

ANALYSIS OF FREE WEB TUTORIALS FOR EDUCATION IN PROPOSITIONAL AND PREDICATE LOGIC

SANDRA LOVRENČIĆ

University of Zagreb, Faculty of Organization and Informatics, sandra.lovrencic@foi.hr

DALIBOR KOFJAC

University of Zagreb, Faculty of Organization and Informatics, dalibor.kofjac@foi.hr

GORAN HAJDIN

University of Zagreb, Faculty of Organization and Informatics, goran.hajdin@foi.hr

Abstract: Logic topics are included in various university courses in formal foundations of computer science. Although students often have some experience with logic in previous education, they face challenges with propositional and predicate logic that is applied in other courses, such as data and knowledge bases or logic programming. To improve students understanding of this topic, existing study options should be analysed, tested, combined and included into course teaching methods after their adaptation to new suggestions. The aim of this paper is an initial analysis and comparison of free web tutorials for learning propositional and predicate logic according to learning materials and exercises they include, as well as their visual and technical characteristics. Analysis results are presented and further steps of research are proposed.

Keywords: propositional logic, predicate logic, web tutorial, online

1. INTRODUCTION

Logic is considered the calculus of computer science [1] with application in many of its areas, such as descriptive complexity, databases, type theory in programming language research, reasoning about knowledge or automated verification of semiconductor designs [2]. This is why formal logic is one of the courses included into computer science (CS) curricula. Other courses in CS curricula, both in undergraduate or graduate level, such as logic programming, artificial intelligence as well as data and knowledge bases benefit from students' knowledge of propositional and predicate logic, logical reasoning and other topics. Which logic topics and at what study levels should be taught is also being debated [3].

Today is education, especially higher education almost unthinkable without e-learning, although it can have both advantages and disadvantages [4]. One of possibilities for e-learning are web tutorials whose purpose is to cover a specific subject to a wider extent. They are developed for specific courses and books or independently and offer learning materials using multimedia and incorporating exercises and tests in an interactive environment. Web tutorials are lately little neglected in favour of popular Massive Open Online Courses (MOOCs) provided by specialized websites like Coursera¹. But many of those courses are offered as self-paced and in that way similar to web tutorials.

As with other university courses, brief Internet research shows that many of logic for CS courses have various materials available online and that many tools have been developed for exercising one of topics that this course can cover. Some of materials that are used include web tutorials that extensively cover course topics and give students the possibility to learn the course more or less independently. Considering the importance of logic for computer science curricula, we decided to analyse available online materials. Our first research interest were web tutorials, because of the amount of knowledge important to this subject that they offer.

This paper is organized as follows. In Chapter 2 we describe chosen web tutorials, which we then analyze and compare in Chapter 3 according to four main criteria. Additional comments based on authors' expertise are given in Chapter 4 and conclusion is presented in Chapter 5.

2. DESCRIPTION OF WEB TUTORIALS

Web tutorials that will be described are: LogicTutor², The Power of Logic Web Tutor³ and The Logic Café⁴. All of them are available in English language. The main criteria used for choosing the tutorials were the following:

- tutorial has to be fully free for online use
- tutorial has to be aimed at learning both propositional and predicate logic

¹ <https://coursera.org/>

² <http://www.wwnorton.com/college/phil/logic3/>

³ <http://www.poweroflogic.com/cgi/menu.cgi>

⁴ <http://thelogiccafe.net/PLI/>

- tutorial needs to have a fair amount of high-quality exercises

There are other tutorials for logic available online, such as Logic & Proofs⁵, Logic Daemon⁶ or newer version of LogicTutor, called StudySpace⁷, but they didn't meet the above criteria.

LogicTutor

LogicTutor is a web tutorial made by M. K. Green in 1998. It was developed to accompany the book "The Art of Reasoning, 3e" by D. Kelley. This tutorial provides more than 1,100 exercises and summaries on every major concept in the book. There are 15 chapters available in the tutorial to choose from, and each chapter is organized into three modules:

- Tutorial** – it reviews the concepts, definitions, rules, procedures and heuristics that are highlighted in The Art of Reasoning's summary
- Practice** – it offers numerous exercises for users to solve unlimited number of times
- Self-Quiz** – module similar to Practice, but with an examination environment in which users can attempt to answer a problem only once; using "mark and mail" feature users can score their performance and email the results directly to instructor

There are two types of exercises in both Practice and Self-Quiz: multiple choice and gapped text.

