

## **Informed Teaching and Learning Using Thought-Bubbles for Focusing Student Attention in Engineering Courses**

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# Informed Teaching and Learning Using Thought-Bubbles for Focusing Student Attention in Engineering Courses

Danda B. Rawat<sup>1</sup> and Chandra Bajracharya<sup>2</sup>

## Abstract

Generally, specialized knowledge, skills, and attitudes in students are developed using structured lectures, laboratory session, and projects. For most of the students, it is very difficult to see the connection between topics covered in the lectures or in the course. Thus, there is an urgent need for focusing student attention towards the fundamental or core ideas related to the topic under discussion as take away points. We implement a teaching approach with “thought bubbles”, commonly used in arts and cartoons, to present core ideas to students as discussion questions. “Thought bubbles” (*aka* clouds) are used to pose as introductory questions for initiating lecture/discussion and as concluding thoughts. This approach helps student to be attentive and to grasp what will be covered during the session and again summarize all concepts at the end. There are following benefits of using the proposed approach: a) The proposed approach helps students to prioritize the information and develop critical thinking skills; b) The proposed approach helps student to get a chance to see a clear picture of essential concept and content relevant to the topic as questions through “thought bubbles” posed at the start of each lecture session and revisiting them at the end of the session; and c) The proposed approach helps students to be motivated around key concepts and use that knowledge to connect the dots. This “thought bubbles” based teaching approach requires students to use critical thinking skill and communication skill while discussing the implications and interconnections between key terms and concepts linked to a topic. In this paper, we present a case study based on the “thought bubbles” approach for ‘Cybersecurity (for Networked Systems)’ and ‘Program Design for Engineers’ courses. Note that the proposed approach can be implemented in any other courses in a straightforward manner. Evaluation (qualitative and quantitative) of the proposed approach is performed through adaptive anonymous online-based feedback systems, assessments, and, pre-and post-surveys.

## Introduction

Over the past several years, there has been a great deal of research on how to attract student’s attention in the 21st century where smart phones and social networking (Facebook, Instagram) are dominating their behaviors<sup>1,2,7</sup>. It is easy for students to be distracted by those gadgets if instructor does not present the lecture materials in an interesting and engaging manner. Even though students are exposed to course materials using structured lectures, laboratory session, homework assignments, quizzes, exams and projects for enhancing their knowledge, skills, and attitudes, for most of the students, it is very difficult to see the connection between topics covered in the lectures or in the course if the instructor clearly does not show it<sup>3</sup>. This is much more predominant for students who are below average in the class. Thus, to get attention of all

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students towards the fundamental concepts and core ideas related to the topic under discussion as take away points, course instructor needs to be proactive.

In this paper, we present a new way of delivering the lectures or lab recitations for engineering courses, which is known as “thought bubbles” approach, to present core ideas to students as discussion questions. Furthermore, “thought bubbles” approach encourages students to think more deeply proposing a variety of linked questions about a topic. Note that the “thought bubbles” are generally used in arts and cartoons to represent their opinions or thoughts. In the proposed approach, instructor can start with the one central question followed by several interlinked sub-questions to enhance the interactive teaching-learning experience of the instructor and the students. By using PowerPoint slides with questions with bubble thoughts (alternatively writing them on the board), the instructor can help students to be attentive so that students can grasp what would be covered during the session or what was covered throughout the session. The “thought bubbles” based teaching approach requires students to use critical thinking and communication while discussing the implications and interconnections between key terms and concepts linked to a topic<sup>6</sup>. In this paper, we present a case study based on the “thought bubbles” approach for ‘Cybersecurity for Networked Cyber-Physical Systems’ and ‘Program Design for Engineers’ courses. We present Evaluation (qualitative and quantitative) of the proposed approach through adaptive anonymous online-based feedback systems<sup>4,5</sup> and, pre-and post-surveys. We note that the proposed approach can be applied in others courses in any disciplines in a straightforward manner. Recent related work includes concept map<sup>8</sup> where ideas are linked together in the form of a map. We note that concept map is different from our proposed bubble-thought based teaching and learning approach since we pose concept as well as central and linked questions through bubbles which is not included in concept map. Furthermore, we compare our approach with the other approach such as organizing questions about the materials in a list.

Note that, the main goal of the course ‘Cybersecurity for Networked Cyber-Physical Systems’ is to introduce the contemporary topics related to cybersecurity for cyber-physical systems such as cybersecurity for smart grid systems<sup>9,11,12</sup>, cybersecurity for connected vehicles<sup>10</sup>, cybersecurity for satellite communication systems<sup>10</sup>, cybersecurity for nuclear power plant, cybersecurity for eHealth, and cybersecurity for aerial vehicle networks<sup>14</sup>. Cybersecurity for networked cyber-physical systems<sup>13</sup> involves protection of all resources or assets including stored data, infrastructures, networks, and data in transmission over a network from cyber threats in networked electrical and electronic systems where physical dynamic units are connected and interact over a communication network. Securing networked cyber-physical systems is a major ongoing challenge in today's world. Even though cybersecurity is a very interesting course, students may not see connection how security of one domain is affecting another domain. Similarly, ‘Program Design for Engineers’ is interesting course. However, if the instructor does not present the course materials in an engaging manner, programming course for engineers can be very difficult one for them. This happens since computer programming may not be their long term career path even though it is one of the required courses to graduate with a college degree.

