

# Development of Online General Chemistry Teaching Materials Integrated with HOTS-Based Media Using the ADDIE Model

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**Abstract:** The 21st century education system prioritizes students to have critical, creative, collaborative thinking skills and communication skills, including higher-order thinking skills. This study aims to develop online teaching materials for HOTS-based integrated General Chemistry courses using the ADDIE model to improve students' higher order thinking skills. This development research resulted in HOTS-based integrated online teaching materials that were feasible and effective in improving students' higher order thinking skills. Through the HOTS-based media integrated online teaching materials produced, students are required and trained to be able to think critically, creatively, analytically towards existing information and data and have the ability to solve problems.

**Keywords:** online teaching materials, media, HOTS, ADDIE

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## 1. INTRODUCTION

The principle of 21st century learning uses a learner-centered learning approach where teachers and lecturers act as facilitators. The quality of an education always refers to the results or academic achievements achieved by students, where good quality education is the goal of education itself [1]. The results of the International Program for International Student Assessment (PISA) study show that the achievement of reading literacy, mathematical literacy, and scientific literacy achieved by Indonesian students is very low and can only occupy the bottom 10 of 65 countries. Furthermore, based on the Education for All Global Monitoring Report 2012 issued by UNESCO, Indonesian education is ranked 64th out of 120 countries. This is because many test materials are not included in the Indonesian curriculum, especially those related to technological and information advancements. In addition, education in Indonesia still places too much emphasis on the cognitive aspect which is still limited to finding numbers, not students' critical analysis abilities of events encountered in everyday life [2].

There are many factors that cause the low results of the PISA study and one of the contributing factors is because students in Indonesia are not trained in solving contextual questions, demanding reasoning, argumentation and creativity in solving them, where these questions are characteristic of the TIMS questions [3]. Various efforts have been made by the government to overcome these problems, including efforts to improve the curriculum to become the 2013 curriculum. One of the efforts to improve the 2013 curriculum is to improve the assessment standards, by gradually adapting the international standard assessment model. Improvements in the assessment of learning outcomes are expected to help students

improve higher order thinking skills (HOTS) and are expected to encourage students to think broadly and deeply about learning materials. HOTS is part of Bloom's taxonomy revised in the form of operational verbs consisting of analysis (C4), evaluation (C5) and creative (C6) which can be used in preparing questions.

The big challenge for the ideal education process is not only to prepare the nation's generation that is able to live today, but the generation that is equipped with the ability to live in the future. Challenges in the global era are increasingly complex and require problem solving with a critical mindset and full of creativity [4]. Most of the problems faced by higher education institutions are how to transfer knowledge and how to develop and ensure professional and up-to-date practical skills [5].

Each individual's higher order thinking ability is certainly different, depending on the exercises that are often done to develop it. In addition to the use of learning strategies or models by teachers/lecturers, another factor that also determines the success of students in learning is the teaching materials used by students as learning resources. Supporting the implementation of an effective learning process cannot be separated from the use of teaching materials. Improving the quality of the learning process in higher education can be done with various strategies and one alternative that can be taken is the development of teaching materials. The development of teaching materials is carried out by a lecturer to solve learning problems by paying attention to the targets or students and also adjusting to the competencies that must be achieved [6].

Teaching materials that can be used by students as a source of independent learning have an important role in improving and

developing higher order thinking skills. Teaching materials can be packaged in printed and non-printed forms [7].

In addition to the use of teaching materials, another factor that a lecturer also needs to consider is the use of innovative and constructive learning media in reconstructing students' knowledge, abilities and creativity. The development of information and communication technology in today's digital era seems to be unstoppable. Currently the world has entered a digital-based industry 4.0 where technology has become the most basic thing and has brought the current generation into the world of digital literacy which has integrated with the conditions of today's society. This condition causes people to be easier, faster and have greater opportunities in finding various information and being able to overcome the limitations of space and time.

There are many factors that influence and play a role in achieving educational goals, one of which is the technology used in educational and learning activities. Utilization of processes and products of communication and information technology to solve educational problems has many benefits or advantages. Various kinds of technology should have been able to be applied in learning activities in the classroom.

An educator, both teachers and lecturers, needs to plan innovative and creative strategies, teaching materials and learning media by utilizing technology-based learning. One of the media that can be applied in the learning process is Adobe Flash media. The use of interactive learning media with Adobe Flash can be used as an alternative learning media and is able to make learning more varied, attract student learning interest, and get a positive response from students [8], it is hoped that students can directly see simulations/images that resemble actual phenomena, so that students are able to understand at once [9].

The development of teaching materials by utilizing online-based computer technology using the internet network and integrated HOTS-based media, it is necessary to pay attention to the development model to ensure the quality of teaching materials in supporting the efficiency and effectiveness of learning, because the development of online teaching materials is basically a linear process with the learning process. In addition, the teaching materials that are prepared and developed must also be adapted to the needs of the learning objectives.

One of the teaching materials development models that is often used is the ADDIE model through five stages of activities, namely Analysis, Design, Development, Implementation and Evaluation. The development process requires several times of testing a team of experts, individual research subjects, on a limited scale and on a wide scale (in the field) and revisions to improve the final product so that although the development procedure is shortened, it includes a testing and revision process so that the product developed has met the product criteria. good, empirically tested and no more mistakes [10].

## 2. METHOD

This research belongs to the type of research and development (R&D), and the results of this development research are online teaching materials or digital books integrated with Adobe Flash media based on Higher Order Thinking Skills (HOTS) in General Chemistry courses (Stoichiometry material, Inorganic Compounds and Organic Compounds). The development model used refers to the ADDIE development model which is a more generic learning design

model, namely as one of its functions to build tools and infrastructure for training programs that are effective, dynamic and support the performance of the training itself [11].

The ADDIE development model uses 5 stages as the name implies, namely: Analysis, Design, Development, Implementation, and Evaluation. The idea of the ADDIE model is to receive feedback continuously and continuously while building learning materials. The existence of this model is expected to save time and costs by capturing problems when these problems can still be fixed [12].

The procedure for developing online teaching materials integrated with HOTS-based media is carried out through several stages, including: (a) Analysis, namely conducting an analysis to collect information related to student needs and reviewing literature related to the product being developed; (b) Design, is the stage carried out to identify goals and design teaching materials and learning media to be developed; (c) Development, is the stage to realize the design into a product that is ready to be implemented; (d) Implementation, namely implementing the developed product in the form of online teaching materials integrated with HOTS-based Adobe Flash media; and (e) Evaluation, which is to evaluate by analyzing the effectiveness of online teaching materials that are integrated with HOTS-based Adobe Flash media on students' higher order thinking skills (HOTS).

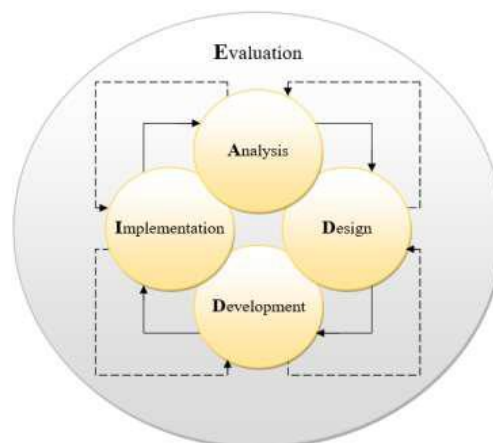


Figure 1. ADDIE Development Model

The techniques and instruments used in this study include (a) interviews used for data collection when conducting research as a preliminary study material to look for problems to be studied and used in product trials both during validation to experts and product trials in the field as considerations in improving the teaching materials developed; (b) the validation sheet used to obtain data on the results of the expert's validation of HOTS-based integrated media teaching materials developed to test their feasibility or validity; and (c) a test instrument designed to obtain data on students' higher order thinking skills. The test is structured and developed according to the HOTS indicators including C4, C5 and C6.

The research data were analyzed in stages to determine the feasibility (validity) and effectiveness of the teaching materials in the developed network. The data from the validation results of the experts were analyzed by considering the input, comments, and suggestions from the validator. The results of the analysis are used as guidelines for revising the developed teaching materials. The validity of the teaching materials that have been made can be analyzed from the

validation sheet filled in by the expert validator and the results of questions and answers during the validation process. The effectiveness of the developed teaching material products is obtained from the results of the students' higher order thinking ability (HOTS) test. The effectiveness test of the teaching materials developed was analyzed from the increase in HOTS with a t-test with a paired sample t-test approach with the help of the SPSS program.