Propositional and predicate logic is covered in 3 out of 15 chapters:

- Propositional Logic-Symbolic Notation** – chapter that covers introduction to propositional logic, logical connectives, statement forms and computing truth values
- Propositional Logic Arguments** – it includes truth table test of validity, the short form of truth table test, proof, equivalence, conditional proof and Reductio ad Absurdum
- Predicate Logic** – it covers introduction to predicate logic, quantifiers, existential import, relations, multiple quantification and proof

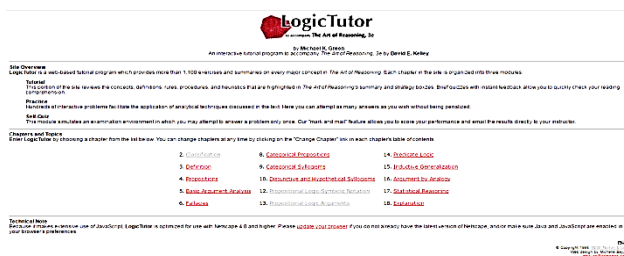


Image 1: LogicTutor home page

Visual characteristics of LogicTutor aren't as good as in some modern web tools, but that has to be expected since it was firstly created in 1998. Main theme of the tutorial is visible on the right side at the main page (Image 1), which

is white background with mostly black letters. The same color combination is also present in Practice module, as well as in other main forms of the tutorial (Tutorial, Self-Quiz). It makes LogicTutor very simple and overall easy to use for everyone.

The Power of Logic Web Tutor

The Power of Logic Web Tutor is a free web tutorial developed in 2012 to accompany the fifth edition of The Power of Logic book by F. Howard-Snyder, D. Howard-Snyder, and R. Wasserman.

The idea behind making Power of Logic Web Tutor was that users read the book first and then use tutor to practice new knowledge with available exercises. That is why this tutor has no materials for learning theory of logic available within the tutorial. Users can only learn the theory using feedback messages tutorial gives while practicing.

Power of Logic Web Tutor provides 10 chapters, each divided in few subchapters containing numerous exercises. Exercises can come in different types, some of which are: gapped text, multiple choice, matching expressions and filling truth tables. The tutorial also offers possibility for users to create their own Venn diagram, truth table or proof.

Propositional and predicate logic is here also covered in three chapters:

- Statement Logic: Truth Tables** – it includes symbolizing arguments, truth tables and abbreviated truth tables, tautology, contradiction, contingency and logical equivalence
- Statement Logic: Proofs** – it covers implicational rules of inference, equivalence rules, conditional proof, proving theorems and Reductio ad Absurdum
- Predicate Logic** – it includes predicates and quantifiers (with symbolization), demonstrating invalidity, constructing proofs and logical equivalents

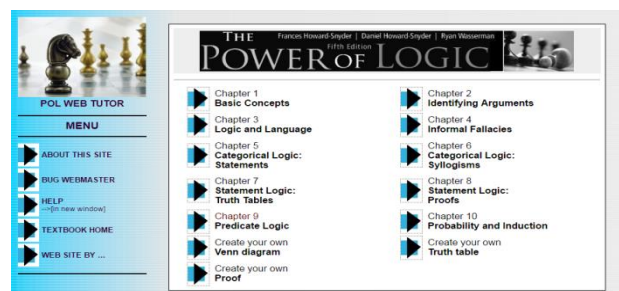


Image 2: Power of Logic Web Tutor main page

Visual characteristics, design and user interface of the Power of Logic Web Tutor are surely few of the main advantages this tutorial can offer. As visible on main page of the tutorial (Image 2), Power of Logic Web Tutor has recognizable blue theme with many small graphics throughout all forms which helps creating relaxing atmosphere that users can experience while using the tutorial. Exercises are mostly simple, on a white

⁵ <https://oli.cmu.edu/jcourse/lms/students/syllabus.do?section=0d007ba680020ca60083e91d71a79918>

⁶ <http://logic.tamu.edu/>

⁷ <http://wnorton.com/college/phil/artreas4/welcome.aspx>

background color with black/red letters. Overall, Power of Logic Web Tutor is a good tutorial with great visual characteristics perfect for users who want to practice their knowledge of logic.