## Thought-bubbles Teaching and Learning Model

In this paper, we propose a novel approach based on thought-bubbles for teaching engineering courses in which the instructor presents lecture/lab topics in thought-bubble format to increase students' attention and enhance their learning outcomes. This approach helps students to become critical thinkers through questions posed using bubble thoughts and proactive feedbacks. In this approach, students also provide feedback to the instructor through a web based anonymous proactive feedback mechanism<sup>5,7</sup> for each topic so that the instructor could revisit the topics in the following class if there are any concerns or question on the topic discussed in the previous class. Main objectives of the proposed “thought bubbles” approach are:

- To prioritize the information and develop critical thinking skills by posing questions at the beginning of the lecture sessions or lab recitation sessions for a given course.
- To allow student to get a chance to see a clear picture of essential concept and content relevant to the topic as questions through “thought bubbles” are posed at the start of each lecture/lab session and revisiting them at the end of each lecture/lab session.
- To help students to be motivated around key concepts and use that knowledge to connect the dots.
- To use thought bubbles to link other supplementary questions related to main question/concept.
- To enhance the teaching and learning process for better outcomes.

To achieve these objectives, instructor follows an approach as shown in Figure 1 where the instructor repeats the process for each topic/class for the course.

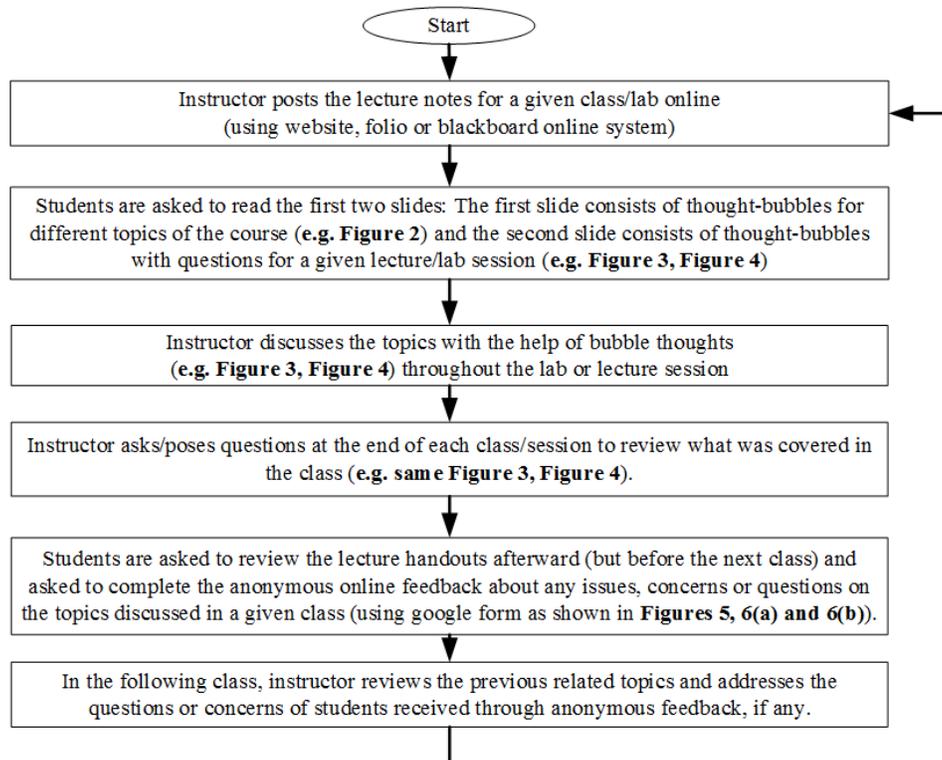


Figure 1 – Typical Flow Diagram for Thought-Bubbles Approach.

The first step for the instructor is to post the lecture slides or handouts online (folio, blackboard online system) with topics covered in the course by linking with each other using bubble-thoughts (e.g. Figure 2 for cybersecurity course) to show their interdependence and links. Main theme question for the course is located at the center of the cloud (thought-bubbles) which is linked with all other topics of the course as shown in Figure 2. This slide reminds how each topic discussed in the class are interlinked and their roles. Furthermore, students can visualize what topics are already covered and what topics are left as well as how different topics are dependent and linked with each other.

Each bubble thought is a chapter or topic which will have its own central/theme question and bubbles with other related questions. For example, for each bubble in Figure 2, there will be main theme question and other questions with thought-bubbles. For instance, “What is the smart energy grid system and why cyber security is important for it” in Figure 2 is one topic which is expanded as in Figure 3 with its own central theme question and other questions with thought-bubbles. Similarly, for other courses, each topic can be presented using thought-bubbles (e.g. “Pointer in C Programming” as shown in Figure 4).