### 3. RESEARCH RESULTS

#### 3.1 Feasibility of online teaching materials

The feasibility (validity) of online teaching materials in General Chemistry courses (Stoichiometry materials, Inorganic Compounds and Organic Compounds) developed, evaluated and assessed by expert validators.

**Table 1. Online teaching materials validation results**

Assessment Aspect	Validator (Mean Score)			Total Mean	Criteria
	I	II	III		
Contents	4.22	4.39	4.20	4.27	Valid
Presentation	4.13	4.30	4.20	4.21	Valid
Language	4.07	4.33	4.22	4.21	Valid
Graphics	4.09	4.33	4.33	4.25	Valid
Mean total				4.23	Valid

Table 1 shows the results of the expert validator's assessment on online teaching materials for the General Chemistry course, which obtained an average total score of 4.23 or declared valid. on the aspect of the feasibility of the content obtained an average score of 4.27 (valid); on the aspect of feasibility of presentation obtained an average score of 4.21 (valid); on the aspect of language feasibility obtained an average score of 4.21 (valid); and in the aspect of graphics obtained an average score of 4.23 (valid). Overall, the results of the assessment by expert validators concluded that the online teaching materials in General Chemistry courses (materials on Stoichiometry, Inorganic Compounds and Organic Compounds) that were developed had met the valid criteria.

#### 3.2 HOTS-based media feasibility

The feasibility (validity) of the HOTS-based media in the General Chemistry course (Stoichiometry, Inorganic Compounds and Organic Compounds) developed, was evaluated by expert validators based on the material and media aspects.

**Table 2. Results of HOTS-based media validation on material aspects**

Assessment Aspect	Validator (Mean Score)			Total Mean	Criteria
	I	II	III		
Coverage and depth of material	4.18	4.17	4.42	4.25	Valid
Accuracy of presentation	3.59	3.95	4.36	3.96	Valid

(systematic) material					
Suitability and clarity of animation	3.78	4.06	4.24	4.02	Valid
Clarity of formulas/symbols	4.00	4.13	4.24	4.12	Valid
The accuracy of the sample questions in each learning activity	4.00	4.00	4.59	4.20	Valid
The accuracy of the answers to the evaluation questions in each learning activity	4.00	4.00	4.00	4.00	Valid
HOTS Rating	4.40	4.30	4.90	4.53	Valid
Mean total				4.16	Valid

Table 2, shows the results of the material expert validator's assessment on HOTS-based media, obtained an average total score of 4.12 or declared valid. In the aspect of coverage and depth of material obtained an average score of 4.25 (valid); on the aspect of presentation accuracy (systematic) the material obtained an average score of 3.96 (valid); on the aspect of suitability and clarity of animation obtained an average score of 4.02 (valid); on the aspect of clarity of formulas/symbols obtained an average score of 4.12 (valid); on the aspect of the accuracy of the sample questions in each learning activity obtained an average score of 4.20 (valid); on the aspect of the accuracy of the answers to the evaluation questions in each learning activity obtained an average score of 4.00 (valid); and in the HOTS rating assessment aspect, an average score of 4.53 (valid) was obtained. Overall, the results of the assessment by expert validators on the material aspect concluded that the HOTS-based media developed had met the valid criteria and could be applied to learning.

**Table 3. Results of HOTS-based media validation on the media aspect**

Assessment Aspect	Validator (Mean Score)			Total Mean	Criteria
	I	II	III		
Software engineering	4.15	3.85	4.30	4.10	Valid
Interface display	4.11	4.23	4.22	4.19	Valid
Visual communication	4.19	4.20	4.05	4.15	Valid
Mean total				4.14	Valid

Table 3, shows the results of the media expert validator's assessment on HOTS-based media, obtained an average total score of 4.14 or declared valid. In the software engineering aspect, the average score is 4.10 (valid); on the aspect of the interface display an average score of 4.19 (valid); and in the

aspect of visual communication obtained an average score of 4.15 (valid). Overall, the results of the expert validator assessment on the media aspect concluded that the HOTS-based media developed had met the valid criteria and could be applied in learning.

### 3.3 Student HOTS achievements

The achievement of student learning outcomes is obtained through the HOTS test given before and after utilizing the HOTS-based integrated online teaching materials produced. This stage is carried out on 30 students and each material is carried out in 3 (three) stages including: (1) the initial stage, namely giving an initial HOTS test (pretest) before students are given action using the resulting HOTS-based online teaching materials, (2) the second stage, namely the learning process in which students learn online with online teaching materials integrated with HOTS-based media that can be accessed and downloaded using a laptop or computer on the Chemistry Education Department's e-learning site, and (3) the third stage, namely giving the final HOTS test (posttest).

**Table 4. Achievement of student HOTS results**

HOTS	Min	Max	Mean	Std. Dev.	K-S Test	Sig
Pretest	44	70	58.87	5.794	.972	.301
Posttest	72	98	88.67	7.227	.973	.300

Table 4 shows the achievement of students' initial HOTS test results (pretest) before being given the action, the lowest score was 44, the highest score was 70 with an average value of 58.87 and a standard deviation of 5.79 and the data had a normal distribution with a Kolmogorov-Smirnov test value of 0.972. with a probability or Sig of 0.301 > 0.05. After taking action through learning using online teaching materials integrated with HOTS-based media, the posttest results obtained the lowest score of 72, the highest score of 98 with an average HOTS value of 88.67 and a standard deviation of 7.227 and the data has a normal distribution with the Kolmogorov-Smirnov value. test is 0.973 and the probability or Sig is 0.300 > 0.05.

### 3.4 Product effectiveness

The effectiveness of teaching material products in the network (online) integrated HOTS-based media that was developed was analyzed based on the increase in learning outcomes obtained by students in completing the HOTS test using a pretest-posttest design.

**Table 5. Product effectiveness test results**

	Paired Differences		t	df	Sig (2-tailed)	
	Mean	Std. Deviation				
Pair 1	Posttest -pretest	29.800	7.919	20.610	29	.000

Table 5 shows the results of the t-test with the paired sample t-test approach and the average difference or difference in the posttest-pretest HOTS scores of students is 29.800 with a standard deviation of 7.919 and a t-value of 20.610 with probability or Sig. of 0.000 < 0.05. Thus, it is concluded that

the application of integrated online teaching materials based on HOTS-based media that has been developed has proven to be effective in increasing student HOTS in General Chemistry courses (Stoichiometry, Inorganic Compounds and Organic Compounds material).

## 4. CONCLUSION

This research and development resulted in online teaching materials integrated with HOTS-based media in General Chemistry courses (Stoichiometry material, Inorganic Compounds and Organic Compounds) through the ADDIE development model. Teaching materials are developed and designed in an integrated manner with HOTS-based media that trains students to think critically, creatively, analytically towards information and data to solve problems that exist in the teaching materials and media developed. The HOTS-based integrated online teaching materials produced can also be accessed by students online and have met valid criteria and have been proven effective in improving students' HOTS abilities.

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# Development of CBT Integrated E-Module to Improve Student Literacy HOTS

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**Abstract:** Generations in the 21st century must be prepared to have HOTS literacy competencies and skills. The application of HOTS literacy in the learning process makes students more resilient and able to solve their own problems. This study aims to develop an integrated CBT e-module to improve student literacy HOTS. The resulting e-module has met the valid criteria and has proven to be effective in increasing student literacy HOTS. Student responses to the resulting e-modules are also very positive because the e-modules are designed using the Kvisof Flipbook Maker application which can be opened on laptops, computers or Android devices so that material can be repeated anytime and anywhere as well as HOTS materials and questions. compiled based on CBT to train and improve student literacy HOTS.

