quickly than with a narrow cross-section. Cross-sectional area than would be the now slower than larger ones. • Static pressure and dynamic pressure increase, this causes increase in speeds. • Air flow through the tube is much where it is the most narrow.
		Wrong presentation – No explanation	1	-	-	-
		Correct presentation - Wrong explanation	1	• Provides the hyperinflation of the ball for more air passes through the expanded location. In areas with narrow vice versa.	2	• Larger cross-sectional area causes more airflow. That's why the ball rises more above the big one. • As speed increases, the dynamic pressure is reduced. Decrease in dynamic pressure results in reduced height.
UNCODEABLE		Irrelevant answers	2	• The balls fall in. Gas in broad areas progresses and spreads more comfortable than in narrow areas. Thus, balls reach the balance so…	-	-
		Explanation and presentation irrelevant	1	• Where the pressure is less, speed is low.	-	-
UNANSWERED		No response	1	-	-	-
Total			**51**		**51**	

Considering the answers given in Table 7, the number of respondents, who gave correct answer, was one and eighteen in the pre and post tests respectively. The students responded that the narrower the cross sectional area, the bigger the speed of the air flow which would increase dynamic pressure and decrease static pressure on the walls of the tube and where the static pressure is high the ball rises more. The answers are more scientific and expository in the post test.

Partially correct answers category consists of five subcategories that are named in line with the responses of students as correct presentation-partially correct explanation, wrong presentation-correct explanation, no presentation-partially correct explanation, wrong presentation-partially correct explanation and correct presentation-no explanation. In the pre test, none of the students and in the post test thirteen students gave answers belong to these subcategories. Eight students made correct presentations and partially correct explanations. The explanations in this category are shallower than the explanations in the correct answer category.

Scientifically unacceptable responses of students have grouped in three subcategories. These are labeled as wrong presentation-wrong explanation, wrong presentation-no explanation and correct presentation-wrong explanation. The number of students who made wrong presentation-wrong explanation was fourty four and eighteen in the pre and post tests respectively.When the responses were analyzed, students mostly referred to narrowed cross-sectional area and increased rate of the air flow and the pressure as a cause of the balls rising upwards. Also, students seemed to make wrong explanations due to mixed or incorrect knowledge of the dynamic pressure and static pressure. Student 48 explained his opinion on this topic in the pre interview as follows:

> "The amount of the air is much, so the ball rises more. In the wide areas, balls rises more, because the pressure will be more."

When the students' opinions are examined, both correct and and wrong ideas are appeared. In large areas, the pressure is much more, but this pressure is called static pressure. The cause of the balls rising higher is not due to more air, because the filling is same in everywhere. The cause is decrease of the rate of flow and in dynamic pressure and increase in static pressure. In the pre test the same student's (48) idea is as follows:

> "In large areas, the air flow rate increases. When the rate increases, dynamic pressure increases and static pressure decreases. The static pressure effects to range of the wall, because of this, when the static pressure decreases, the ball rises more."

Also, the number of students who made correct presentation and wrong explanation was one and two in the pre and post tests respectively. When the students' responses were examined it was clear that students believed to the idea of 'when the cross sectional area was increased, the amount of air flow was increased too'.

Uncodeable answers category consists of two subcategories that are named in line with the responses of students as irrelevant answers and both explanation and presentation irrelevant. Only three students' answers were coded in these categories in the pre test. Also, only one student unanswered the question in the pre test.

Inquiry Skills Scale

Students' responses, which were given to inquiry skills scale before and after teaching, were compared. In doing this, paired samples t-test analysis was used. Findings showed that there was a statistically significant difference ($t_{(50)}$= 3.39; p<.05) between the pretest and posttest scores of the scale as can be seen in Table 8.

Table 8. The comparison of the answers of pre-service teachers to inquiry skills scale before and after teaching.

Inquiry Skills	N	Mean ($\overline{X}$)	SD	df	T	Sig.
Pretest	51	3.7519	.42264	50	3.390	.001*
Posttest	51	4.0003	.53403			

(t=3.390; p<0.05)

Considering the means that are given in Table 8, average of the pre-service teachers' answers in the post test (4.0003) is higher than it is in the pre test. In this study, inquiry skills are analized in three sub categories that are getting information, checking data and self-esteem. Prospective teachers' opinions on these subjects are as follows:

> "I am normally a quiet person. I'm not one who participated in a course. In the physics lab, I was the spokesman and made the conversations, so I've noticed that I've done and turned to. My self-confidence has increased." (self-esteem, student 28)

> "Throughout this course, I destroyed my prejudice against physics completely. I started to learn and love physics. Now I believe I'm going to be a better teacher." (Self-esteem, student 50)

> "We investigated the concepts and then, discussed in the groups. In discussions, I was able to say my ideas freely without being bored. At the end of the each lesson, the teacher helped us to see our shortcomings about the subject to understand it. It was very useful. I found opportunity to learn about myself in this course. I learned how to talk in the community, to explain ideas to other people and experiments were very useful when learning something." (Checking data, self-esteem, student 47)

> "When we came to the classroom, we had some information about the course. Some were right, some were wrong. We learned new ideas from experiments, books and computers by ourselves in this course. Then our teacher went over the details of the subject. We had been provided to make brainstorming about different ideas by working together in our group and other groups. After investigation, we came together with other friends who were in different groups and discussed our opinions about the subject. It was nice to complete our incomplete opinions." (Getting information and checking data, student 49)

CONCLUSIONS

Active learning has been one of the most popular areas of research in recent years. The number of studies conducted on active learning is increasing day by day (Ün Açıkgöz, 2011). In this study, learning environment has been designed by using full studio approach which is known to be one of the active learning approaches. The reason for selecting full studio approach is that it covers course process as a whole compared to other active learning approaches and it is applicable to large classes. Learning process has been enriched with group works and active learning techniques which are aimed at developing inquiry skills in a learning environment that is prepared in accordance with full studio approach.

Several conducted studies showed that active learning techniques increased students' physics achievement, became more effective during the learning of physics concepts and caused students to be more active in classroom activities compared to traditional teaching (Gibson & Chase, 2002; Kalem & Fer, 2003). When students' responses given to the conceptual understanding test were examined it was found that the number of correct responses to the questions increased in the post test.

Active learning is a process in which a learner is responsible for his/her own learning and finds an opportunity to make a decision and observes the outcome of that decision. Curiosity, suspicion, learning by doing, investigation and practice substitute the concept of memorization in active learning (Bonwell & Eison, 1991). Learning environment is not restricted to a class. Inquiry-based learning and group works are the most important characteristics of the active learning (Bell, Uhrarne, Schanze & Ploetzner, 2013). When pre and post test scores of inquiry skills scale were compared it was found that full studio class was successful in improving pre-service teachers' inquiry skills. Also, interview data supported the findings obtained from conceptual understanding test in terms of the quality in students' responses.

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