Momentum: Physics Education Journal
7 (1), 2023, 164-177
Available at: ejournal.unikama.ac.id/index.php/momentum
ISSN 2548-9127(print) | 2548-9135 (online)

The learning program validity of using the ExPRession model to stimulate students' systems thinking and numeracy skills

Septina Sri Haryanti, Kartini Herlina*, Abdurrahman

University of Lampung, Jl. Prof. Dr. Sumantri Brojonegoro No. 1 Bandar Lampung, 35145, Indonesia
e-mail: kartini.herlina@fkip.unila.ac.id
* Corresponding Author.

Received: 8 January 2023; Revised: 24 January 2023; Accepted: 31 January 2023

Abstract: This study aims to describe a learning program using the ExPRession model which is valid in stimulating students' systems thinking and numeracy skills on the topic of light interference. The design of this research is Design and Development Research (DDR). The data from this study were in the form of validity test results which were analyzed using mixed methods (quantitative and qualitative). The results of the data analysis showed that the learning program developed obtained a score percentage of 91.1% with very valid criteria. Based on the results of data analysis, it can be concluded that the learning program with the Expression model is very valid to stimulate students' systems thinking and numeracy skills. This is because the content validity shows that the learning program using the Expression model can be applied in learning Physics in Senior High School Class XI in the even semester on the topic of Optics (Light Interference) to stimulate students' systems thinking and numeracy skills. Furthermore, in terms of media and design validity, the teaching materials in this learning program are very interactive or multimedia-based. Therefore, they can be innovations to attract interest and motivate students to learn.
Keywords: Learning Programs; Expression Learning Models; System Thinking Skills, Numeracy Skills

How to Cite: Haryanti, S. S., Herlina, K., & Abdurrahman, A. (2023). The learning program validity of using the expression model to stimulate students' system thinking and numeracy skills. *Momentum: Physics Education Journal*, *7*(1). https://doi.org/10.21067/mpej.v7i1.8096

Introduction

Student knowledge and academic development is a learning challenge in the 21st century. This challenge can be met by applying skills of creativity, critical thinking and problem solving, communication, collaboration, life and career skills, information, media, and technology. The 21st Century Skills are recognized as competency standards that students need to possess to meet the demands of success in future work and life (Asrizal et al., 2018; Kan'an, 2018; Menggo et al., 2019; Partnership, 2019). Therefore, improving basic education in society (Cheng, 2017) is very important.

Improvements to the education system can be made by changing the mindset, way of learning, and how students develop creative innovations in various fields (Adel & Dayan, 2021; Lucas & Hanson, 2016; Reid et al., 2021; Rotherham & Willingham, 2009; Shurygin & Krasnova, 2016; Suryawati & Osman, 2017). Teachers can support this by exploring students' potentials in adapting to existing changes to be successful in today's life (Ashraf, 2020; Bower et al., 2014; Gleason, 2018; Häkkinen et al., 2017; Iglesias-Pradas et al., 2021; Keiler, 2018; Onyema et al., 2019; Schelly et al., 2015). The novelty of ideas and teacher creativity in developing ways of presenting subject matter at school is indispensable as part of 21st century learning innovation. The creativity in question relates to a teacher's ability to choose the right methods, approaches, and media in presenting learning material

DOI: 10.21067/mpej.v7i1.8096

(Gunawan et al., 2019; Kusasi et al., 2021; Putranta & Supahar, 2019; Serevina et al., 2018; Shurygin & Krasnova, 2016; Trnova & Trna, 2014).

Learning in Indonesia, which is currently partially implementing the 2013 curriculum, in practice is more than just the task of the government and school principals. The role of professional teachers is needed in developing learning programs, namely the development of syllabus, textbooks, learning resources and media, learning models, instrument assessment, and lesson plans preparation that refer to the syllabus. Learning tools developed must also be able to train students' 21st century skills (Aslan, 2015; Barak, 2017; Jang, 2016). One of the essential 21st century skills to practice is critical thinking and problem-solving (Afandi et al., 2019; Doleck et al., 2017; Hudha & Batlolona, 2017; Jang, 2016; Mutakinati et al., 2018; Prayogi & Yuanita, 2018; Saputro et al., 2020; Wong & Cheung, 2020). Both require systems thinking to make it easier for students to relate the causes and effects of a phenomenon, examine interactions between components as an arrangement of interactions and increase their understanding of many topics, one of which is science (Hmelo-Silver, 2014; Jacobson, 2006; Ke et al., 2021; Matlin et al., 2016; Orgill et al., 2019, 2019b; Pallant & Lee, 2015; Saxton et al., 2014; Vachliotis et al., 2014; Weintrop et al., 2016).

Systems thinking is used to analyze part of the overall interaction between learners in providing overall results in complex systems that receive increasing attention not only in education but also in everyday life (Bobek & Tversky, 2016; Hilpert & Marchand, 2018; Jacobson, 2001; Maani & Maharaj, 2004; Orgill et al., 2019; Penner, 2000; Richmond & Peterson, 2001; Stuntz et al., 2001; York et al., 2019). Systems thinking is essential for obtaining information, making decisions, and solving problems in all aspects of personal, social, and professional life (Afandi et al., 2019; Hogan, 2000; Jang, 2016; Orgill et al., 2019; Saxton et al., 2014; Weintrop et al., 2016). Some factors, namely exploring various perspectives, considering problems appropriately, defining boundaries, distinguishing and quantifying elements, identifying and characterizing relationships, identifying and characterizing feedback, and explaining and predicting system behavior, are indicators of systems thinking that require completion in numeracy skills (Can, 2021).

Numeracy skills are appropriate to support the training of indicators of systems thinking activity in accessing and assessing situations mathematically by identifying important features of real-world problems to be represented mathematically and solving problems using operations, processes, and mathematical tools. Acting and using mathematics, as well as evaluating, critically reflecting, and making judgments, are also part of numeracy skills, which are carried out, among other things, by applying measurements, making and extracting information from graphs and charts, collecting information, making estimates or forecasts, and using mathematical arguments to establish, defend, or oppose decisions or judgments (OECD, 2021). All these skills can be applied to solve problems related to existed phenomena in everyday life (Gurr et al., 2020; Nurse & Grant, 2020).