**Keywords:** e-module, CBT, HOTS literacy

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## 1. INTRODUCTION

The development of modernization and globalization of the 21st century has had a tremendous impact. One of the worrisome impacts is the inability of children (students) independently to know, understand, and overcome problems around them. For the Indonesian people, another impact that is felt due to the challenges of modernization and globalization is the low thinking skills of students [1]. The results of the PISA study show that the achievement of reading literacy, mathematical literacy, and scientific literacy achieved by Indonesian students is very low and has only been able to occupy the bottom 10 of 65 countries. Furthermore, based on the 2012 Education for All Global Monitoring Report issued by UNESCO, Indonesian education is ranked 64th out of 120 countries. This is because many test materials are not included in the Indonesian curriculum, especially those related to technological and information advancements. In addition, education in Indonesia still places too much emphasis on the cognitive aspect which is still limited to finding numbers, not students' critical analysis abilities of events encountered in everyday life [2].

The low level of higher order thinking skills (HOTS) is not only experienced by students at the school level, but this also happens to students at the tertiary level. The results of the initial study conducted, it was found that there were still many new students whose higher-order thinking skills were still low, including in the General Chemistry course. The results of the analysis, it was found that most students still had difficulty solving HOTS questions on indicators C4, C5, and C6 [3].

Studying in university should be very different from studying in pre-university schools. Learning at the university does not only provide courses, topics, and strategic concepts, but is also expected to provide a learning experience that allows students' independent learning abilities to develop. Independent learning is learning with your own initiative, responsibility, and effort [4]. However, the main problem in learning in higher education is how to plan and prepare lecturers to manage learning in order to achieve the desired competencies in students [5].

When students are directed to be able to think critically, creatively and able to solve problems, it means that students are targeted to have high-order thinking skills (HOTS) [6]. HOTS is learning designed to prepare the 21st century generation. The 21st century generation must be prepared to have competencies and skills which include: critical thinking and problem solving competence, creativity, communication skills, and the ability to work together [7]. HOTS measures the ability to: a) transfer concepts, b) process and apply information, c) relate different kinds of information, d) solve problems using information, and e) examine ideas and information critically. HOTS is defined as the ability to use the mind to solve problems at hand. Therefore, one must understand, interpret, analyze, and interpret information. HOTS also teaches a person to be critical in evaluating information, making conclusions, and making generalizations. In the revised Bloom's Taxonomy, HOTS is a cognitive ability at the level of application, analysis, evaluation, and innovation [8].

The most important thing in 21st century education is to encourage students to have a deep knowledge base and understanding to be able to become life-long learners. Thus, the education system needs to consider a number of aspects that are domains in 21st century education, one of the most important domains in 21st century education is digital-age literacy. In the 21st century, literacy skills are not only limited to the ability to read, listen, write and speak orally, but more than that, literacy skills are emphasized on literacy skills that are connected to one another in the current digital era [9].

The success of learning, including in higher education, must also be accompanied by the availability of learning tools, including teaching materials. Teaching materials are not only in the form of books or worksheets based on print media. Non-print-based teaching materials can also be used in learning, for example in the form of electronic teaching materials. Currently, electronic-based teaching materials can be easily obtained due to the presence of information technology network devices. Through this information technology network, educators can use it as teaching materials

easily. The ease of accessing networks and information technology is an advantage for the world of education. The world of education can be used as a means of advanced learning and learning is not only conventional but can also be integrated through online.

One form of online learning is by utilizing media and teaching materials in the form of e-modules or can be called electronic modules. An E-Modul or electronic module is an electronic version of a printed module that can be read on a computer and designed with the required software. E-module is a tool or learning tool that contains materials, methods, limitations and ways of evaluating which are designed systematically and attractively to achieve the expected competencies according to the level of complexity electronically. E-module is a display of information in book format that is presented electronically using a hard disk, diskette, CD, or flash disk and can be read using a computer or electronic book reader [10].

In addition to the ability to develop the learning process, an educator, both teachers and lecturers, is required to have the ability to evaluate and assess student learning outcomes. The ability of educators in mastering evaluation techniques is indicated by their ability to design evaluation patterns, develop instruments, set goals, see the results obtained by students, and choose appropriate actions as an effort to follow up on the results of evaluations and assessments. Therefore, an educator, both teachers and lecturers, must be able to make the right evaluation media, because the evaluation media is very influential in increasing students' understanding and learning achievement. On the other hand, if the evaluation media is not appropriate, there will be errors in measuring learning outcomes and students' understanding.

The 21st century, with the rapid development of information and technology, also demands changes and adjustments in evaluation activities which generally use paper and pencil based tests (PBT) which have now turned into computer based tests (CBT), namely evaluation activities or assessments using computer media and based online. managed by server [11]. CBT is a test used to measure learning achievement using a computer [12], through internet access with the assessment carried out automatically by the computer [13], so don't need paper, pen or pencil to answer every question [14], Student responses to tests can be stored and analyzed electronically and widely used [15].

Seeing the existing phenomena related to the development of modernization and globalization of the 21st century as well as the rapid development of information and technology, it is necessary to develop an e-module on CBT integrated General Chemistry learning which is expected to support the implementation of an effective and efficient learning process. The development of the integrated CBT e-module is expected to facilitate lecturers and students in the learning process of General Chemistry (Biochemistry, Solutions, Thermochemistry) and is expected to assist lecturers in conducting diagnostic tests and in making academic policies for students.

The e-module developed in this study uses the Kvisof Flipbook Maker software or application, which is an application to create e-books, e-modules, e-papers and e-magazines. In general, this multimedia device can include files in the form of pdf, images, videos and animations so that the flip book maker is made more attractive. In addition, flip book maker has design templates and features such as background, control buttons, navigation bar, hyperlinks and back sound. Students can read by feeling like reading a book

physically because there is an animation effect where when switching pages it will look like physically opening a book. The final result can be saved to html, exe, zip, screen saver and app formats [16].

## 2. METHOD

This research belongs to the type of research and development (R&D), and the result of this development research is an integrated CBT e-module in General Chemistry courses (Biochemistry, Solutions, Thermochemistry). The development model used refers to the ADDIE development model which is a more generic learning design model, namely as one of its functions to build training program tools and infrastructure that are effective, dynamic and support the performance of the training itself [17].

The ADDIE development model uses 5 stages as the name implies, namely: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model in designing instructional systems uses a systems approach. The essence of the systems approach is to divide the learning planning process into several steps, to organize the steps into logical sequences, then use the output of each step as input for the next step [18].

The procedure for developing an integrated CBT e-module is carried out through several stages, including: (a) Analysis, namely conducting an analysis to collect information related to student needs and reviewing literature related to the product being developed; (b) Design, is the stage carried out to identify goals and design teaching materials and learning media to be developed; (c) Development, is the stage to realize the design into a product that is ready to be implemented; (d) Implementation, namely implementing the developed product in the form of an integrated CBT e-module; and (e) Evaluation, namely conducting an evaluation by analyzing the effectiveness of the integrated CBT e-module on students' higher order thinking skills (HOTS).

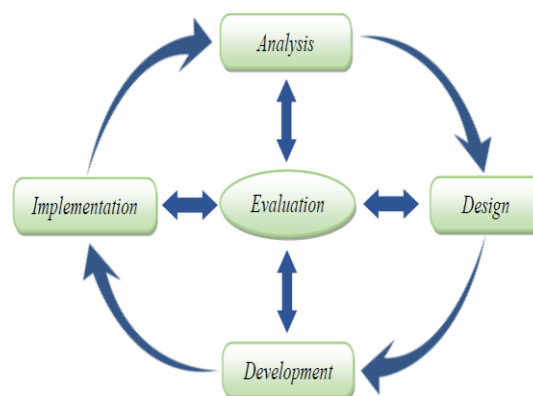


Figure 1. ADDIE Development Model

The techniques and instruments used in this study include (a) interviews used for data collection when conducting research as a preliminary study material to look for problems to be studied and used in product trials both during validation to experts and product trials in the field as consideration in improving the developed e-module; (b) validation sheet used to obtain data on the results of expert validation on the integrated CBT e-module developed to test its feasibility or validity; and (c) a test instrument designed to obtain data on CBT-based student literacy HOTS. CBT is prepared and developed in accordance with HOTS literacy indicators including C4, C5 and C6 on Biochemistry, Solutions, Thermochemical materials.