The Logic Café

The Logic Café is a free, interactive, web-based logic tutor and online textbook developed in 1999 by J. F. Halpin at the Oakland University. It was in active development until 2006 and it's still updated if necessary.

The Logic Café can be used by two different types of users. First type is an **instructor**. The tutorial offers guidelines, exercises, presentations and demos for instructors so that they can prepare themselves for teaching logic. Second type is a **student**. The Logic Café provides 9 chapters for students to learn logic. Each chapter contains tutorial and numerous exercises. Some of the types of exercises are: multiple choice, gapped text, drag-and-drop, filling truth tables, solving puzzles, etc.

Propositional and predicate logic is covered in eight chapters that cover specific topics designated by chapter titles and do not need additional description:

- **Sentence Logic**
- **Truth Tables**
- **SL Symbolizations**
- **SL Derivations**
- **Predicate Logic**
- **PL Semantics and Symbolizations**
- **PL Derivations**
- **Predicate Logic with Identity**

Visual characteristics of The Logic Café are decent, but much like with LogicTutor, it's hard to compare it with some modern websites. The design of the tutorial is very simple (Image 3), mostly white background with black letters, with few occasional background color changes.

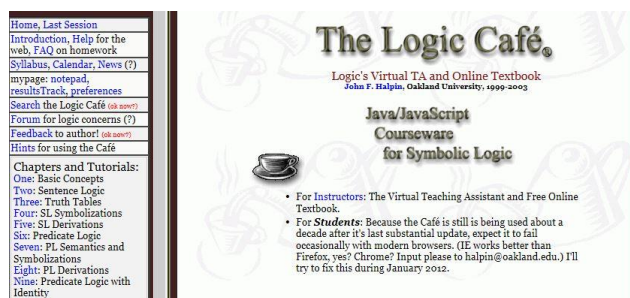


Image 3: The Logic Café home page

The main advantage of this tutorial is interactivity. From going through tutorials to solving exercises, tutorial will keep displaying interactive messages to keep user's attention and focus on the learning. However, all interactive content will only be displayed if using Internet Explorer as a web browser. Overall, The Logic Café is an interactive tutorial with a lot of content that will help both instructors and students in teaching/learning logic.

3. COMPARISON OF WEB TUTORIALS

Our research of chosen web tutorials is concentrated on their contents and visual and technical characteristics. The main goal was to analyze what possibilities they offer for learning propositional and predicate logic. We acknowledge that full analysis is, of course, impossible without users. The comparison is made based on four main criteria: learning materials, exercises, visual appearance and technical characteristics. Each criterion has three subcriteria with the purpose of better and more objective comparison.

Each web tutorial can be awarded with 1, 2 or 3 points per subcriterion, according to their rank for a given subcriterion. At the end, the points from all subcriteria are summed and tutorial with most points is chosen as the best according to individual criterion. Finally, tutorials are graded according to all four criteria.

Comparison based on learning materials

The following subcriteria were determined for the comparison based on learning materials:

- **The amount of materials** – comparison based on the amount of materials for learning logic that tutorial offers
- **The amount of examples** – comparison based on the amount of given examples by the tutorial while learning logic
- **The level of interactivity** – comparison based on the level of interactivity while learning logic. Tutorials with good interactivity level often include the user in the learning process, giving him small exercises to solve and notifications that keep user's attention, while tutorials with bad interactivity level will simply avoid it. Interactivity is very important characteristic of e-learning tutorials that helps promote active learning through a meaningful exchange of information between the content and the learners [5][6].