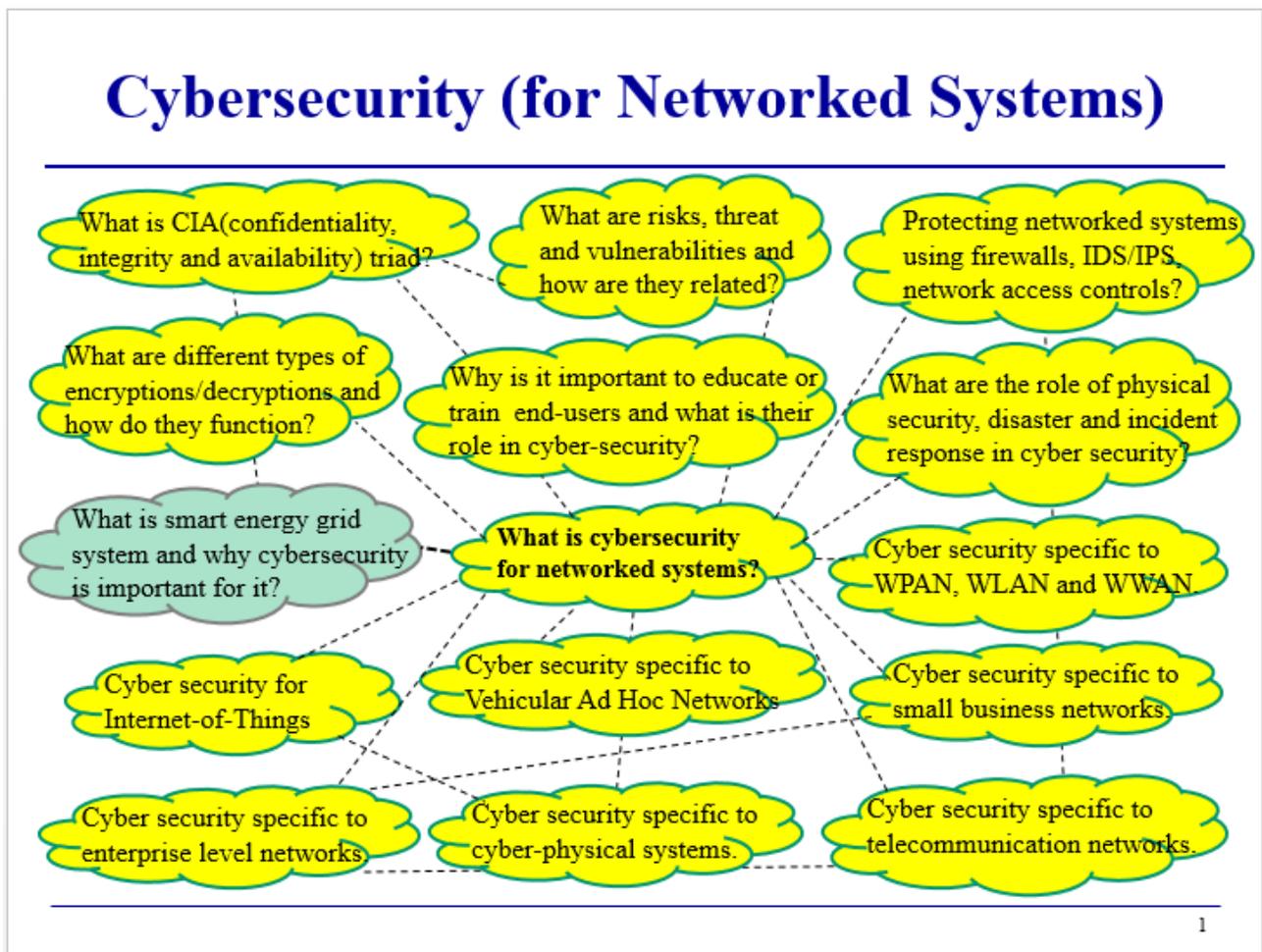


Figure 2 – Sample slide for “Cybersecurity” course (Undergraduate and Graduate Levels)

## Cybersecurity for Smart Energy Grid System

**In today's session, we will address the following questions:**

**What is smart energy grid system and why cybersecurity is important for it?**

- What are typical communication frameworks for smart energy grid?
- What are typical cybersecurity requirements, issues, challenges and motivations in smart grid?
- What are typical and emerging cyber attacks and defense solutions to protect smart grid?
- What are typical smart grid communication protocols and their limitations?
- What are the typical features of smart grid communication networks and their role in security?

2

Figure 3 – Sample slide for “Cybersecurity” course (Undergraduate and Graduate Levels) for “Cybersecurity for Smart Grid Topic”

## Pointer in C Programming

**In today's class, we will address the following questions:**

**What is a pointer in C programming?**

- Why do we care about pointer in C programming?
- How do define a pointer variable?
- How do we pass a pointer variable as a function argument?
- What are Pointer operators?

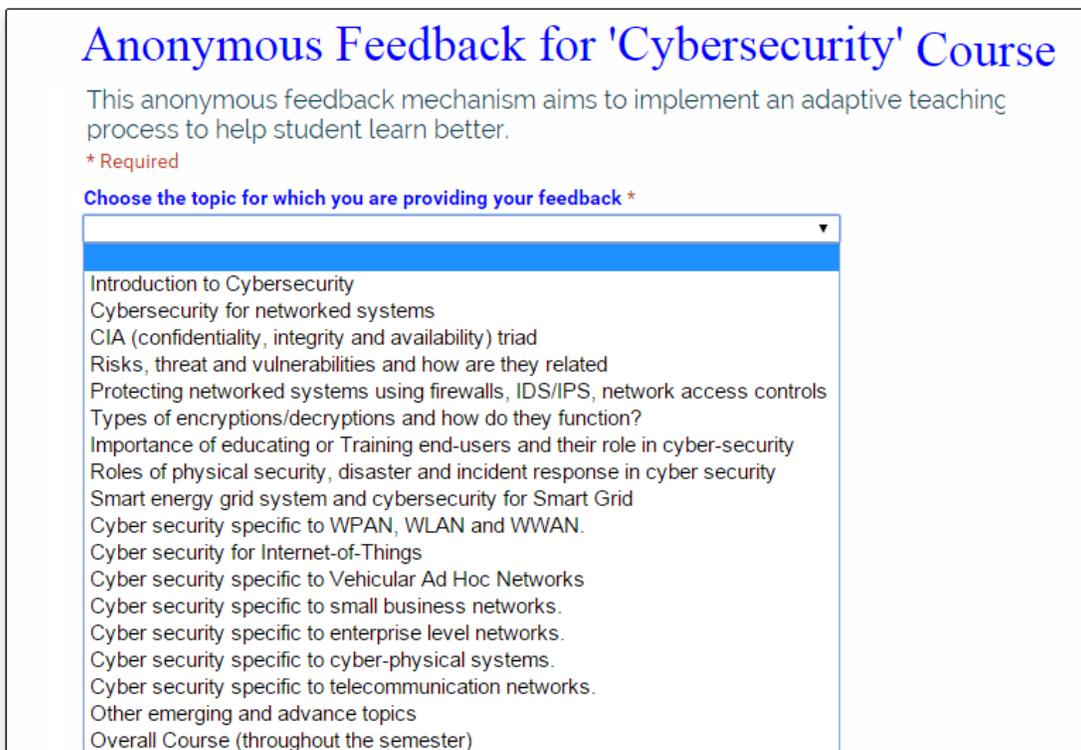
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Figure 4 – Sample slide for “Program Design for Engineers” course (Undergrad) for “Pointer in C Programming” topic.