The research data were analyzed in stages to determine the feasibility and effectiveness of the developed CBT integrated e-module. The data from the validation of the experts were analyzed by considering the input, comments, and suggestions from the validator. The results of the analysis are used as guidelines for revising the developed teaching materials. The validity of the e-module that has been made can be analyzed from the validation sheet filled in by the expert validator and the results of questions and answers during the validation process. The effectiveness of the developed CBT integrated e-module is obtained from the results of CBT on students' higher order thinking skills (HOTS). The effectiveness test was analyzed from increasing literacy HOTS with a t-test with a paired sample t-test approach with the help of the SPSS program.

### 3. RESEARCH RESULT

The product developed in this study is in the form of an integrated CBT e-module in the General Chemistry course on Biochemistry, Solutions and Thermochemistry. E-modules are compiled and developed using the Kvisof Flipbook Maker application so that students can read by feeling like reading a book physically with the help of a computer, laptop or Android because there is an animation effect where when switching pages it will look like physically opening a book. Validation or feasibility of the integrated CBT e-module is evaluated by expert validators in their field. The products produced and have been declared feasible by expert validators are then applied to students to analyze the effectiveness of the products produced.

#### 3.1 Product feasibility

The feasibility (validity) of the e-module in the General Chemistry course for Biochemistry, Solutions and Thermochemistry developed, evaluated and assessed by expert validators based on the feasibility of the material and the feasibility of the media.

**Table 1. E-module validation results on the material aspect**

Course	Aspects of assessment	Mean Score	Criteria
Biochemistry	Content feasibility	4.11	Valid
	Serving feasibility	4.23	Valid
	Language feasibility	4.15	Valid
	HOTS rating	4.20	Valid
	Total Mean	4.16	Valid
Solutions	Content feasibility	4.28	Valid
	Serving feasibility	4.10	Valid
	Language feasibility	4.26	Valid
	HOTS rating	4.27	Valid
	Total Mean	4.23	Valid
Thermochemistry	Content feasibility	4.11	Valid
	Serving feasibility	4.23	Valid
	Language feasibility	4.15	Valid

	HOTS rating	4.20	Valid
	Total Mean	4.16	Valid

Table 1, shows the results of the assessment and evaluation of material expert validators in the e-module of the General Chemistry course for Biochemistry, Solutions and Thermochemistry. The results of expert validation on biochemical material obtained an average total score of 4.16 or declared valid. The results of expert validation on the solution material obtained an average total score of 4.23 or declared valid. The results of expert validation on thermochemical material obtained an average total score of 4.16 or declared valid. Thus, overall the results of the material expert validator's assessment concluded that the e-module of the General Chemistry course on Biochemistry, Solutions and Thermochemistry developed had met the valid criteria in the material aspect so that it was feasible to be applied in learning.

**Table 2. E-module validation results on the media aspect**

Course	Aspects of assessment	Mean Score	Criteria
Biochemistry	Software	4.30	Valid
	Interface view	4.11	Valid
	Visual communication	4.04	Valid
	Characteristics of e-module	4.27	Valid
	Total Mean	4.18	Valid
Solutions	Software	4.23	Valid
	Interface view	4.19	Valid
	Visual communication	4.13	Valid
	Characteristics of e-module	4.27	Valid
	Total Mean	4.20	Valid
Thermochemistry	Software	4.30	Valid
	Interface view	4.11	Valid
	Visual communication	4.04	Valid
	Characteristics of e-module	4.27	Valid
	Total Mean	4.18	Valid

Table 2, shows the results of the assessment and evaluation of media expert validators in the e-module of the General Chemistry course for Biochemistry, Solutions and Thermochemistry. The results of media expert validation on biochemical material obtained an average total score of 4.18 or declared valid. The results of media expert validation on the solution material obtained an average total score of 4.20 or declared valid. The results of media expert validation on thermochemical material obtained an average total score of 4.18 or declared valid. Thus, overall the results of the media expert validator's assessment concluded that the e-module of the General Chemistry course on Biochemistry, Solutions and



Thermochemistry developed had met the valid criteria in the media aspect so that it was feasible to be applied in learning.

### 3.2 Achievement of student literacy HOTS

Student literacy HOTS achievements are obtained through CBT-based tests given before and after utilizing the resulting CBT integrated e-module. This stage is carried out to 30 students and each material is carried out in 3 (three) stages including: (1) the initial stage, namely giving a CBT-based pretest before students take action using the resulting CBT integrated e-module, (2) the second stage, namely the learning process in which students learn online by utilizing the integrated CBT e-module, and (3) the third stage, namely the administration of the CBT-based final HOTS test (posttest).

**Table 3. Achievement of student literacy HOTS**

HOTS Literacy	Min	Max	Mean	S. Dev	K-S Test	Sig
Pretest	48	72	60.87	6.073	0.953	0.324
Posttest	76	100	90.47	5.865	1.113	0.168

Table 3 shows the achievement of the students' initial literacy HOTS test results (pretest) before being given the e-module, the lowest score was 48, the highest score was 72 with an average value of 60.87 and a standard deviation of 6.073 and the data had a normal distribution with the Kolmogorov-Smirnov score. test = 0.953 and  $p = 0.324$ . After taking action through learning using an integrated CBT e-module, the posttest results obtained the lowest score of 76, the highest score of 100 with an average student literacy HOTS score of 90.47 and a standard deviation of 5.865 and the data has a normal distribution with the Kolmogorov-Smirnov value. test = 1.113 and  $p = 0.168$ .

### 3.3 Product effectiveness

The effectiveness of the developed General Chemistry e-module was analyzed from the increase in student learning outcomes in completing the literacy HOTS test using a pretest-posttest design. The test results were analyzed using a t-test or a paired sample t-test approach using the SPSS program.

**Table 4. Test results paired sample t-test**

	Paired Differences		t	df	Sig
	Mean	Std. Deviation			
Pair 1 Posttest -pretest	29.600	8.024	20.205	29	0.000

Table 4 shows the results of the t-test with the paired sample t-test approach and the average difference or difference in the posttest-pretest HOTS scores for student literacy is 29,600 with a standard deviation of 8024 and a t-value of 20,205 with probability or Sig. of  $0.000 < 0.05$ . Thus, it is concluded that the application of integrated online teaching materials based on HOTS-based media that has been developed has proven to be effective in increasing student HOTS in General Chemistry courses (Stoichiometry, Inorganic Compounds and Organic Compounds material).

## 4. CONCLUSION

This research and development resulted in an integrated CBT e-module in General Chemistry courses (Biochemistry, Solutions and Thermochemistry materials). E-Modules are developed using the Kvisof Flipbook Maker software or application through the ADDIE development model. The resulting CBT integrated e-module has met the valid criteria and has been proven to be effective in increasing student literacy HOTS. The validity is met qualitatively based on the assessment of the validators of material experts and media experts which are overall stated in the valid category. The effectiveness is fulfilled based on the implementation of learning using integrated CBT e-modules and evidenced by the increase in student literacy HOTS achievements and from the results of statistical hypothesis testing. Student responses to the resulting e-modules are also very positive because the e-modules are designed using the Kvisof Flipbook Maker application so that students can read by feeling like reading a book physically because there is an animation effect where when moving page by page it will look like physically opening a book. This e-module can also be opened on a laptop, computer or android device and can be run offline so that the material can be repeated anytime and anywhere, besides that the material and questions contained in the e-module are arranged in an integrated CBT.

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## Survey on Sanitizing Drones

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**Abstract:** The COVID-19 pandemic has profoundly altered common social and economic patterns. With the clear need to sanitize and disinfect. The drone can effectively disinfect areas without human intervention with remote monitoring. The Quadcopter is Remote controlled which enables remote monitoring to disinfect the required areas. The Quadcopter is designed in such a way that it can carry the required payload up to 12 feet and disinfect the areas without human intervention.

**Keywords:** Covid-19, Drone, Quadcopter, Sanitizer, ESC, Li-Po Battery, Motors.

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### 1. INTRODUCTION

Covid-19 has led the world to an unprecedented public health crisis. Corona virus outbreak features a significant impact on health, economy and standard of living for the people around the world. To beat the difficulties caused by pandemic, we should evaluate any alternative technique to confront the new coronavirus.

At present world drone technology is incredibly familiar and versatile. Nowadays Drones are employed in long range wars as a weapon and also as a helper of fighter within the war. Drones, because the foremost dynamically developing an element of the aviation industry, are going to be a awfully special tool within the hand of experts fighting against this pandemic. It has been effectively employed within the past for an unlimited number of applications including spraying pesticide in agricultural fields.