One of the lessons must bring up everyday phenomena closely related to student life and requires student involvement in reflecting on them is Physics (Calmer, 2019; Furtak & Penuel, 2019; Geller et al., 2018). Physics learning can be done by applying stages in understanding the problems of the phenomena presented, explaining them, and producing predictions about the following situation, which are still interrelated (Docktor & Mestre, 2014; Herlina, 2020; Kubricht et al., 2017; Pedaste et al., 2015). This is contained in one of the learning models called the ExPRession learning model, which is a learning model consisting of problem-solving activities displayed in the form of phenomena to motivate students and trigger learning, especially on the topic of optics (Herlina, 2020; Putranta & Jumadi, 2019).

One of the materials included in the topic of optics is light waves, in which there is a sub-topic of Light Interference. This sub-topic is considered difficult for students (Aminudin et al., 2019; Krijtenburg-Lewerissa et al., 2017; Marshman & Singh, 2017; Mešić et al., 2016; Nurdiansah et al., 2020). This difficulty is shown by many students who need help applying the wave model to explain interference after the teacher has explained it traditionally (lecture) (Ambrose et al., 2006). Students who have studied physical optics at an introductory level and beyond also do not develop a coherent model using to predict and explain the effects of light interference (Wosilait et al., 2012). If learning difficulties on this topic are not corrected, it can hamper understanding later, more complex topics, such as the wave nature of matter and the photon model for light (Ambrose et al., 2006).

Several students also experienced some shortcomings in learning this sub-topic, which were known from the results of preliminary research conducted in schools in 4 districts in Lampung. Preliminary research was carried out through questionnaires, semi-structured interviews, and literature studies to capture the need assessment related to the learning program on optics implemented in these schools. It is known that the syllabus that is used as a reference in learning is the one of The Ministry of Education. The components of Core Competencies, Basic Competencies, indicators, and learning objectives formulated in the Learning Implementation Plan (LIP), refer to the syllabus. The learning model written in the LIP generally uses the Discovery Learning model, such as the LIP circulating on the internet. However, in practice, the teacher still needs to implement this model. The reason is that more than the time allocation is needed to accommodate the stages of learning with this model, this makes the Light Interference sub-topic only delivered conventionally, and students are asked to learn more independently.

This limited time allocation is also why learning in this material has yet to apply practical methods independently or in groups. Even by applying this practical, students can analyze phenomena that exist in everyday life. Learning media and learning resources available in schools are in the form of printed books. Worksheet and special modules for this sub-topic have yet to be made available. This is one of the reasons students have yet to implement experiments, either directly or virtually. Some of the weaknesses in this sub-topic certainly illustrate that students' system thinking and numeracy skills have not been trained. The results of the analysis of system thinking and numeracy skills show that these two skills are very important to be applied to the learning process as a form of improving education in today's modern era (Hmelo-Silver, 2014; Jacobson, 2006; OECD, 2021). Delgado, 2021; Rahman et al., 2020; Vanbecelaere et al., 2021; Wang et al., 2018).

In addition, some previous studies in the last six years related to improving the learning process has led to the development of learning tools: 1) the use of PhET virtual media (Doyan et al., 2021); 2) integration of the Massive Open Online Course (MOOC) (Febrian & Ma'ruf, 2021); 3) a Realistic Mathematics Education (RME) approach based on stories (Rezeki et al., 2020); 4) a problem-based learning model with a cultural context (Aufa et al., 2016); and 5) the use of integrated STEM e-modules in flipped classrooms (Aspridanel et al., 2022). All those studies are only limited to being applied to learning and has not fully mastered students' system thinking and numeracy skills. Because of this, it is important to conduct research improving the education system by developing learning programs using models that include activities that lead to problem solving in everyday life to stimulate students' systems thinking and numeracy skills. Based on this background, this study aims to describe learning programs using valid ExPRession models in stimulating students' systems thinking and numeracy skills, especially on the light interference sub-topic.

Method

This research utilizes Design and Development Research (DDR) (Richey et al., 2007), which is a structure that involves several processes. It starts from the design and development process and an evaluation based on empirical research. The stages passed in product development, including analysis, design, development, and evaluation, are detailed in the research flowchart in Figure 1.