Table 1: Comparison based on learning materials

The criterion: learning materials			
Name of the web tutorial:	LogicTutor	Power of Logic Web Tutor	The Logic Café
Name of the subcriterion:			
The amount of materials	2 points	1 point	3 points
The amount of examples	2 points	1 point	3 points
The level of interactivity	2 points	1 point	3 points
Total points	6 points	3 points	9 points
Rank (1-3)	2	3	1

As can be seen in the last row of the Table 1, The Logic Café scored total of 9 points and thus took the first place in

the comparison based on learning materials. The Logic Café is at the first place because of large amount of learning materials (chapter descriptions, detailed tutorials and glossary), large amount of examples in each chapter's tutorial (given to help understanding of definitions and concepts) and high level of interactivity that it offers while learning. LogicTutor is in second place with total of 6 points. It also offers tutorial for learning logic, but it is less complex with less examples and interactivity than The Logic Café's. At the third place with 3 points is Power of Logic Web Tutor, which doesn't have real tutorial section, but can still be used for learning logic theory through solving exercises and getting helpful feedback.

Comparison based on exercises

The following subcriteria were determined for the comparison based on exercises:

- **The amount of exercises** – comparison based on the amount of exercises (exercises) available in the tutorial
- **The variety of exercises** – comparison based on the number of different exercise types that the tutorial offers, which influences learner satisfaction [7]
- **The quality of the feedback** – comparison based on the feedback messages given to the user after finishing certain exercise. Good quality of the feedback includes giving status of the answer (right/false), and if the answer is wrong, explanation why is it wrong. Bad quality of the feedback means only status of the answer or no feedback at all. Feedback is one the most important features of e-learning tutorials and should never be neglected [6].

Table 2: Comparison based on exercises

The criterion: exercises			
Name of the tutorial:	LogicTutor	Power of Logic Web Tutor	The Logic Café
Name of the subcriterion:			
The amount of exercises	1 point	3 points	2 points
The variety of exercises	1 point	2 points	3 points
The quality of the feedback	1 point	3 points	2 points
Total points	3 points	8 points	7 points
Rank (1-3)	3	1	2

In the second comparison (Table 2) at the first place is Power of Logic Web Tutor with 8 points because of the largest number of available exercises, good quality of the feedback (with both status and explanations) and decent variety of the exercises with 4 different types. At the second place with 7 points is The Logic Café, which has better variety of the exercises with more than 5 different types, but lacks in other subcriteria. LogicTutor is at the last place with 3 points. Even though it has the lowest

score, LogicTutor still offers many good quality exercises of 2 types and a feedback that will let the user know if given answer was right or wrong.

Having a lot of high-quality exercises was one of the main reasons for choosing those 3 tutorials for preview and comparison so it's important to say that all three are quite rich in that domain.

Comparison based on visual appearance

The following subcriteria were determined for the comparison based on visual appearance:

- **The ease of use of the user interface** – comparison based on the user interface of the tutorial. Good and well-organized intuitive user interface is important feature of e-learning tutorials that can make learning and using the tutorial much easier [6].
- **Design** – comparison based on the quality of the tutorial's design (appearance of the web-page, usage of different colors, fonts, forms, etc.). Design of the tutorial should always be taken seriously because it significantly influences learner satisfaction [7].
- **The usage of additional visual content** – comparison based on the usage of pictures, graphs, videos, animations and similar visual content that greatly influences user's experience and general visual appearance of the tutorial. Multimedia usage is very important for users [5][6].

Table 3: Comparison based on visual appearance

The criterion: visual appearance			
Name of the tutorial:	LogicTutor	Power of Logic Web Tutor	The Logic Café
Name of the subcriterion:			
The ease of use of the user interface	2 points	3 points	1 point
Design	1 point	3 points	2 points
The usage of additional visual content	1 point	3 points	2 points
Total points	4 points	9 points	5 points
Rank (1-3)	3	1	2

The results of the comparison based on visual appearance (Table 3) show that once again Power of Logic Web Tutor took the first place with 9 points. Even though all three tutorials share similar graphical interface with mostly white background and black letters, Power of Logic stands out with really good design, user interface that is easy to use and recognizable blue theme with many small graphics and usage of Venn's diagrams. At the second place with 5 points is The Logic Café, mostly because of the short animations that tutorial allows users to preview. At third place with 4 points is a tutorial with very simple design and easy to use interface, but no real additional visual content, LogicTutor.