Drones could also be effectively accustomed perform the sanitization process. A drone mounted sprayer was developed for application of sanitizer sprays in areas which needs disinfection which reduces human intervention. The device plays a awfully important role in running the drone system, this drone is essentially controlled with the help of a remote controller. Motors are accustomed pump the sanitizer through pipe to sprayed through nozzles and also the desired areas are sanitized. Therefore, the foremost objective of this project is to sanitize areas with less human intervention and help to hunt out good or best sanitization using drones to support the fight against the COVID-19 pandemic.

### 2. LITERATURE SURVEY

Dwi Mutiara Harfin et al [1]. has proposed a drone or Unmanned Aerial Vehicle (UAV) to spray disinfectant indoors. The use of drones which are easy to manage and will reach various parts of an area in an exceedingly building by only using one controller can reduce human physical contact with places prone to corona virus. This research paper used a quadcopter UAV which consists of 4 propellers, each which is mounted on an 11.1 Volt brushless motor. A 2200 KV BLDC motor is used and controlled by the SP Racing F3 flight controller. The motor functions as a propeller drive and LiPo 3S is used as current source. 200 ml of disinfectant is carried and sprayed. These drones are accustomed monitor high-risk residents, in order that they do not leave their homes, to deliver food to chop back human physical and drones within the delivery of medicines for patients who need medical treatment reception.

Shubham Kishor Patil et al. [2] Proposed health monitoring and sanitizing drone for pandemic. As drones are becoming employed in our standard of living and it's great demand within the market. during this paper they have used Quadcopter because of its durability, and it's good weightlifting capacity which can lift up to a few to 4 kg of weight easily and additionally to this, they have also installed health monitoring system so as that the drone could also be operated from one fixed position. MLX 90614 temperature sensor is utilized during this paper, which provides the upper stability to the drone, it also has receiver which determines information like

location, time and velocity and it must be assigned with the trail which might help the drone to wing its own. Arduino UNO is utilized here as microcontroller, this project requires two microcontrollers, one for the drone and also the opposite UNO board is installed within the bottom station. Using ESP32 camera module for camera and surveillance and thus the camera board is AI thinker module, it's programmed for face detection and action detection. they have used two software namely Arduino IDE and Mission Planner, two software are required to program both the receiver and AI thinker camera module. This drone is accustomed conduct survey at public place to chop back the manpower, which automatically reduces the infection and setting the trail for the drone is being very useful function. By using such techniques, the time for sanitizing the given area is being reduced. The temperature sensing range is being boosted up to 5 meters from 2 to 5 meters.

Tuton Chandra Mallick et al. [3] This paper proposed the event of an autonomous unmanned aerial vehicle (UAV) which is controlled by wireless technology through graphical programme (GUI). This proposed design is capable of flying autonomously and also capable to trace pre-loaded mission automatically. Drone calculations are which makes it fly manually and automatically. The author used IMU 9DOF (3-axis accelerometer, 3-axis gyroscope & 3-axis magnetometer) which ensures smooth movement, graceful motion, and trajectory tracing. This drone is capable to fly in several modes. The full weight of implemented design is 1.46kg and it carrying capacity is 0.5kg. Several PID loops designed to induce better stability and performance in several mode. All signals are processed by a strong high speed controller board which makes it more efficient and effective. during this paper the work was the aimed to style a quad copter which will try stable its position in line with preferred altitude.

Karan Kumar Shaw et al. [4] The potential of using drones for spraying disinfectant liquid to fight against the COVID-19 pandemic is examined. The effect of drone-parameters such as flight altitude, flow rate and flight speed are used to examine the characteristics of the drone. The task is to create a thick film layer by wiping 3D matrix, this is used for the calculation of the drone parameters. This represented the presence of disinfectant in the optimal surface coverage by the parameters. Thickness of the layer of the surface coverage is determined and it is about 10g/m<sup>2</sup>(10um). By using the flight parameters with surface coverage data and the tank size, which is mounted on the board, it is possible to calculate the area which can be covered by the drone. The speed of the drone is calculated in different range of flight speed. First flight speed range is about 10km/h, in this case the thickness of the layer is between 12 to 300 times. Second range is about 30km/h flight speed, in this case the layer thickness is between 4 to 100 times. Third range is about 40km/h and in this case the layer thickness is between 3 to 75 times. From these 3 cases it is observed that disinfectant surface volume varies with the change in parameter. With the 10km/h low flight speed it is reached the highest value of 30g/m<sup>2</sup> and at 50km/h of high flight speed the lowest value is achieved. By the results it is observed that the disinfectant per unit area is varies with respect to the changes in the parameter and the disinfectant per unit area is in the range of 30-0.24g/m<sup>2</sup>.

T Andrasto et al. [5] Proposed a system for sanitization. The system includes the usage of a drone for sanitization. The drone is assembled in a X6 Tarot framework. This design can accommodate 6000ml of sanitizer. But it can lift 4500ml of

liquid and spray it when it is flying. The system uses Mission Planner software which has co-ordinates of the areas to be disinfected. The co-ordinate system uses 6 axes for the movement of the drone. The drone can spray continuously for 7.38 minutes. During the testing process, a remote control has been used. Spraying system using a drone can help in spraying easily and cut the amount of time needed.

Yallappa D et al. [6] mentioned that in India, agriculture plays an important role. Farmers should also adapt new framing technologies so that they can enhance the crop growth and save time in doing things manually. Using technologies will defiantly help the farmers to meet all their needs. As the demand for the food is increasing, using these technologies will help farmers to grow the required amount of crop and meet the needs of the costumers. A six blade hexa-copter is used in this proposed paper. It can lift up to 5kg of payload, uses the battery of 8000mAh, and 12V battery is coupled with the pump and helps in pumping mechanism. And camera is also installed for the better view of the farm can spray the pesticides effective to all the parts of the field. This has helped in effectively spraying the pesticides and also it is less time consuming.

Agoston Restas et al. [7] A drone is designed to perform the dissection course in the agricultural land. Disinfecting the crop field plays an important role in the development of agricultural fields. Spraying pesticides in agricultural field using drone reduces the manual work and the time required for the dissection of the entire agricultural land. BLDC motor is used to run the drone system. Propellers are used to take off the drone and this propeller produces 38.2KV of thrust. Electronic Speed Controller is used to control the speed of the motors. An external power supply is used with 22000mAh batteries. In addition to this flight controller is used. Flight controller contains accelerometer and gyroscope, this combination of accelerometer and gyroscope receives information from the receiver and passes it to the Electronic Speed Controller. Radio Transmitter and Receiver section is used to collect the information from the accessing remote and to act accordingly. To capture the navigation of the drone a FPV camera and transmitter is mounted on the board. A tank with the storage capacity of 6lit disinfectant liquid is fixed on the drone body. A set of pump and nozzle is used for the pumping mechanism. DC water pump with 12DC capacity is used to pump the sanitizer through the nozzle. The proposed drone is successfully disinfected the required area in the crop field.

K Ramesh et al. [8] Proposed a system during the pandemic which can sanitize indoor and outdoor. The system uses a hexacopter for spraying the sanitizer. The UAV is remote controlled and autonomous. The hexacopter has a capacity to carry 2 litres of sanitizer. The Pixhawk autonomous module is used as the flight controller. The UAV has vertical take-off and landing and does not need a runway. In the autonomous mode, it uses GPS to locate the places to be sanitized. The co-ordinates of the areas to be sanitized is uploaded manually by the user via a graphical interface of the Mission Planner software. The hexacopter follows the co-ordinates for sanitizing. This system can sanitize large areas in a short span of time and a smaller work force. It also improves the safety of the personnel working in the disinfection process.

Vikram Puri et al. [9] proposes the aim to spotlight the importance of drones in agriculture and elaborate top drones present within the marketplace for Agriculture monitoring and



observation for yielding better crop quality and preventing fields from any style of damage. With the mixture of Wi-Fi technology in drones stylish of person View (FPV), drones are visiting be integrated with HD cameras like GoPro, DJI, Parrot and many of others.

C Y N Norasma et al. [10] reviews the usages of UAV in agriculture applications. The aim of the project must be investigated before using the UAV technology for better data quality and analysis. an appropriate sensor and UAV should be identified before using UAV to assemble accurate data and precise analysis during this.