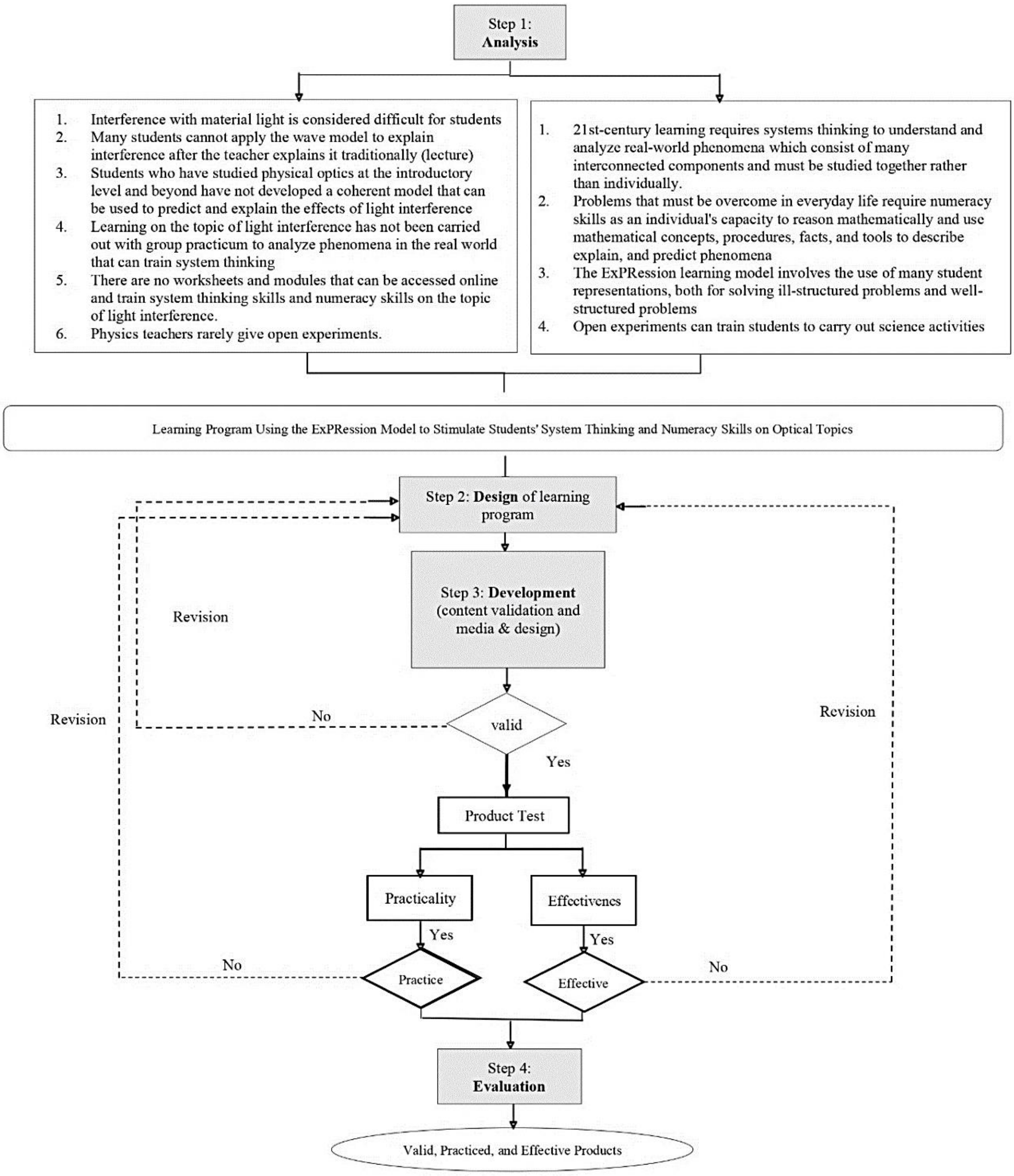

Figure 1. Research Flowchart

The development stage is the stage where the product is developed in a learning program using the ExPRession model to stimulate students' systems thinking and numeracy skills in the topic of light interference. The learning program in question includes syllabus, Learning Implementation Plan (LIP), e-Worksheets, and e-Handouts. The learning programs that have been made are then validated, tested for effectiveness, and tested for practicality, but this article is only focused on product validation. The validation consisted of content and media validation as well as design validation which was carried out by three validators. Subjects in this validation study were determined purposively according to the criteria that must be met based on the research topic. The sample of this study were three experts (validators) who were selected based on their educational background in the field of physics education, including one lecturer in physics master's education, one physics education practitioner, and one high school physics teacher who had completed the master's program. The object of this research is a learning program using the ExPRession model with the characteristics of each syntax which contains activities to stimulate indicators of students' systems thinking and numeracy abilities in physics learning, especially light interference.

Validity data in this study were collected using instruments in the form of content validation scales for syllabus, lesson plans, e-worksheets and e-handouts, as well as media and design validation for e-worksheets and e-handouts. All of these scale instruments were given to 3 experts accompanied by demonstrations of learning programs using the ExPRession model. The three experts assessed the program by giving a score for each aspect. The scoring options can be seen in Table 1.

Table 1. Likert Scale in the Validation Questionnaire

Answer Choices	Score
Very Valid	4
Valid	3
Less Valid	2
Invalid	1

The scores collected were then analyzed using mixed methods covering the qualitative and quantitative ones. The data analysis technique was carried out through percentage analysis, then the percentage weights obtained were converted to the criteria in Table 2. The product developed is said to be valid if it reaches the score determined by the researcher, which is at least 60% with sufficiently valid criteria.

Table 2. Validity Percentage Weight Conversion

Percentage _	Criteria _
0.00%-20%	Inalid
20.1%-40%	Less Valid
40.1%-60%	Enough
60.1%-80%	Valid
80.1%-100%	Very Valid

Results and Discussion

Results

This study produced a learning program using the ExPRession model, valid to stimulate students' system thinking and numeracy skills on light interference. The resulting learning program includes a syllabus, lesson plans, e-Worksheet, and e-Handout shown in Figure 2. The validation results were obtained from the assessment carried out by three experts. Then the average score was converted into percentage form as a result of quantitative data, then categorized in qualitative form. The detailed validation results are shown in Table 3, Table 4, Table 5, Table 6, and overall in Table 7.