Comparison based on technical characteristics

The following subcriteria were determined for the comparison based on technical characteristics:

- **Speed** – comparison based on the loading speed of the tutorial’s web page. All tutorials were tested using free website speed testing tool called “Dotcom-monitor Website speed test”⁸. Web browser used for the test was Internet Explorer 11 and testing region was New York, USA.
- **Compatibility with web browsers** – comparison based on the number of web browsers that tutorials are fully compatible with. Tutorials are tested on three well-known web browsers (Internet Explorer, Mozilla Firefox and Google Chrome). Each web browser they are compatible with brings one point with a maximum of three.
- **The tendency of failure** – comparison based on a tendency of failure of the tutorials. After a regular user test (validation), points will be given based on a number of failures (web page crashes and similar) experienced during test. Web browser used for the test was Internet Explorer 11 for all three tutorials.

All three subcriteria can be listed under technology quality, which will to some extent positively influence perceived e-learner satisfaction with e-learning [7].

Table 4: Comparison based on technical characteristics

The criterion: technical characteristics			
Name of the tutorial:	LogicTutor	Power of Logic Web Tutor	The Logic Café
Name of the subcriterion:			
Speed	3 points	2 points	1 point
Compatibility with web browsers	3 points	3 points	1 point
The tendency of failure	3 points	3 points	3 points
Total points	9 points	8 points	5 points
Rank (1-3)	1	2	3

The results of the last comparison, based on technical characteristics, show that at the first place is LogicTutor with 9 points. Tests show that LogicTutor is the fastest tutorial with speed of 263 ms and it is compatible with all three tested web browsers. At second place with 8 points is Power of Logic Web Tutor, which had speed of 638 ms and also compatibility with all three web browsers. The Logic Café with 5 points is at the third place, with speed of 816 ms and full compatibility with only one web browser, Internet Explorer. It can be opened with other explorers, but in that case some of the functionalities won’t be working properly. As for the tendency of failure, during user testing neither tutorial showed any kind of failure, so all tutorials were given 3 points for that subcriterion.

Choosing generally best tutorial

After selection of the best tutorial according to each of four main criteria, ranking according to all criteria has been done. After summing up all ranks from previous comparisons, tutorial with lowest number is at the first place.

Table 5: Choosing generally best tutor

Choosing generally best tutor			
Name of the tutorial:	LogicTutor	Power of Logic Web Tutor	The Logic Café
Name of the criterion:			
Learning materials	2	3	1
Exercises	3	1	2
Visual appearance	3	1	2
Technical characteristics	1	2	3
Total rank	9	7	8

As seen in the last row of the Table 5, with total of 7 points, generally best tutorial for learning propositional and predicate logic is **Power of Logic Web Tutor** with first place in “Exercises” and “Visual appearance”, second place in “Technical characteristics”, but third place in “Learning materials”.

The fact that the difference between all three tutorials is only in 1 point shows that generally best tutorial doesn’t necessarily mean best for every person, because The Logic Café and LogicTutor are surely better for learning logic theory than Power of Logic Web Tutor (if user doesn’t have the book), so the selection depends on one or more criteria the user gives preference and on user’s needs.

4. ADDITIONAL COMMENTS

Since third author has large experience in the field of pedagogy in computer science and first author in the field of teaching logic, we also give additional comments of three web tutorials according to authors’ respective fields of expertise.

Pedagogical perspective

LogicTutor has clear and accessible menus, but they are not in logical order. For example, first lesson is related to “Language, Concepts, and Classification” and has comprehension questions related to terms: Concept, Referent, Genus and Species, while those four terms are explained in the next lesson. Learning tutorial provides instant feedback to the user, but does not provide any additional information in case of incorrect answer. It is confusing that some comprehension questions come before, while others come after a lesson they are related to. Positive is that learning tutorial consists of simple and clear

⁸ <https://www.dotcom-tools.com/website-speed-test.aspx>

examples as well as instructions and that comprehension questions have consistency in their form and format.

Power of Logic Web Tutor has clean and easy to use user interface. It has clearly separated and well organized chapters. Each chapter consists of several exercises. They are easy to use and comprehend. The tutorial provides relevant information and user can learn from his or her own mistakes. Each exercise has additional option regarding question selection (all, random, or user selected) which adds to exercise variety.

The Logic Café has multiple and confusing menus. Positive is that once a user manages to start a chapter, the tutorial will partially guide a user through the content and automatically progress after registering correct answer. If a user provides incorrect answer, the tutorial provides relevant feedback. Content is easy to understand and tutorial provides decent examples as well as feedback.