Varun Sharma et al. [11] Agriculture is one of the major sources of occupation in India. With the growing technologies in the field of drone. The drone is also being used in the field of agriculture which helps the farmers and the labours. As the drones works more efficiently than humans. The main aim of this paper is to increase the awareness to use the drones in the agriculture field so that the farmers will be aware of the growing technologies and can learn how to control the drone using remote and to implement them in their farms. To improve the production and the cultivation of the crops, the author in this paper has proposed that they are sprinkling water, spraying the fertilizers and pesticides, and used to spray chemicals like UREA. Drones are being used to spray the pesticides and fertilizers to the large farms and the drones can also click pictures from the certain height so that the framers can identify if the crops are being infected or if the crops are healthy, it also has a temperature sensor, which senses the temperature that is required for the crop and how much water is required for the certain crop. The UAV is used in this paper to increase the crop production and reduces the workload for the farmers and helps to save time for the farmers.

Olaiya O et al. [12] proposed that smart farming should be used in India and the farmers should use them to sow the seeds and to monitor the growth crop growth. As this the octocopter it is mainly used in the irrigation techniques, spraying fertilizers and pesticides and the drone can carry fertilizers or pesticides roughly around 3liters. The outcome of this paper suggests that there is limited intervention of human and improves the efficiency of the crop growth and accuracy in the production of healthy crops and saves time for the farmers and the decreases he workload for the farmers. Using such kinds of drones, helps farmers to reduce the wastage of pesticides, money and helps in managing the resources

### 3. LITERATURE GAPS

In [1], the proposed system has less load capacity, to increase loads capacity the specifications of the BLDC motor and battery capacity needs to be increased. The drone used here needs to be controlled manually which can be further improved to an automized drone as a future work.

In [2], the prototype has a camera which will capture the photos of sneezing or coughing action and notify the operator at the base station and it is required to assign a path to the drone so that the drone will fly on its own which is complicated needs a lot of requirements.

In [3], The PID loops used in this drone are roll control, Pitch control and Yaw control. It's difficult to monitor and control the

drone along with all these axes. The dynamics used for the design is in accordance with the autonomous drone. The drone orientation and acceleration and also, its angular rate depends on the algorithm and the design dynamics of the drone. The drone is autonomous, and its movement completely depends on GPS module system. It is a multicopter drone and it need some aerodynamic knowledge and mathematical solutions for the design with respect to the flight capacity. A ground station is established with a Laptop/PC for the monitoring purpose. Here it fails to meet all those autonomous requirements.

In [4], The octo-copter configuration is designed with eight arms. Electronic Speed Controllers controls the flight speed of the drone. This ESC is connected to the motors and to the power distribution board. The sanitizer tank should be placed on the board, and it should not touch the ground. If the ESC fails to guide the drone, then the drone falls back to the ground. In this case it is impossible to control the drone movement by the ground station. The established ground station should be able to monitor the drone even after the ESC stops working. The PC/Laptop should be in maintenance until the drone lands on the ground.

In [5], Spraying of disinfectant includes a lot of effort due to the COVID-19 pandemic. The effectiveness of spraying the disinfectant depends on the drone. The drone has some limitations for spraying the disinfectant, it can only carry 4500ml of disinfectant and spray them in 7-8 minutes. As you cannot disinfectant the entire area within 7-8 minutes. Motors speed also plays an important role in spraying mechanism. Remote control plays a very important role in running the drone, the components can be operated according to their function and can spray disinfectant liquid.

In [6], Spraying pesticides is one of the technologies that is in high demand. As the pesticide drones are expensive, many of the farmers cannot afford them. It is only helpful for that large fields. Farmers will not be having the knowledge to use the drone and they will want to use the old conventional methods for their farming. Many of the farmers will not be willing to take up new technologies because they want to continue the old conventional method, which is time consuming and also that include much of labour work on the field. Also doing things manually consumes a lot of time than doing it with technology.

In [7], the disinfectant spray covers different surface areas at different heights. Lower the drone, the layer of disinfectant spray is more. Hence, the area covered by the spray differs resulting in non-uniform spraying in uneven areas. Another issue here is the evaporation rate of the disinfectant spray. In humid areas, it stays in the liquid form for a longer time. The proposed system does not include any safety measures for the drone.

In [8], even though the drone is autonomous, the marked areas for disinfection should be checked before the process. The marked areas may be changed by anyone who knows how to do it. The level of sanitizer is not monitored continuously. The user should check the level of sanitizer before the process. It cannot fly to greater heights due to heavy payload.

In [9], it suffers from limited battery life and might kick off and land safely in small, confined areas and are best for starters to be told Drone Flying which might be improved with a much better battery.

In [10], the limitations of the UAV are the load and dimension of the sensors of low-cost UAV. the insufficient or medium format chosen are normally less stable and not accurate. The Low-cost UAV have limitations in reaching a particular altitude due to a the less powerful engine. The path-planning system doesn't use professional pilot, the high-speed ultra-low situation, data downloading function during real-time application, the dimensions and payload to avoid bottleneck then the software for its automatic processing.

In [11], the proposed paper the major disadvantage is that it is very difficult to teach farmers how to use the drones as many of them are illiterate. Not every farmer knows the advantages of using the drone. If there is any problem while spraying the sanitizer, pesticides, or any chemical the farmers are not capable of rectifying them and hence, will stop using the agriculture drone.

In [12], being exposed to pesticides for a long time has been linked to many health issues such as cancer, chronic illness, asthma, hypersensitivity and many more. It can also cause reproductive problems as the pesticides contain harmful chemicals.

#### 4. PROPOSED METHODOLOGY

This project is being designed to sanitize the given area with the help of drone and with less human interaction. Flight controllers are installed to send the instruction to the drone and the drone acts accordingly. Gyro sensor is used which will even sense smallest change, it will be having drive arm, stator and sensible arm and gives us the correct reading of roll, yaw and pitch motions' receiver which is present on the flight controller receives the signal and the it decodes it and sends it back to the microcontroller.

Microcontroller sends the received signal to the ESC (Electronic Speed Controllers). ESC is used to control the brushless DC motors, when the signal is received by the microcontroller, it creates thrust and the drone can be moved in the desired direction.

Two kinds of propellers are used in this project, pushers and pullers which gives the thrust when it rotated clockwise and anti-clockwise direction respectively. KK is used as it has accelerometer and gyro sensors which is used for stabilization and feedback control, no direct power supply from battery is given to the KK board, board will be having ATMEGA 168 microcontroller which process the input and gives the desired output. This system is powered by 11.1V LiPo battery.

Power distribution board distributes the power equally among the four motors. IR controlled switch is implemented to control the spraying mechanism, when the button is pressed, it will send the infrared signals to IR receiver which consists of photo LEDs. It produces a high input which will drive the submersible motor connected at a 9V battery through a relay to switch it ON or OFF. When the motor is switched ON, it pumps the sanitizer through the pipes and

then the sanitizer is sprayed through the nozzles. IR switch helps in controlling the spraying mechanism and to avoid the excess spraying of the sanitizer.

For the pumping mechanism, submersible DC motor pump, 9V battery, switch, pipes fitted to T-split and mini nozzles are used. When the switch is turned ON, the motor pumps the sanitizer to the pipe with the help of battery. Infrared remote switch is used, as there is direct contact connection from battery to motor there are chances of wastages of sanitizer before the quadcopter takes off, IR switch is used to control the ON and OFF motion of the motor, this is done to avoid the wastages of sanitizer

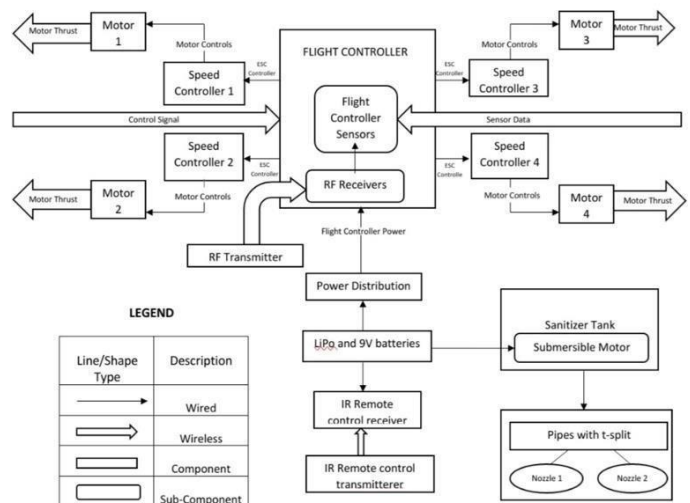


Figure 4.1: Block Diagram

#### 5. CONCLUSION

The proposed mechanism provides a drone sanitizer which can be controlled using a remote control. A pumping mechanism is provided for spraying of the sanitizer. The drone can fly up to 15 feet and carry the payload. The same mechanism is used in Agricultural drones.