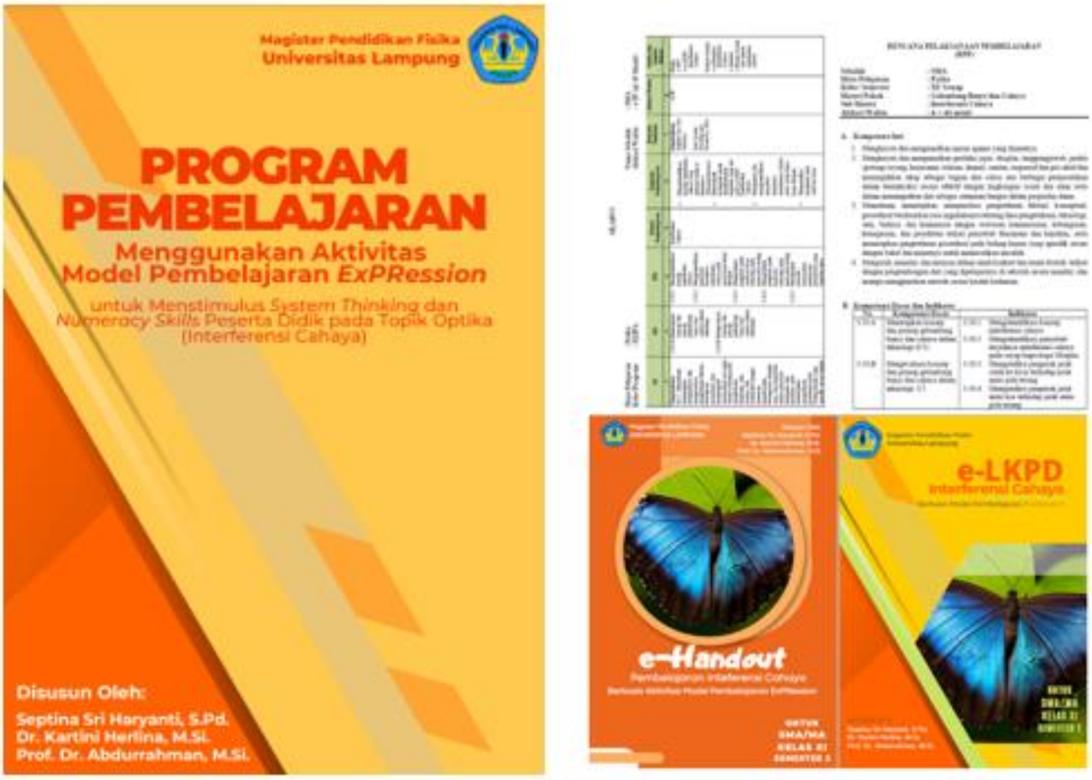

Figure 2. Display of Learning Program Cover Page

Table 3. Validation Results from 3 Validators Against the Syllabus

No.	Rated aspect	Average Score	Percentage Validity (%)
1	There are syllabus components	12.0	100.0
2	Learning materials by essential competencies	11.0	91.7
3	GPA (Competency Achievement Indicator) is developed based on the Basic Competencies to be achieved	11.0	91.7
4	Learning activities direct students to find concepts and solve problems and allow for interaction between students	10.0	83.3
5	Learning presents real problems that exist in the environment	11.0	91.7
6	Using three or more learning methods	9.0	75.0
7	Using more than two learning media	12.0	100.0
8	Learning activities encourage student activity	10.0	83.3
9	Allocation of time is appropriate for the attainment of essential competencies	10.0	83.3
10	Using various learning resources	11.0	91.7
11	Assessment includes the realm of knowledge and skills	12.0	100.0
12	Assessment takes into account assignments during learning	11.0	91.7
13	The assessment includes the aspects being measured and measurement techniques	10.0	83.3
	Average Percentage of Syllabus Validity	10,8	89.7
	Criteria		Very Valid

Table 4. Validation Results from 3 Validators on LIP

No.	Rated aspect	Average Score	Percentage Validity (%)
1	LIP identity	12.00	100.0
2	Main Components of LIP	12.0	100.0
3	Formulation of core competencies, basic competencies, competency achievement indicators	11,3	94.4
4	Formulation of Learning Objectives	10.5	87.5
5	Learning materials	10,8	89.6
6	Learning methods	10,8	90.0
7	Media and Learning Resources	11,3	93.8
8	Learning Steps	10.5	87.5
9	Assessment of Learning Outcomes	10,4	86.9
	Average Percentage Validity of LIP	11,1	92,2
	Criteria		Very Valid

Table 3 shows the results of the syllabus validation, which consists of 13 assessment aspects related to the components of the syllabus, starting from the indicator aspect to the learning assessment. This aspect gets an average score of 89,7% with very high validity criteria. The results of the validation were then carried out on the LIP described in Table 4, showing that there were nine assessment aspects related to the components in the LIP, starting from the identity aspect to the assessment of learning outcomes. An average score was obtained and converted into a percentage of 92,2% with very valid criteria.

Table 5. Validation Results from 3 Validators for e-worksheets

No.		Rated aspect	Average Score	Percentage Validity (%)	Average Percentage Validity (%)
Content Validation					
1	Content Eligibility Aspects	Steps for Presenting e-worksheets	10.5	87.5	92.6
2		Social System	11,7	97.2	
3		Reaction Principle	10.5	87.5	
4		Support System	12.0	100.0	
5		Instructional and Accompaniment Impact	11.0	91.7	
6	Aspects of Language Feasibility	straightforward	12.0	100.0	
7		Communicative	11.0	91.7	
8		Dialogic and Interactive	11.0	91.7	
9		Compatibility with the Developmental Level of Students	11.0	91.7	
10		Consistency and Integration of Thought Flow	10.5	87.5	
11		Use of Terms, Symbols, or Icons	11.0	91.7	
Media and Design Validation					
1	Cover section		11.8	98.1	95.7
2	Contents Section		11.2	93.3	
	Average Percentage Validity of e-worksheets				94.08
	Criteria				Very Valid

Table 5 shows the results of e-worksheets validation, including content validation and media and design validation. Content validation consisted of content and language feasibility aspects, with an average validity percentage of 92,6%. In comparison, media and design validation consisting of aspects of the cover section and content section obtained an average validity percentage of 95,7%. These results were then averaged and obtained a percentage of 94,08% with very valid criteria.

Table 6. Validation Results from 3 Validators on e-Handout

No.		Rated aspect	Average Score	Percentage Validity (%)	Average
Content Validation					
1	Content Eligibility Aspects	Step e-Handout	10.5	87.5	89.2
2		Social System	9,8	81.3	
3		Reaction Principle	9.0	75.0	
4		Support System	10.5	87.5	
5		Instructional and Accompaniment Impact	9,3	77,8	
6	Aspects of Language Feasibility	straightforward	11,7	97.2	
7		Communicative	11.0	91.7	
8		Dialogic and Interactive	11.0	91.7	
9		Compatibility with the Developmental Level of Students	12.0	100.0	
10		Consistency and Integration of Thought Flow	11.0	91.7	
11		Use of Terms, Symbols, or Icons	12.0	100.0	
Media and Design Validation					
1	Cover section		11.8	97.1	87.5
2	Contents Section		11.2	83.3	
Average Percentage Validity of e-Handout					88.35
Criteria					Very valid

Table 6 shows the results of e-Handout validation, including content validation and media and design validation. Content validation consisted of aspects of content feasibility and language feasibility with an average percentage of validity of 89,2%, while media and design validation consisting of aspects of the cover section and content section obtained an average percentage of validity of 87,5%. These two results were then averaged and obtained a percentage of 88,35% with very valid criteria.