## Formative Assessment, Evaluation and Survey

In the proposed approach, for assessment and evaluation, the instructor asked a pop-up quiz in the following class after covering a given topic (total 12 quizzes for a given course with 10% towards final grade). All quizzes had questions to assess the student learning outcomes for a given topic and the course. The average grade for quizzes was 4.75 out of 5 in ‘Cybersecurity’ course and 4.55 out of 5 in ‘Program Design for Engineers’ course. Students were also asked to study the lecture handouts after each class at least for 15 minutes and complete the feedback/survey for each topic covered in the course (topics for cybersecurity course are listed in drop down list of anonymous survey in Figure 5 and complete online survey form is shown in Figures 6(a) and 6(b)).

Once students complete the anonymous feedback and submit, the response goes to the instructor without any private information of the students. Instructor reads the anonymous feedback received from students and prepares the responses for the class. In the beginning of the class, instructor presents the responses based on the feedback, if any. Instructor assigns a quiz for 5 minutes or so based on the topic discussed in the previous topic. Then, instructor reviews the previous topic to make smooth transition between previous topic and topic to be discussed following the same approach shown in the Figure 1. Note that the anonymous feedback mechanism gives students an opportunity to ask questions anonymously and fearlessly about the course, topics and comment about the instructor. Furthermore, students, who are doing poorly in the course who are hesitant to ask questions in the class and see the instructor during office hours to not be noticed as poor student, would be able to ask questions through anonymous feedback approach.



**Anonymous Feedback for 'Cybersecurity' Course**

This anonymous feedback mechanism aims to implement an adaptive teaching process to help student learn better.

\* Required

Choose the topic for which you are providing your feedback \*

- Introduction to Cybersecurity
- Cybersecurity for networked systems
- CIA (confidentiality, integrity and availability) triad
- Risks, threat and vulnerabilities and how are they related
- Protecting networked systems using firewalls, IDS/IPS, network access controls
- Types of encryptions/decryptions and how do they function?
- Importance of educating or Training end-users and their role in cyber-security
- Roles of physical security, disaster and incident response in cyber security
- Smart energy grid system and cybersecurity for Smart Grid
- Cyber security specific to WPAN, WLAN and WWAN.
- Cyber security for Internet-of-Things
- Cyber security specific to Vehicular Ad Hoc Networks
- Cyber security specific to small business networks.
- Cyber security specific to enterprise level networks.
- Cyber security specific to cyber-physical systems.
- Cyber security specific to telecommunication networks.
- Other emerging and advance topics
- Overall Course (throughout the semester)

**Figure 5 – Anonymous feedback form for “Cybersecurity” course with list of topics to give feedback to the instructor on a given topic (First drop down list of Figure 6(a)).**

# Anonymous Feedback for 'Cybersecurity' Course

This anonymous feedback mechanism aims to implement an adaptive teaching process to help student learn better.

\* Required

Choose the topic for which you are providing your feedback \*

This is a required question

Were the lecture and content interesting? \*

1 2 3 4 5

Very uninteresting      Very interesting

Were lecture and content adequate in terms of the coverage of the subject? \*

1 2 3 4 5

Poor Coverage      Excellent Coverage

Instructor precisely answered the questions \*

1 2 3 4 5

Not at all      Completely and precisely

What is your overall opinion of this course? \*

1 2 3 4 5

Poor      Very good

What specific things did the instructor do that succeeded in helping you learn in this topic?

Please be specific: interaction with students, analogy, examples, demonstrations, videos, etc.

What specific things did the instructor do that hindered or interfered with your learning in this topic?

Please be specific: too much interaction with students, slides, boring analogy, examples, demonstrations, videos, etc.

Figure 6(a) – Anonymous feedback form for “Cybersecurity” course

List specific, practical suggestions for the instructor that would help improve your learning in this topic?  
Please be specific: too much interaction with students, slides, analogy, examples, demonstrations, videos, etc.

Any Additional Comments  
About instructor, topics, methodology, slides, demonstrations, etc.

[Submit](#)

*Never submit passwords through Google Forms.*

Powered by  Google Forms [Report Abuse](#) - [Terms of Service](#) - [Additional Terms](#)

Figure 6(b) – Anonymous feedback form for “Cybersecurity” course (continuation of Figure 6(a))

### Summative Assessment, Evaluation and Survey

For the summative assessment, instructor had 2 assessments (15% each towards final grade) and final exam (25% towards final grade) for a given course in addition to bi-weekly homework (15% towards final grade) and term paper or term project (20% towards final grade). Bi-weekly homework shows how students are doing in the course and 2 assessments show how they are doing one-third and two-third of a semester in the course. Student can choose either term paper or term project. Term paper allows students to read some emerging and interesting topic related to the course. Typically, textbooks contain at least one year old material (even they are published recently) because of editing, reviewing, publishing and press delays. Thus, term paper allows student to read about recent advances in the topic and do some independent research. This helps them to be a life-longer learner and reader as well as technical writer. If students wish to design, analyze, implement and evaluate some interesting projects, they can choose term project and learn how engineering systems are designed, implemented and evaluated. This provides some hands-on experience for students and provides learning by doing. Term paper and term projects are due by the second-last week of the semester. Students are informed about their grades

regularly through online systems such as folio, blackboard systems, website, etc. Thus students know what grade they will be getting in the class (except the 25% final exam towards final grade). Note that if a student miss the final exam but had received full credit in all other assessments, he/she cannot receive higher than letter grade ‘C’.