The project can be improved by making it autonomous, or by adding camera and GPS. The drone can be tracked using a phone or a software. There is high scope of improvement in this project. It is really important in the current scenario.

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# Combined Traffic Flow Prediction Based on Graph Convolution

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**Abstract:** Traffic flow data has strong temporal and spatial correlation. The traffic flow in the previous moment will affect the traffic flow in the next moment, and the traffic flow in the upstream and downstream will affect each other in space. In order to alleviate traffic congestion and improve the accuracy of traffic flow prediction, this paper proposes a combined traffic flow prediction model C GCN based on graph convolution. product to extract the temporal features of the traffic flow. The experimental results show that the prediction effect of the C- GCN combination prediction model is better.

**Keywords:** traffic flow prediction; temporal convolution; spatial convolution

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## 1. INTRODUCTION

In recent years, with the improvement of residents' living standards, the per capita car ownership is also increasing, and the resulting traffic congestion problem has become more and more serious. Traffic congestion not only brings many problems to people's travel, but also increases. The work load of public transport managers increases the occurrence of traffic accidents, and the exhaust emissions caused by traffic congestion also lead to environmental pollution and waste of resources. Because of the seriousness and harmfulness of this problem, it has attracted the research of various scholars, and various countries have also established the ITS system<sup>[1]</sup>. The key of this system is the accuracy of traffic flow prediction.

At present, the existing methods and models in the field of traffic flow prediction can be mainly divided into three categories, namely, prediction models based on statistical theory, prediction models based on traditional machine learning, and prediction models based on deep learning. Prediction models based on statistical theory include historical average model, time series model, Kalman filter model<sup>[2]</sup>; traffic flow prediction models based on traditional machine learning include support vector regression model<sup>[3]</sup>, K Nearest neighbor algorithm<sup>[4]</sup>, BP neural network and other methods; Traffic flow prediction models based on deep learning mainly include Long-Short Term Memory (LSTM), Convolutional Neural Networks (Convolutional Neural Networks, CNN)<sup>[5]</sup> and Gated Recurrent Unit (GRU)<sup>[6]</sup> and other combined models, etc.

The statistical-based prediction model was popular in the early days due to its simple algorithm and the advantages of using less equipment, but its conditions are relatively limited, it is only suitable for a single road with stable traffic flow, and the prediction in complex road sections The effect is poor<sup>[7]</sup>; the prediction model based on traditional machine learning is generally a nonlinear model, which usually starts with traffic data to explore its hidden features and changing relationships, so as to achieve the purpose of improving the accuracy of the model<sup>[8]</sup>; the prediction model based on deep learning is a multi-layer perceptron with a hidden layer, which can extract high-level feature information and discover hidden features of data by aggregating low-level feature information<sup>[9]</sup>. Its core idea is to extract important information through continuous learning and parameter optimization in the modeling process. And obtain accurate prediction results, and its expression

ability is better<sup>[10]</sup>. Therefore, in recent years, deep learning has become more and more popular in the field of traffic flow prediction. With the development of deep learning models in the field of traffic flow, it is found that combined models can better extract the characteristics of traffic flow. More and more scholars use different Combination methods extract different features to improve prediction accuracy.

## 2. THE SPATIOTEMPORAL CHARACTERISTICS OF TRAFFIC FLOW

Traffic flow refers to the actual number of traffic participants passing through a certain location or section of the road within a unit time. The number of vehicles, also known as traffic flow<sup>[11]</sup>.

Because the traffic volume is affected by many factors, such as time, weather, environment, road conditions, driving status, etc., the traffic volume has strong complexity and uncertainty. Since the traffic flow is constantly changing, its dynamic characteristics are very strong, so it also shows strong randomness. And due to various subjective and objective factors, the traffic flow has nonlinear characteristics<sup>[12]</sup>.

Temporal characteristics and spatial characteristics are the main factors affecting traffic flow prediction, and these two characteristics are random and nonlinear, and become the main problems in the study of traffic flow.

Time correlation means that in a given road section, the traffic flow at the current moment is not only affected by the current traffic conditions, but also by the historical traffic data of the previous time period, because traffic congestion has a dissipation period, and the dissipation period is determined by the congestion state. And the congestion state is generally longer, so the traffic flow at the previous moment also affects the traffic flow at the next moment. The traffic flow of urban roads is a complex and huge data set with strong similarity in daily, weekly and monthly traffic volumes. In the long run, the traffic volume has obvious periodic characteristics, and it exhibits strong static stability. Periodicity is the most important characteristic of temporal correlation of traffic flow. Traffic flow data usually shows strong regularity within a certain period of time, showing its trend information and characteristics. For example, in urban road traffic, on the whole, the data of each day in the week will show a certain



similarity, but there is a big difference between the week and the weekend, and there is a strong similarity between the weekend and the weekend. All of these are caused by people's travel habits. Because of the laws of people's life and work, the peak of traffic flow is generally fixed. The correlation of traffic flow in time, so it can be regarded as a time series data processing.

Spatial correlation refers to the influence between the upstream and downstream of the traffic flow, because the traffic road network is also a huge connected system, and the traffic flow of each road segment will affect and be affected by other road segments, such as when a traffic segment is congested, the upstream section will also be congested due to fluctuations, and the traffic volume on the downstream section will increase. The traffic flow of the road at each time period is more dependent on the flow of the upstream and downstream sections. Therefore, each road cannot be simply considered as an independent study. It is these complex road network structures that make traffic flow also spatially correlated. Spatial correlation distinguishes traffic flow data from other time series data. The early prediction of short-term road traffic flow only extracts temporal features and ignores spatial features, so the prediction results are quite different from the actual results. The spatial feature extraction of traffic flow in this paper makes the prediction results more accurate.

Traffic network diagram is shown in Figure 1:

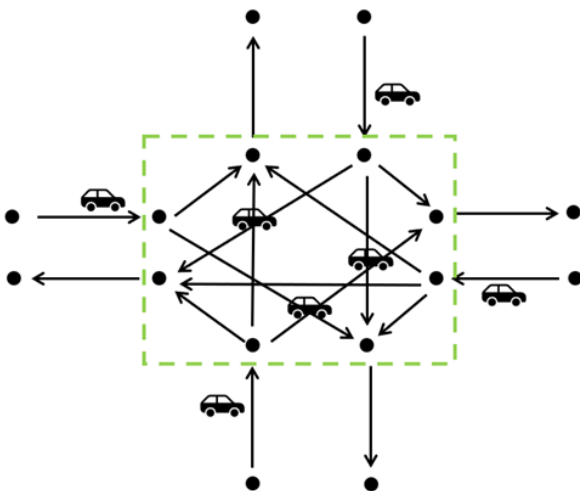


figure 1. Traffic road network map

### 3. GRAPH CONVOLUTIONAL NEURAL NETWORKS

#### 3.1 Basic theory

In mathematics and signal systems, Fourier transform is used to describe a function that is expressed as a linear combination of several orthogonal functions. Through Fourier transform, the image domain and the frequency domain can be transformed into each other.

The traditional Fourier transform is defined as:

$$F(w) = F[f(t)] = \int f(t) e^{-iwt} d(t) \quad (1)$$

The inverse Fourier transform is:

$$F^{-1}[F(w)] = \frac{1}{2\pi} \int F(w) e^{iwt} d(w) \quad (2)$$

For finding the Fourier transform of Graph is to find the eigenvector of the Laplacian matrix of Graph. The Fourier transform on Graph is discrete, while the traditional one is continuous. The latter can represent the Fourier of the eigenvalues of the former. Lie transform is:

$$F(\lambda_l) = \bar{f}(\lambda_l) = \sum_{i=1}^N f(i) u_l^*(i) \quad (3)$$

Among them,  $f$  it represents an N-dimensional vector,  $f(i)$  which is a mapping relationship with the point in Graph, and  $u_l(i)$  represents the i-th component of the l-th feature vector.