The validation results of all the learning components that have been described, then the overall average is calculated, and a percentage of 91,1% is obtained with very high validity criteria as shown in Table 7. These results indicate that the learning program uses the ExPRession model in the very valid category of stimulating system thinking and students' numeracy skills on the topic of light interference.

Table 7. Results of Learning Program Validation Using the ExPRession Model

No.	Rated aspect	Percentage Validity (%)
1	Syllabus	89.7
2	LIP	92,2
3	e-worksheets	94,1
4	e-Handouts	88.4
Average Percentage Validity (Learning Program Validity)		91.1
Criteria		Very Valid

Discussion

Product validity was obtained from validation results by three experts (validators): one lecturer in the Masters of Physics Education, one education practitioner, and one high school physics teacher who had completed his master's program. The validity of the syllabus and lesson plans shown in Table 3 and Table 4 shows a percentage weight of 89.7% and 92.2% respectively with very valid criteria. These criteria are obtained because the syllabus and lesson plans developed include competency standards, basic competencies, learning materials, learning activities, competency achievement indicators, assessments, time allocation, and learning resources.

Core Competencies and Basic Competencies function to develop the potential that exists in students, as well as learning material in Basic Competencies, to give meaning to the Basic Competencies that are formulated (Fahrurrozi & Mohzana, 2020). Competency Achievement Indicators are formulated with Operational Verbs sequentially from low to high cognitive or psychomotor level. The learning activities contained in the syllabus and lesson plans encourage students to be active because they are directed to find the concept of light interference from phenomena presented in the form of images of Morpho butterfly wings, as well as graphs and results of light interference experiments. Students can solve problems and allow for interaction among students according to the characteristics of learning Physics (Calmer, 2019; Furtak & Penuel, 2019; Geller et al., 2018). This problem is presented realistically related to the surrounding environment so that it can motivate students to seek various information in solving these problems (Novitra et al., 2021).

The advanced syllabus and lesson plans show that learning is carried out using experiments, questions and answers, and discussions which are part of effective and efficient methods in learning physics (Sommerauer & Müller, 2014; Touchton, 2015). The learning process described in the lesson plan contains activities by the stages of the ExPRession learning model, namely orientation, expression, investigation, evaluation, and generalization (Herlina, 2020). These learning activities are then carried out by an assessment that can measure competence formation (Fahrurrozi & Mohzana, 2020).

The next validity is e-Worksheet and e-Handout as multimedia-based teaching materials, both in content and media and design. As shown in Table 5 and Table 6, the average percentage weight is obtained, 94,1% and 88,4%, with very valid criteria. Content validity was viewed from the aspect of content feasibility and language feasibility, both of which were categorized very well. In terms of content feasibility, the validity of e-Worksheet and e-Handout can be seen in terms of presentation steps, social systems, reaction principles, support systems, and instructional and accompaniment impacts. Furthermore, from the aspect of language feasibility, it shows that the language used is straightforward, communicative, dialogic, and interactive, according to the level of development of students, presents stages of learning that are coherent and consistent in the use of terms, symbols, and icons. The eligibility of the content and the feasibility of the language in the e-Worksheet and e-Handout meet the criteria for good physics teaching materials, namely accurate in quoting and presenting theory, appropriate between competence and content coverage, communicative, complete and systematic, student-oriented, using language rules correct, and has good readability (Sinaga, 2019; Wang et al., 2018).

The validation of e-Worksheet and e-Handout is also reviewed regarding media and design in the cover and content sections. The cover section of e-Worksheet and e-Handout has a center of view, the balance of composition and size of layout elements, alignment of cover design, alignment of title color with background, and combination of fonts in a very good category. The illustrations presented in the e-Worksheet and e-Handout can describe the content/material and have shapes, sizes, colors, and illustrated proportional objects by reality. Furthermore, the contents, the placement of the title, and layout elements are consistent, the print area and margins are proportional, the suitability of the shape, color, and size of the layout elements is good, and has elements of page numbers, illustrations, and descriptions of images, uses a combination of fonts, letters ornamental/decorative, and a good variety of letters. This is a teacher's innovation to attract students' interest and motivate students to learn because the media presented is not only in the form of words or text but consists of words or text, pictures, animations, and videos (Collins, 2002; Mayer, 1999).

Overall, the validation results for learning programs using the ExPRession model obtain a percentage weight of 91,1% with very valid criteria, as shown in Table 7. The criteria obtained show that learning programs using the ExPRession model meet the criteria for valid learning programs. This means that this learning program has material components that are the basis for up-to-date knowledge. All components are appropriate and consistently interrelated (Plomp & Nieveen, 2010). Thus the product can be tested to measure its effectiveness and practicality in learning Physics.

Conclusion

Based on the results of the research data analysis that has been done, it can be concluded that the learning program using the ExPRession model is very valid for stimulating students' system thinking and numeracy skills. This is because content validity shows that the learning program using the ExPRession model can be applied in learning Physics in Senior High School Class XI Even Semester on Optics (Light Interference) to stimulate students' system thinking and numeracy skills. Furthermore, teaching materials as part of this learning program in terms of media and design validity are very interactive or multimedia-based so that they can be innovations that attract interest and motivate students to learn.

References

Adel, A., & Dayan, J. (2021). Towards an intelligent blended system of learning activities model for New Zealand institutions: an investigative approach. *Humanities and Social Sciences Communications*, *8*(1), 1–14.

Afandi, A., Sajidan, S., Akhyar, M., & Suryani, N. (2019). Development frameworks of the Indonesian partnership 21st-century skills standards for prospective science teachers: A Delphi Study. *Jurnal Pendidikan IPA Indonesia*, *8*(1), 89–100.

Ambrose, B. S., Shaffer, P. S., Steinberg, R. N., Mcdermott, L. C., Ambrose, B. S., Shaffer, P. S., Steinberg, R. N., & Mcdermott, L. C. (2006). *An investigation of student understanding of single-slit diffraction and double-slit interference An investigation of student understanding of single-slit diffraction and double-slit interference*. *146*(May 2014). https://doi.org/10.1119/1.19210

Aminudin, A. H., Kaniawati, I., Suhendi, E., Samsudin, A., Coştu, B., & Adimayuda, R. (2019). Rasch analysis of Multitier Open-ended Light-Wave Instrument (MOLWI): Developing and assessing second-years sundanese-scholars alternative conceptions. *Journal for the Education of Gifted Young Scientists*, *7*(3), 557–579.