The easiest to use is Power of Logic Web Tutor, then LogicTutor and finally The Logic Café. The Logic Café also provides more content, better explanations and relevant feedback. Power of Logic Web Tutor does not have theoretical nor introductory sections which would provide relevant information to the user, but, as already mentioned, it is created to accompany The Power of Logic book. Keeping this in mind it is the best and easiest to use tutorial of the three. If viewing only the online elements, it is lacking information which is present in the book.

Contents perspective

LogicTutor offers information and clarification about various terms prior to introduction to propositional and predicate logic, such as classification, definition, propositions, argument analysis, fallacies, categorical propositions and syllogisms. It covers all main topics for propositional and predicate logic that are already describe in Chapter 2.

Power of Logic Web Tutor, as noted before, has only available exercises that accompany book. But considering the contents it comprises in general, this tutorial also has introductory information about terms such as validity, soundness, forms, arguments, definitions, fallacies, categorical statements and syllogisms. It also covers all main topics with addition of proofs for theorems.

The Logic Café covers following introductory terms: arguments, validity, soundness, deduction, induction and informal proofs. As other two tutorials, it also covers all important topics, with more details about proof strategies. It also has additional notions on identity (“equals”) that actually emphasizes the constants in logic.

All three tutorials cover main topics of propositional and predicate logic: syntax and semantics, symbolizations, evaluation of statements with truth tables, formal proofs and deduction rules of inference, equivalences, conditional proofs and Reductio ad Absurdum. They also give proper introduction to the subject. But, considering the application of logic in computer science, they give only introductory knowledge. Other proof methods, such as analytic tableaux or resolution, as well as application in knowledge

reasoning are topics that should be covered in logic courses for CS. Of course, they can be included in other courses after introductory course.

5. CONCLUSION

Considering that logic is an important part of computer science curricula and that many advanced courses can benefit from it, it is important that students comprehend this subject. Web tutorials offer learning and exercising materials in one place accessible at any time and from anywhere. Analysis of chosen tutorials has shown that all of them have good introductory materials and that differences among them are small if we take combination of all criteria into account. But, if we consider individual criteria, differences are more emphasized. Therefore, we can conclude that the choice of the tutorial largely depends on the importance of each main criteria to the user. Also, all of them need improvement in visual characteristics.

The contents available in all three web tutorials is an excellent start to learn propositional and predicate logic, but it is important to note that other advance topics are necessary for other courses in computer science curricula. Further research should analyze differences among introductory and advanced logic courses that are currently offered in various CS curricula and among materials they make available online with the aim to develop a tutorial more suitable to logic for computer science courses.

REFERENCES

- [1] L. S. Moss, “Applied Logic: A Manifesto”, in *Mathematical Problems from Applied Logic I: Logics for the XXIst Century*, D. M. Gabbay, S. Goncharov and M. Zakharyashev, Eds. New York: Springer, 2006, pp. 317-343.
- [2] J. Y. Halpern, R. Harper, N. Immerman, P. G. Kolaitis, M. Y. Vardi and V. Vianu, “On the Unusual Effectiveness of Logic in Computer Science”, *Bulletin of Symbolic Logic*, Vol. 7, pp. 213-236, May 2001.
- [3] J. A. Makowsky, “Teaching Logic for Computer Science: Are We Teaching the Wrong Narrative?”, in *Proc. TTL2015*, 2015, pp. 101-109.
- [4] V. Arkorful and Nelly Abaidoo, “The role of e-learning, the advantages and disadvantages of its adoption in Higher Education”, *International Journal of Education and Research*, Vol. 2, pp. 397-410, Dec. 2014.
- [5] P. Jaypuriya, “eLearning Interaction Building Tools: Explore And Compare Them”, June 20, 2016. <https://elearningindustry.com/explore-compare-elearning-interaction-building-tools>
- [6] D. McIntosh, “eLearning Authoring Tools Checklist”, March 30, 2013. <https://elearningindustry.com/elearning-authoring-tools-checklist-features>
- [7] P.-C. Sun, R. J. Tsai, G. Finger, Y.-Y. Chen and D. Yeh, “What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction”, *Computers & Education*, Vol. 50, pp. 1183–1202, May 2006.