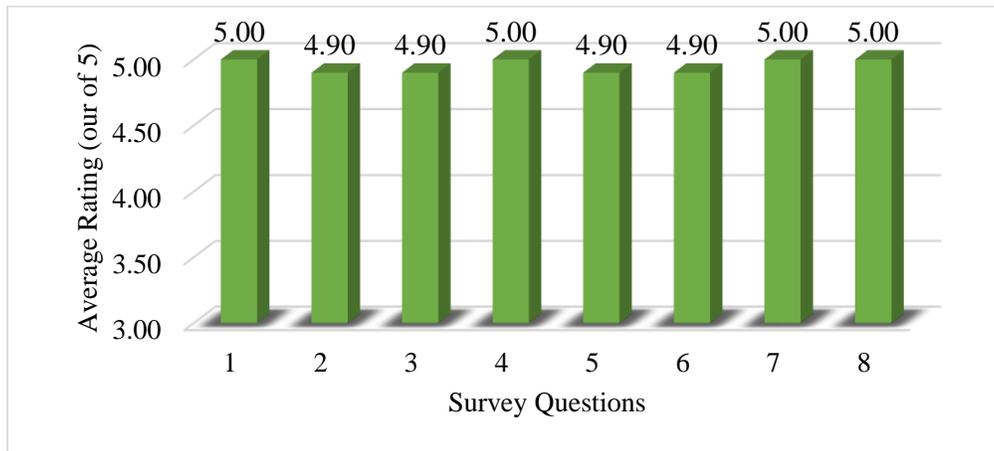
Finally, during the last week of the semester, department does Student Rating of Instruction, *aka* SRI (evaluation of the instructor by the student for each course) independently on behalf of the instructor (form not shown in this paper). Furthermore, instructors also conducts anonymous survey/feedback using a form with questions given in Table 1.

	<b>5-Outstanding</b>	<b>1-Need Improvement</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
	Questions						
1	How do you rate the Thought-Bubble based teaching method?						
2	How do you rate the linking of different lecture sessions using Thought-Bubble based teaching method?						
3	How do you rate the linking of different topics for a given class/session using Thought-Bubble based teaching method?						
4	How do you rate the emphasizing the main question related to the topic (to be discussed) using Thought-Bubble based teaching method?						
5	How do you rate the linking of different questions related to topics using Thought-Bubbles?						
5	How do you rate the emphasizing all questions for a given class/session using Thought-Bubble based teaching method?						
6	How do you rate the Thought-Bubble based teaching method to improve your grade?						
7	How do you rate the Thought-Bubble based teaching method to improve your learning process/outcomes?						
8	How do you rate the Thought-Bubble based teaching method?						
9	How do you rate the instructor for this course?						
10	Should this approach be standardized in all courses? Circle one - Yes or No						

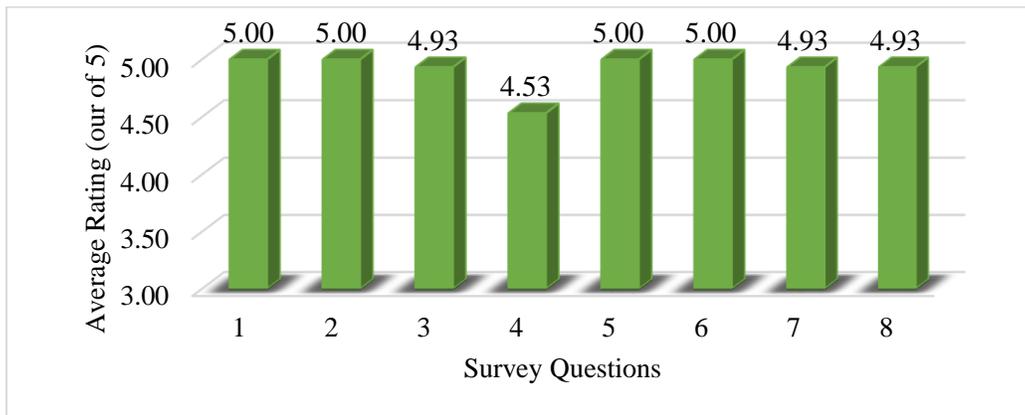
**Table 1 - Anonymous post survey (with questions) conducted at the end of the semester (before the final exam)**

After collecting data from 23 students (10 graduate and 13 undergraduate) in ‘Cybersecurity’ course and 24 undergraduate students in ‘Program Design for Engineers’ course, we plotted scores given by the students for questions 1 through 8 listed in Table 1 as shown in Figure 7 for ‘Cybersecurity’ undergraduate course, Figure 8 for ‘Cybersecurity’ graduate course and Figure 9 for ‘Program Design for Engineers’ course. We observed that all students benefited from the proposed approach as their supplied values are greater than 4.9 for almost all questions. For undergraduate students seemed benefited more than the graduate students as graduate students know little bit more about how different topics or subtopics are interlinked with each other.