Ashraf, A. (2020). Challenges and possibilities in teaching and learning of calculus: A case study of India. *Journal for the Education of Gifted Young Scientists*, *8*(1), 407–433.

Aslan, S. (2015). Is learning by teaching effective in gaining 21st century skills? The views of pre-service science teachers. *Educational Sciences: Theory & Practice*, *15*(6).

Aspridanel, A., Abdurrahman, A., Lengkana, D., & Jalmo, T. (2022). STEM-Integrated Flipped Classroom in the Teacher’s Perspective: Could its Implementation in E-Module Improve System Thinking Ability? *Indonesian Journal of Science and Mathematics Education*, *5*(1), 43–52.

Asrizal, Amran, A., Ananda, A., Festiyed, F., & Sumarmin, R. (2018). The development of integrated science instructional materials to improve students’ digital literacy in scientific approach. *Jurnal Pendidikan IPA Indonesia*, *7*(4), 442–450. https://doi.org/10.15294/jpii.v7i4.13613

Aufa, M., Saragih, S., & Minarni, A. (2016). Development of Learning Devices through Problem Based Learning Model Based on the Context of Aceh Cultural to Improve Mathematical Communication Skills and Social Skills of SMPN 1 Muara Batu Students. *Journal of Education and Practice*, *7*(24), 232–248.

Barak, M. (2017). Science teacher education in the twenty-first century: A pedagogical framework for technology-integrated social constructivism. *Research in Science Education*, *47*, 283–303.

Beatty, A., Berkhout, E., Bima, L., Coen, T., Pradhan, M., & Suryadarma, D. (2018). Indonesia Got Schooled: 15 Years of Rising Enrolment and Flat Learning Profiles. *Jakarta: RISE Programme in Indonesia*.

Bobek, E., & Tversky, B. (2016). Creating visual explanations improves learning. *Cognitive Research: Principles and Implications*, *1*, 1–14.

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education–cases, places and potentials. *Educational Media International*, *51*(1), 1–15.

Calmer, J. M. (2019). Teaching Physics within a Next Generation Science Standards Perspective. *Pedagogical Research*, *4*(4), 1–6. https://doi.org/10.29333/pr/5868

Can, H. (2021). *Implementation Of Systems Thinking Skills Module For The Context Of Energy*.

Cheng, K.-M. (2017). *Advancing 21st Century Competencies in East Asian Education Systems*.

Collins, J. (2002). Teaching and Learning with Multimedia. In *Teaching and Learning with Multimedia*. https://doi.org/10.4324/9780203441305

Delgado, F. (2021). Teaching physics for computer science students in higher education during the COVID-19 pandemic: A fully internet-supported course. *Future Internet*, *13*(2), 35.

Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics-Physics Education Research*, *10*(2), 020119.

Doleck, T., Bazelais, P., Lemay, D. J., Saxena, A., & Basnet, R. B. (2017). Algorithmic thinking, cooperativity, creativity, critical thinking, and problem solving: exploring the relationship between computational thinking skills and academic performance. *Journal of Computers in Education*, *4*, 355–369.

Doyan, A., Makhrus, M., & Zamrizal, W. (2021). Development of Modern Physics Learning Devices Using Inquiry Learning Model Assisted with Virtual Media to Improve Student Cognitive Learning Result. *5th Asian Education Symposium 2020 (AES 2020)*, 213–216.

Fahrurrozi, M. & Mohzana. (2020). *Pengembangan Perangkat Pembelajaran.* NTB: Universitas Hamzanwadi Press.

Febrian, A., & Ma'ruf, Z. (2021). Design and development of e-learning devices based on massive open online course (MOOC) on static fluids material. *Journal of Physics: Conference Series*, *2049*(1), 012059.

Furtak, E. M., & Penuel, W. R. (2019). Coming to terms: Addressing the persistence of "hands-on" and other reform terminology in the era of science as practice. *Science Education*, *103*(1), 167–186.

Geller, B. D., Turpen, C., & Crouch, C. H. (2018). Sources of student engagement in Introductory Physics for Life Sciences. *Physical Review Physics Education Research*, *14*(1), 10118.

Gleason, N. W. (2018). Higher Education in the Era of the Fourth Industrial Revolution. In *Higher Education in the Era of the Fourth Industrial Revolution*. Springer Singapore. https://doi.org/10.1007/978-981-13-0194-0

Gunawan, G., Harjono, A., Herayanti, L., & Husein, S. (2019). Problem-based learning approach with supported interactive multimedia in physics course: Its effects on critical thinking disposition. *Journal for the Education of Gifted Young Scientists*, *7*(4), 1075–1089.

Gurr, D., Longmuir, F., & Reed, C. (2020). Creating successful and unique schools: leadership, context and systems thinking perspectives. *Journal of Educational Administration*.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher-students for twenty-first-century learning practices (PREP 21): a framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching*, *23*(1), 25–41.

Herlina, K. (2020). *Model Pembelajaran ExPRession untuk Membangun Model Mental dan Kemampuan Problem Solving* (Pertama). Graha Ilmu.

Hilpert, J. C., & Marchand, G. C. (2018). Complex systems research in educational psychology: Aligning theory and method. *Educational Psychologist*, *53*(3), 185–202.

Hmelo-Silver, C. E. (2014). *Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems and designs for learning*. https://www.researchgate.net/publication/230726725

Hogan, K. (2000). Assessing students' systems reasoning in ecology. *Journal of Biological Education*, *35*(1), 22–28.

Hudha, M. N., & Batlolona, J. R. (2017). How are the physics critical thinking skills of the students taught by using inquiry-discovery through empirical and theorethical overview? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 691–697.

Iglesias-Pradas, S., Hernández-García, Á., Chaparro-Peláez, J., & Prieto, J. L. (2021). Emergency remote teaching and students' academic performance in higher education during the COVID-19 pandemic: A case study. *Computers in Human Behavior*, *119*, 106713.