So the graph is represented by the Fourier transform on Graph as:

$$\bar{f} = U^T f \quad (4)$$

The traditional Fourier transform is to integrate the frequency, and when describing the transformation on the graph, it is called the sum of the eigenvalues  $\lambda_l$ :

$$f(i) = \sum_{l=1}^N f(i) u_l(i) \quad (5)$$

inverse Fourier transform on Graph is also expressed as:

$$f = U \bar{f} \quad (6)$$

Given two sets of graph signals  $x_1, x_2$  the graph convolution operation can be expressed as:

$$x_1 * G x_2 = (U \text{diag}(\bar{x}_2) U^T) x_2 \quad (7)$$

\* G represents graph convolution, which  $\odot$  is the Hadamard product. The result of graph convolution of the available graph signal is:

$$x_1 * G x_2 = g_\theta(H) x = U g_\theta(\Lambda) U^T x \quad (8)$$

It is a trainable filter, where:

$g_\theta(\Lambda) = \text{diag}(\theta), \theta \in R^N$  are the parameters to be learned.

For GCN, the convolution from graph to frequency domain is realized by Fourier transform, which can reduce a lot of computation. First perform Fourier transform on the graph and the convolution kernel, you can get their frequency domain representation, then multiply, and then inversely transform back to get the graph domain convolution, the formula is as follows:

$$g * x = U \left( U^T g \cdot U^T x \right) \quad (9)$$

$g$  is the filter function, that is, the convolution kernel,  $x$  is expressed as  $x = (f(1) \dots f(n)) \in R^n$ , that is, the signal set at the point of the graph, and  $U$  is the basis of the Fourier transform, that is, the feature vector of the Laplacian matrix.

Combining graph Fourier transform and discrete convolution, we can get:

$$(f * h)_G = U \text{diag} [\theta_1, \dots, \theta_n] U^T f \quad (10)$$

### 3.2 Development of Spectral Convolution

Please The first generation of graph convolutional neural networks is also called spectral GNN, as in Eq. 2-13, in which its convolution operation is replaced by graph theory.

$$y = \sigma \left( U g_\theta U^T \right) = \sigma \left( U \text{diag} [\theta_1, \dots, \theta_n] \right) U^T x \quad (11)$$

The computational complexity of the first generation graph convolution is too high, and its convolution operation is based on the global rather than a single node, so the second generation GCN appears, such as Equation 2-14:

$$F_T (\lambda_k) = \hat{g}_k (i) u_k (i) \quad (12)$$

$g_\theta$  The eigenvalue function  $g_\theta(\Lambda)$  used to represent the Laplacian matrix can be obtained:

$$y = \sigma \left( U g_\theta U^T \right) = \sigma \left( U g_\theta (\Lambda) U^T x \right) \quad (13)$$

The schematic diagram of the graph convolutional network is shown in Figure 2:

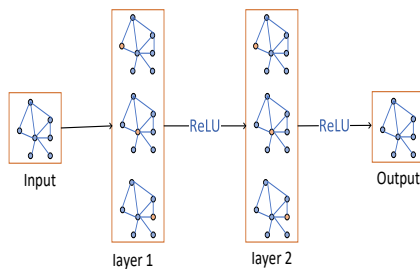


figure 2. Schematic diagram of graph convolutional network

## 4. EXPERIMENTAL SIMULATION AND RESULT ANALYSIS

### 4.1 Source of experimental data

Caltrans PeMS, a web-based software tool designed by the California Department of Transportation, which collects data sets from Caltrans traffic sensors from highways in California. Traffic speed data in the San Francisco Bay Area from January 1 to February 28, including 307 sensors on 29 roads, with a total of 16,992 data. In the experiment, the training set and the test set were divided in a ratio of 8:2. As shown in Table1:

Table 1. Data set division

data set	P EMS04	
sensor	3 07	
time	2 0180101~20180228	
sample interval	5min	
\	Proportion	quantity
Training set	80%	13593
test set	2 0%	3398

### 4.2 Evaluation indicators

In the experiments of this paper, the mean absolute error (MAE) and the root mean square error (RMSE) are used as evaluation indicators. The introduction of the two indicators is as follows:

(1) MAE

MAE is the average of the absolute error between the actual value and the predicted value, and its calculation formula is as follows:

$$MAE = \frac{1}{n} \sum_{i=1}^n |v_i - \bar{v}_i| \quad (14)$$

Another variant of MAE is MAPE. Because MAPE is more intuitive, it is easy to understand. You can know the result by looking at its value. If the MAPE is how much, it means how much the predicted result deviates from the real result. Its calculation formula is as follows:

$$MAPE = \frac{100\%}{n} \sum_{i=1}^n \left| \frac{v_i - \bar{v}_i}{v_i} \right| \quad (15)$$

(2) RMSE

The root mean square error is a representation of the degree of dispersion and an important evaluation index to describe the stability, not the absolute error. Its formula is as follows:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (v_i - \bar{v}_i)^2} \quad (16)$$

$v$  represents the actual value,  $\bar{v}$  represents the predicted value, and  $n$  represents the number of predicted values. The smaller the value of these three evaluation indicators, the better the prediction effect of the model.

### 4.3 Experimental environment and data settings

This experiment is based on the Python language and uses the Pytorch framework to implement the graph convolutional network (CGCN) model that introduces the spatiotemporal attention mechanism in this paper. The model training is mainly performed on the GPU. The relevant configuration of the experimental environment is shown in Table 4-1:

**Table 2. Experimental environment settings**

	category	version model
hardware	CPU	Main frequency 3.2GHz
	GPU	16G
software	language	Python 3.6
	Deep Learning Framework	C UDA 11.1
		Pytorch 1.8.0

#### 4.4 Comparison of experimental results

In order to compare and analyze the prediction results of the CGCN model, this paper selects several models of HA<sup>[13]</sup>, LSTM<sup>[14]</sup>, GRU, and T-GCN<sup>[15]</sup> as the control group. First, the prediction results of CGCN and each model are compared to verify the prediction accuracy of CGCN. The performance of CGCN is analyzed by comparison, and the experimental comparison results are shown in Table 3:

**Table 3. Comparison of experimental results**

Model	PEMS04	
	RMSE	MAE
HA	67.60	54.03
LSTM	58.05	36.99
GRU	56.61	35.06
TGCN	48.28	34.51
CGCN	<b>42.01</b>	<b>30.17</b>

It can be seen from the experimental results that the traditional prediction method HA has a particularly poor effect. This is because the traditional time series prediction method cannot handle the multi-dimensional data of traffic flow, and the traffic flow data is multi-dimensional and complex data with many features. These are the traditional methods. traditional methods that only deal with simple one-dimensional time series data are less effective in predicting traffic flow. GRU and LSTM are slightly better than HA, but they are still worse than the combined model TGCN, because GRU and LSTM can only extract single-dimensional features, and the data extraction effect for multi-dimensional features such as traffic flow is still poor. For the combined model TGCN, it uses GCN to extract spatial features and GRU to extract temporal features, which shows that the more sufficient the feature extraction of traffic flow data, the more accurate the prediction results. Overall, the combined C-GCN model proposed in this paper can better predict traffic flow. The prediction results are shown in Figure 3:

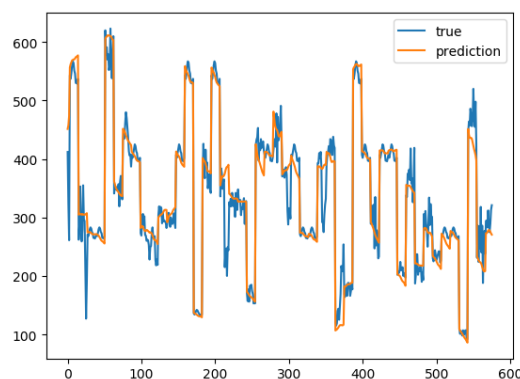


figure 3. Prediction result graph

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