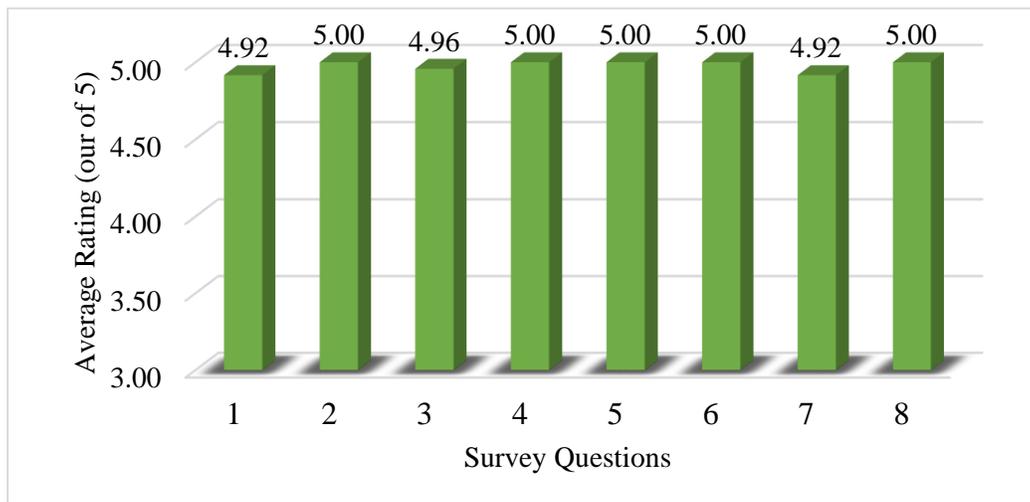
From Figures 7, 8 and 9, we can see that all students enjoyed the thought-bubble approach integrated with proactive anonymous feedback for different courses which help them to enhance their learning skills, concepts, and grades.



**Figure 7 – Survey Outcome for ‘Cybersecurity’ Course (Undergraduate Level)**

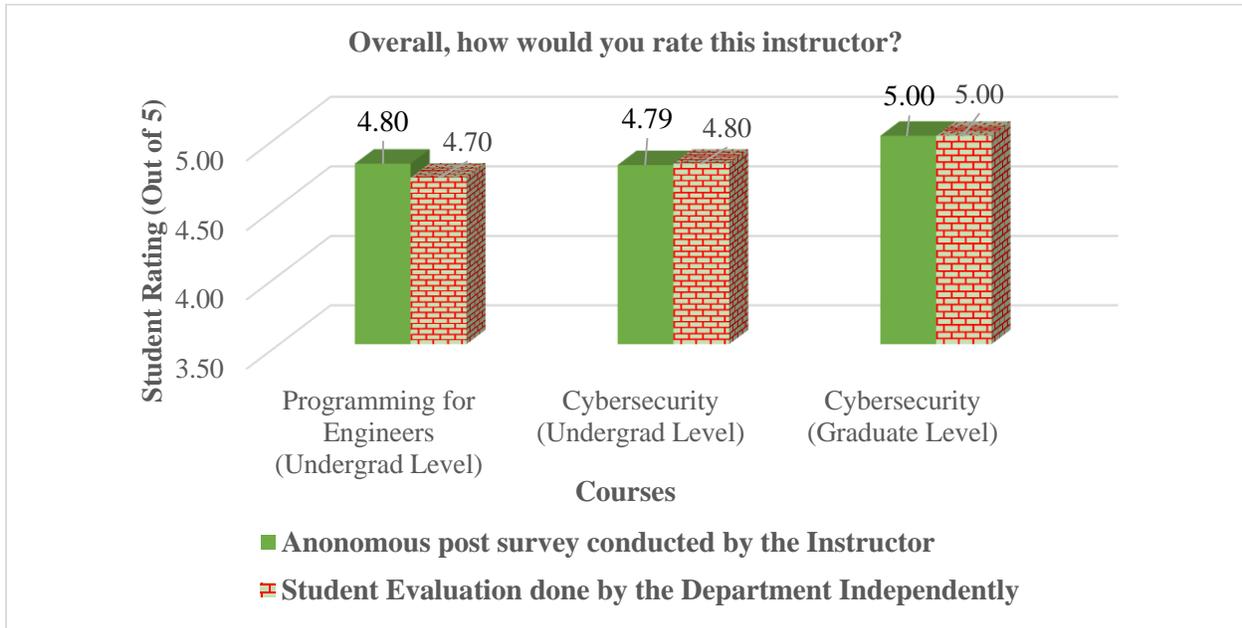


**Figure 8 – Survey Outcome for ‘Cybersecurity’ Course (Graduate Level)**



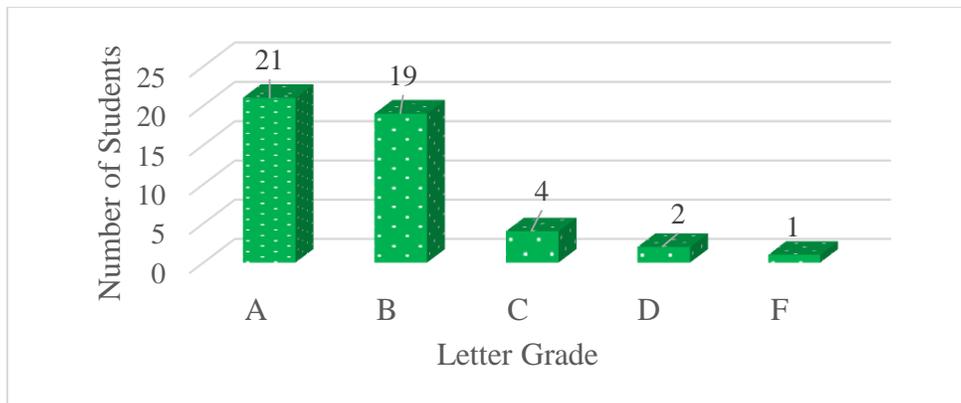
**Figure 9 – Survey Outcome for ‘Program Design for Engineers’ course (Undergraduate)**