Jacobson, M. J. (2001). Problem solving, cognition, and complex systems: Differences between experts and novices. *Complexity*, *6*(3), 41–49.

Jacobson, M. J. (2006). *Complex systems in education: Scientific and educational importance and implications for the learning sciences Human-Agent Teamwork in Collaborative Virtual Environments View project*. https://www.researchgate.net/publication/220040401

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*, 284–301.

Kan'an, A. (2018). The Relationship between Jordanian Students' 21st Century Skills (Cs21) and Academic Achievement in Science. *Journal of Turkish Science Education*, *15*(2), 82–94.

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues. *Science & Education*, *30*(3), 589–607.

Keiler, L. S. (2018). Teachers' roles and identities in student-centered classrooms. *International Journal of STEM Education*, *5*, 1–20.

Krijtenburg-Lewerissa, K., Pol, H. J., Brinkman, A., & van Joolingen, W. R. (2017). Insights into teaching quantum mechanics in secondary and lower undergraduate education. *Physical Review Physics Education Research*, *13*(1), 010109.

Kubricht, J. R., Holyoak, K. J., & Lu, H. (2017). Intuitive physics: Current research and controversies. *Trends in Cognitive Sciences*, *21*(10), 749–759.

Kusasi, M., Fahmi, F., Sanjaya, R. E., Riduan, M., & Anjani, N. (2021). Feasibility of STEM-based basic chemistry teaching materials to improve students' science literature in wetland context. *Journal of Physics: Conference Series*, *2104*(1), 012022.

Lucas, B., & Hanson, J. (2016). *Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education*.

Maani, K. E., & Maharaj, V. (2004). Links between systems thinking and complex decision making. *System Dynamics Review: The Journal of the System Dynamics Society*, *20*(1), 21–48.

Marshman, E., & Singh, C. (2017). Investigating and improving student understanding of quantum mechanics in the context of single photon interference. *Physical Review Physics Education Research*, *13*(1), 010117.

Matlin, S. A., Mehta, G., Hopf, H., & Krief, A. (2016). One-world chemistry and systems thinking. *Nature Chemistry*, *8*(5), 393–398.

Mayer, R. (1999). Research-based principles for the design of instructional messages: The case of multimedia explanations. *Document Design*, *1*(1), 7–19. https://doi.org/10.1075/dd.1.1.02may

Megawati, L. A., & Sutarto, H. (2021). Analysis numeracy literacy skills in terms of standardized math problem on a minimum competency assessment. *Unnes Journal of Mathematics Education*, *10*(2).

Menggo, S., Suastra, I., Budiarsa, M., & Padmadewi, N. N. (2019). Needs Analysis of Academic-English Speaking Material in Promoting 21st Century Skills. *International Journal of Instruction*, *12*(2), 739–754.

Mešić, V., Hajder, E., Neumann, K., & Erceg, N. (2016). Comparing different approaches to visualizing light waves: An experimental study on teaching wave optics. *Physical Review Physics Education Research*, *12*(1), 010135.

Mutakinati, L., Anwari, I., & Kumano, Y. (2018). Analysis of Studentsâ€™ Critical Thinking Skill of Middle School through STEM Education Project-Based Learning. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 54–65.

Nahdi, D. S., Jatisunda, M. G., Cahyaningsih, U., & Suciawati, V. (2020). Pre-service teacher's ability in solving mathematics problem viewed from numeracy literacy skills. *Ilkogretim Online*, *19*(4).

Novitra, F., Festiyed, Yohandri, & Asrizal. (2021). Development of Online-based Inquiry Learning Model to Improve 21st-Century Skills of Physics Students in Senior High School. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(9), 1–20. https://doi.org/10.29333/ejmste/11152

Nurdiansah, I., Islami, F. H., & Nana, N. (2020). Penerapan Model Poe2we yang di Integrasikan Dengan Bencana Tsunami Sebagai Upaya Pemahaman Konsep Fisika Pada Materi Gelombang Berjalan Dan Gelombang Stasioner Bagi Siswa Kelas XI SMA. *EduFisika*, *5*(01), 16–22.

Nurse, M. S., & Grant, W. J. (2020). I'll see it when I believe it: Motivated numeracy in perceptions of climate change risk. *Environmental Communication*, *14*(2), 184–201.

Onyema, E. M., Ogechukwu, U., Anthonia, E. C. D., & Deborah, E. C. (2019). Potentials of mobile technologies in enhancing the effectiveness of inquiry-based learning approach. *International Journal of Education (IJE)*, *2*(01), 1–22.

Orgill, M., York, S., & MacKellar, J. (2019). Introduction to systems thinking for the chemistry education community. *Journal of Chemical Education*, *96*(12), 2720–2729.

Pallant, A., & Lee, H.-S. (2015). Constructing scientific arguments using evidence from dynamic computational climate models. *Journal of Science Education and Technology*, *24*, 378–395.

Partnership for 21st Century - A Network of Battelle for Kids [P21]. (2019). Framework for 21st Century Learning. *Partnership for 21st Century Learning*. http://static.battelleforkids.org/documen%0Ats/p21/P21_Framework_Brief.pdf

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61.

Penner, D. E. (2000). Explaining systems: Investigating middle school students' understanding of emergent phenomena. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(8), 784–806.

Plomp, Tj. (Tjeerd), & Nieveen, N. M. (2010). *An introduction to educational design research : proceedings of the seminar conducted at the East China Normal University, Shanghai (PR China), November 23-26, 2007*. SLO.

Prayogi, S., & Yuanita, L. (2018). Critical Inquiry Based Learning: A Model of Learning to Promote Critical Thinking among Prospective Teachers of Physic. *Journal of Turkish Science Education*, *15*(1), 43–56.

Putranta, H., & Jumadi, J. (2019). Physics teacher efforts of Islamic high school in Yogyakarta to minimize students' anxiety when facing the assessment of physics learning outcomes. *Journal for the Education of Gifted Young Scientists*, *7*(2), 119–136.

Putranta, H., & Supahar, S. (2019). Development of physics-tier tests (PysTT) to measure students' conceptual understanding and creative thinking skills: a qualitative synthesis. *Journal for the Education of Gifted Young Scientists*, *7*(3), 747–775.