Next we plotted the average score variation for question number 9 in Table 1, i.e., ‘How do you rate the instructor for this course?’ Note that this question was also included in the Student Rating of Instruction (SRI) conducted by the instructor’s department on behalf of the instructor. The results of SRI is shared with the instructor in the following semester (to avoid any biasness on students’ grades). We plotted the variation of average score for this question as shown in Figure 10. We observed that the ratings are consistent (within 0.01 difference for undergraduate courses and no difference in graduate courses) as shown in Figure 10. Rating score (average value) for the given question is higher than 4.7 out of 5 in all courses as shown in Figure 10.



**Figure 10 – Student evaluation for “Overall, how would you rate this instructor?” conducted by the instructors in the class and by the instructors’ department independently.**

Next we plotted the final letter grade distribution of students as shown in Figure 11, where we can see that more than 50% students were able to secure good grade. The proposed teaching and learning approach helped them to better understand the topics and concepts.



**Figure 11 – Letter grade distribution for the courses.**

Finally, we plotted the student responses for “Should this approach be standardized in all courses?” as shown in Figure 12. We observed that ~85% of undergraduate student agreed to see this approach adopted in other courses whereas ~65% of the graduate students agreed to see this approach adopted in other courses. As expected, most of the undergraduate students do not know how different topics and concept are interlinked in a given course and what the core concept for a given topic is. Thus thought-bubbles approach helps them to focus on core concepts, connect the dots (different topics and sub-topics) in the course. However, for graduate students interlinking of different sub-topics is somewhat clearer than that for undergraduate students. This may be the reason that fewer graduate students than the undergraduate students agreed to make this approach standardized in all courses. However, majority of graduate students (65%) thought adopting the proposed approach in other courses would help them to understand the topics and concepts.

Few students (high achieving students) did not think that the proposed approach should be adopted as standard approach in other courses because high achieving students may have found that the proposed approach needs little extra time (benefit vs. effort) and found not very beneficial since learning process is natural to them.

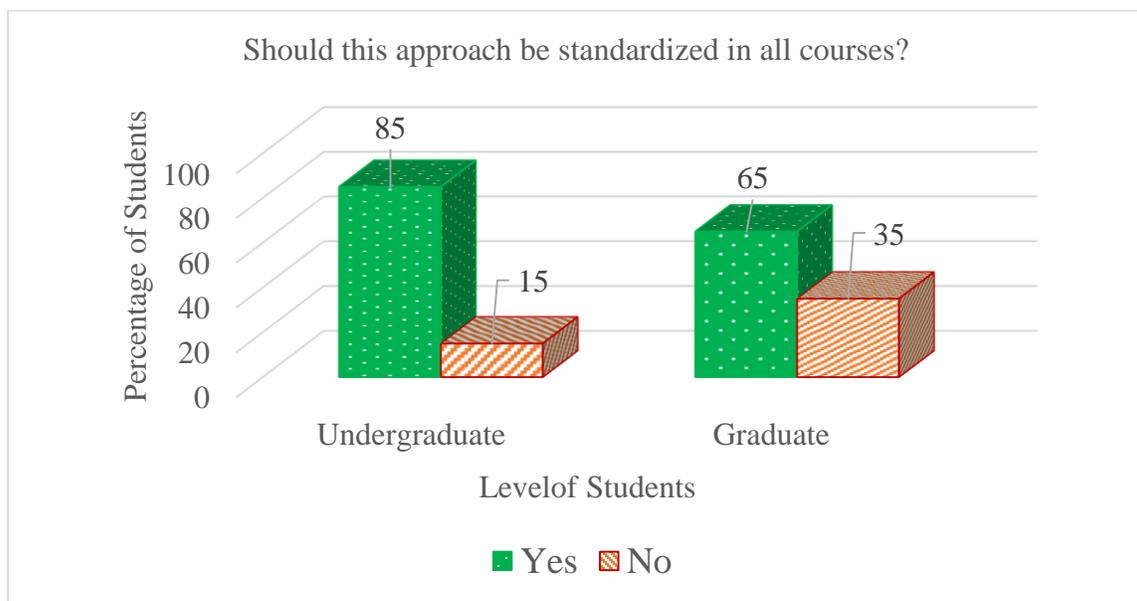


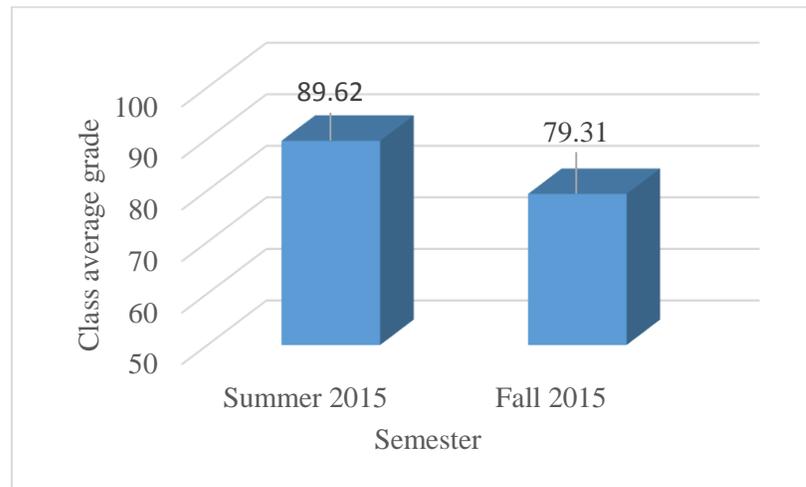
Figure 12 – Letter grade distribution for the courses.

### Additional comments received through anonymous feedback mechanism

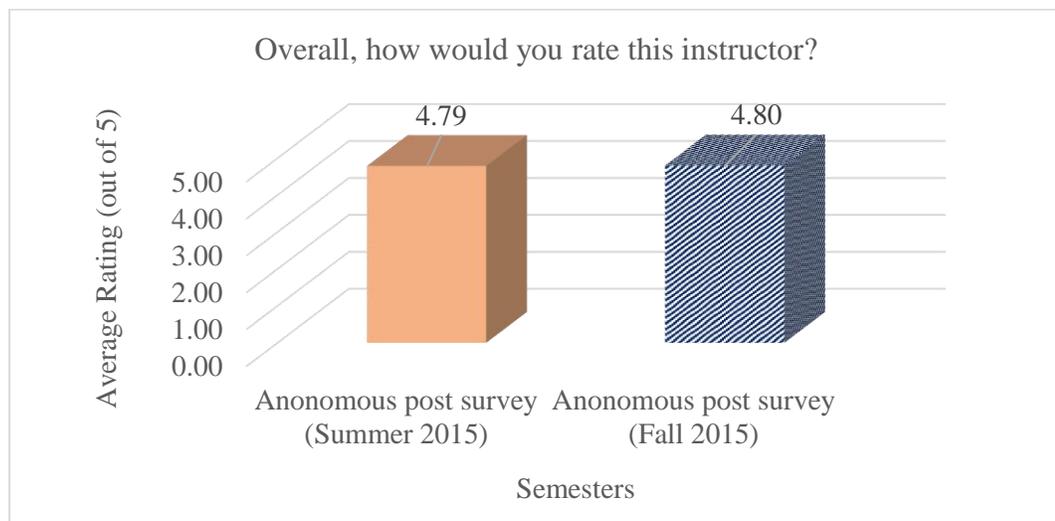
Following are some of the additional comments received from anonymous feedback mechanism provided by the students for undergraduate courses

1. Questions in thought-bubbles help me focus on core concept and ideas
2. This approach is handy and useful to my learning style.
3. I learned more by reading after class to provide feedback and prepare for quizzes.
4. I wish every course/instructor has this approach adopted for me.
5. Having the first slide is very important for me to connect the dots for the course.

Furthermore, the instructor also taught ‘Program Design for Engineers’ course in summer and used a list of questions method instead of bubble-thought process for teaching and learning. Student response was collected through anonymous survey which is compared with the responses received in fall 2015 (where bubble-thought approach was implemented). There was no significant difference in response for “Overall, how would you rate this instructor?” question as shown in Figure 14. However, we observed the significant improvement in terms of students’ grades where average grade of students significantly improved when proposed bubble-thought process was used as shown in Figure 13. We note that the proposed bubble-thought based teaching and learning approach is proactive that encourages each student to be an active participant and learner which enhances student’s overall performance.



**Figure 13 – Comparison of average grade of students for ‘Program Design for Engineers’ course for Summer 2015 semester (where a list of questions instead of bubble-thought approach was used) and Fall 2015 semester (where proposed bubble-thought approach was used).**



**Figure 14 – Comparison of response for the question “Overall, how would you rate this instructor?” for Summer 2015 semester (where a list of questions instead of bubble-thought approach was used) and Fall 2015 semester (where proposed bubble-thought approach was used) for ‘Program Design for Engineers’ course.**

## **Summary and Conclusions**

In this paper, we have presented a novel teaching approach with “thought bubbles”, commonly used in arts and cartoons, to present core ideas to students as discussion questions and show how different subtopics and topics are interlined with each other. The proposed teaching approach is more effective than the traditional PowerPoint or chalkboard presentations. This approach is based on learning by being involved and participating in anonymous feedback mechanism. Generally, specialized knowledge, skills, and attitudes in students are developed using structured lectures, laboratory session, and projects. For most of the students, it is very difficult to see the connection between topics covered in the lectures or in the course. The proposed approach with “thought bubbles” is used to pose as introductory questions for initiating lecture/discussion and as concluding thoughts. Before the actual lecture session, course instructor posts the slides with thought bubbles related to the course and topic to be discussed in the following class. Student review first two slides before coming to the class. Students also provide the feedback on previous topic using anonymous feedback mechanism. Then, instructor discusses the students concerns or questions provided through anonymous feedback mechanism, asks a quiz based on previous topic and starts the discussion on a topic for the class. By doing this, students are not only able to understand the core concept of the topic but also understand how different topics and subtopics are interlinked with each other in a given course. This approach helps student to be attentive and to grasp what will be (was) covered during the lecture session. Using proposed approach student were able a) to prioritize the information and develop critical thinking skills; b) to get a chance to see a clear picture of essential concept and content relevant to the topic as questions through “thought bubbles” are posed at the start of each lecture session and revisiting them at the end of each lecture session; and c) to be motivated around key concepts and use that knowledge to connect the dots. This “thought bubbles” based teaching activity requires students to use critical thinking and communication skills while discussing the implications and interconnections between key terms and concepts linked to a topic. In this paper, we have present results based on the “thought bubbles” approach for ‘Cybersecurity (for Networked Systems)’ course and ‘Program Design for Engineers’ course. However, the proposed approach can be implemented in any other courses in a straightforward manner.

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