Rahman, K., Qodriyah, K., Bali, M. M. E. I., Baharun, H., & Muali, C. (2020). Effectiveness of android-based mathematics learning media application on student learning achievement. *Journal of Physics: Conference Series*, *1594*(1), 012047.

Reid, A., Dillon, J., Ardoin, N., & Ferreira, J.-A. (2021). Scientists' warnings and the need to reimagine, recreate, and restore environmental education. *Environmental Education Research*, *27*(6), 783–795.

Rezeki, S., Andrian, D., Wahyuni, A., & Nurkholisah, H. (2020). The sustainability concept of Riau cultures through development of mathematics learning devices based on Riau folklore at elementary schools. *Journal of Physics: Conference Series*, *1538*(1), 012066.

Richey, R. C., Klein, J. D., & Nelson, W. A. (2007). *Developmental Research : Studies Of Instructional Design And Development*.

Richmond, B., & Peterson, S. (2001). *An introduction to systems thinking*. High Performance Systems., Incorporated Lebanon, NH.

Rotherham, A. J., & Willingham, D. (2009). 21st century. *Educational Leadership*, *67*(1), 16–21.

Saefurohman, S., Maryanti, R., Azizah, N. N., al Husaeni, D. F., Wulandary, V., & Irawan, A. R. (2021). Efforts to increasing numeracy literacy of elementary school students through quiziz learning media. *ASEAN Journal of Science and Engineering Education*, *1*(3), 167–174.

Samo, D. D., & Kartasasmita, B. G. (2018). Culture-Based Contextual Learning to Increase Problem-Solving Ability of First Year University Student. *Journal on Mathematics Education*, *9*(1), 81–94.

Saputro, A. D., Atun, S., Wilujeng, I., Ariyanto, A., & Arifin, S. (2020). Enhancing Pre-Service Elementary Teachers' Self-Efficacy and Critical Thinking Using Problem-Based Learning. *European Journal of Educational Research*, *9*(2), 765–773.

Sasmoko, G. N., Indrianti, Y., & Ronald Hermanus, D. (2021). Linen Assessment Apps: Artificial Intelligence Integration to develop Android-based applications that measure the" literacy, numeracy, entrepreneurial mindset" capacity of students in Indonesia. *2021 4th Artificial Intelligence and Cloud Computing Conference*, 160–164.

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N., & Skinner, E. A. (2014a). A common measurement system for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Studies in Educational Evaluation*, *40*, 18–35.

Schelly, C., Anzalone, G., Wijnen, B., & Pearce, J. M. (2015). Open-source 3-D printing technologies for education: Bringing additive manufacturing to the classroom. *Journal of Visual Languages & Computing*, *28*, 226–237.

Serevina, V., Astra, I., & Sari, I. J. (2018). Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill. *Turkish Online Journal of Educational Technology-TOJET*, *17*(3), 26–36.

Shurygin, V. Y., & Krasnova, L. A. (2016). Electronic Learning Courses as a Means to Activate Students' Independent Work in Studying Physics. *International Journal of Environmental and Science Education*, *11*(8), 1743–1751.

Sinaga, M. (2019). Implementation of innovative learning material to improve students competence on chemistry. *Indian Journal of Pharmaceutical Education and Research (IJPER)*, *53*(1), 28–41.

Siswanto, J., Susantini, E., & Jatmiko, B. (2018). Practicality and effectiveness of the IBMR teaching model to improve physics problem solving skills. *Journal of Baltic Science Education*, *17*(3), 381.

Sommerauer, P., & Müller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. *Computers & Education*, *79*, 59–68.

Stuntz, L. N., Lyneis, D. A., Richardson, G. P., Barcan, D., Costello, W., Fisher, D., Forrester, J., Heinbokel, J., Lyneis, D., Lyneis, J., Mons, J., Potash, J., Quaden, R., Richardson, G., Richmond, B., Stuntz, L., Ticotsky, A., & Weathers, L. (2001). Learner-Centered Learning in K-12 Education. *Education*, *2001*.

Suryawati, E., & Osman, K. (2017). Contextual learning: Innovative approach towards the development of students' scientific attitude and natural science performance. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 61–76.

OECD. (2021). *The Assessment Frameworks for Cycle 2 of the Programme for the International Assessment of Adult Competencies*. https://doi.org/10.1787/4bc2342d-en

Touchton, M. (2015). Flipping the classroom and student performance in advanced statistics: Evidence from a quasi-experiment. *Journal of Political Science Education*, *11*(1), 28–44.

Trnova, E., & Trna, J. (2014). Implementation of creativity in science teacher training. *International Journal on New Trends in Education and Their Implications*, *5*(3), 54–63.

Vachliotis, T., Salta, K., & Tzougraki, C. (2014). Meaningful understanding and systems thinking in organic chemistry: Validating measurement and exploring relationships. *Research in Science Education*, *44*, 239–266.

Vanbecelaere, S., Cornillie, F., Sasanguie, D., Reynvoet, B., & Depaepe, F. (2021). The effectiveness of an adaptive digital educational game for the training of early numerical abilities in terms of cognitive, noncognitive and efficiency outcomes. *British Journal of Educational Technology*, *52*(1), 112–124.

Wang, J., Jou, M., Lv, Y., & Huang, C.-C. (2018). An investigation on teaching performances of model-based flipping classroom for physics supported by modern teaching technologies. *Computers in Human Behavior*, *84*, 36–48.

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, *25*, 127–147.

Wong, G. K.-W., & Cheung, H.-Y. (2020). Exploring children's perceptions of developing twenty-first century skills through computational thinking and programming. *Interactive Learning Environments*, *28*(4), 438–450.

Wosilait, K., Heron, P. R. L., Shaffer, P. S., & Mcdermott, L. C. (2012). *Addressing student difficulties in applying a wave model to the interference and diffraction of light to the interference and diffraction of light*. *5*(1999). https://doi.org/10.1119/1.19083

York, S., Lavi, R., Dori, Y. J., & Orgill, M. (2019). Applications of systems thinking in STEM education. *Journal of Chemical Education*, *96*(12), 2742–2751.