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### Why Excel?

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## CONTENT ARTICLE IN ECONOMICS

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### Why Excel?

Humberto Barreto

This article is not the usual Excel pedagogy fare in that it does not provide an application or example taught via a spreadsheet. Instead, it briefly reviews the history of spreadsheets in the economics classroom and explores the current environment, with an emphasis on modern learning theory. The conclusion is not surprising: spreadsheets improve learning outcomes across the economics curriculum and are increasingly being used. They offer the “just right” option that gives a middle way between too little and too much focus on software in an economics course.

**Keywords** *learning, Microsoft Excel, pedagogy, spreadsheet*

**JEL codes** *A20, A22*

Consider Goldberger’s (1998, 44) crystal clear explanation of a sampling distribution:

Imagine that we repeatedly drew samples of size  $n$  from the population (with replacement), recorded the sample mean and sample variance of each, wrote those on a clean chip, and put the chip into a bowl. As this process was continued indefinitely, the proportions in the new bowl would stabilize, the relative frequencies approaching the joint probability distribution of sample means and sample variances in size- $n$  random sampling from the original population. Such a derived distribution—a probability distribution of one or more sample statistics for a given sample size—is called a *sampling distribution*.

For most students, problems begin with the very first word. The abstract thinking required to construct a mental image of what is being described presents a serious obstacle to learning. Many more students can be reached by actually implementing this data generation process in a spreadsheet, repeatedly resampling, and directly examining the outcomes.

Applying lessons from modern learning theory and neuroscience, I explain why concrete examples and visual displays of results are the secret to the success of spreadsheets in teaching economics and econometrics. I also discuss the pros and cons of Microsoft Excel versus its current

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Color versions of one or more of the figures in this article can be found online at [www.tandfonline.com/vece](http://www.tandfonline.com/vece).

rivals. As Colander (2009) has argued regarding why students choose to major in economics, Excel is the “just right” option.

The next section offers a brief history of spreadsheets and Excel, including highlights in the literature of teaching and learning. The following section is a review of modern learning theory, and the section after that presents the case for Excel.<sup>1</sup> The final section concludes.

### A BRIEF HISTORY OF SPREADSHEETS IN THE ECONOMICS CLASSROOM

In a summary of the literature on what was then called CAI, computer-assisted instruction, Siegfried and Fels (1979, 942) found that “overall, games and CAI in economics do not appear to be the route to nirvana they were once expected to be.” At that time, a computer was a large machine, housed in a basement or other large room, and users submitted jobs via punch cards or from terminals. Within a few years, however, the computer landscape was radically restructured.

Spreadsheets were an initial killer app that revolutionized the business world in the early 1980s, destroying entrenched mainframes with millions of microcomputers. Economists and business schools responded quickly and began teaching with *Lotus 1-2-3* and *QuattroPro*. *Microsoft Excel* was a latecomer, but it leapfrogged the early leaders by the 1990s because it had a more powerful macro language and integration with word processing and other office software. After crushing the competition, Excel enjoyed a dominant position in the doc-spreadsheet-presentation suite until the recent rise of Google and its free, online model.

An article by Post (1985) was the first of many in the *Journal of Economic Education* and elsewhere that explored the pedagogical consequences of using microcomputers, in general, and spreadsheets, in particular. A series of papers followed, covering a wide array of applications. Day (1987) argued for simulation, Smith and Smith (1988) reviewed microeconomics examples, and Adams and Kroch (1989) focused on macroeconomic models in a spreadsheet.

Lovell (1987, 320) described in detail how a spreadsheet was different from the earlier mainframe approach:

For example, the instructor can use the arrow keys to move the cursor onto the cell containing the correlation coefficient and enter a new value (say, 0.3); as soon as the RETURN button is pressed, the table will be recomputed right in front of the class—the relevant entries (covariance, standard deviations of alternative portfolios, etc.) will be adjusted in rapid sequence and the investment opportunity locus graph will shift appropriately. By executing a number of experiments in front of an undergraduate class in money and banking, an instructor can convey an appreciation of the problem of portfolio selection to students who have not yet studied statistics. This illustrates a fundamental point:

*For students with limited preparation, the computer makes comprehensible models that cannot be understood easily when only a blackboard presentation is used.*

This means that CAI will encourage a rethinking of our traditional curriculum choices: topics previously reserved for more advanced students may now be included in introductory courses.

After pointing out that “*Lotus 1-2-3* is the most popular microcomputer program ever written,” Yohe (1989, 431) went on to identify four major kinds of uses for spreadsheets in the classroom: “(1) as a content-free computational environment [computing IRR from a net revenue stream], (2)

as an enhanced computational environment [DW statistic], (3) with content-specific templates, which may or may not contain explicit tutorial materials [macro model or simulation], and (4) for computer-managed instruction, including test and problem generation.”

Judge (1990, 1027) followed up on the third use and pointed out that “the use of spreadsheets in teaching need not be limited to the purely quantitative courses. Other courses such as managerial economics or even microeconomics and macroeconomics can benefit from a spreadsheet’s problem-solving and simulation potential.” Thus, the dissemination of spreadsheets in the economics curriculum went from formulas and what-if analyses to simulation and data analyses, and then expanded to optimization and more specialized applications across the curriculum.

Today, of course, we expect students to have a basic understanding of word processing and spreadsheet software. Economics professors do not explain how to use a mouse or open a file. More advanced uses, such as creating a graph or using an Excel add-in, must be taught, and this forms the core of modern spreadsheet teaching.

Many articles and books have been published using Excel to deliver content. A JSTOR search of *excel* in the *Journal of Economic Education* since 2000 yields over fifty hits with content in every area of economics, from micro to macro and econometrics, and from introductory to advanced levels. A search of *excel economics* in books at Amazon.com yields over 2,300 results, with many Excel-based books beyond economics in areas such as quantitative analysis and financial modeling.

## MODERN LEARNING THEORY

A good definition of learning is provided by Brown, Roediger, and McDaniel (2014, 2): “acquiring knowledge and skills and having them readily available from memory so you can make sense of future problems and opportunities.” Our intuitions about learning and teaching can be right, but we can also be misled and deluded by our experiences. There is no doubt that learning requires memory so that we can recall and use information. We can also agree that some students may be better or worse at learning, but everyone can improve.

We make serious mistakes, however, in the ways we believe that we can learn more productively. It is in studying that students make poor decisions, often because they and their teachers do not understand how we learn. To advise students on how to learn and study, see Ambrose and colleagues (2010); Brown and colleagues (2014); and Carey (2014) for succinct, accessible reviews of current lessons from cognitive science. It is now clear, for example, that massed practice and cramming are vastly inferior to alternating, spaced repetition.

A spreadsheet enhances learning for one simple reason: Neuroscience research has shown that we do not pay as much attention to things we find boring, and as Medina (2008, 74) noted, “Better attention always equals better learning.” This is why sitting and merely listening to a speaker is dominated by listening and taking notes. Listening, writing, and doing something with a computer (figuring out the effect of changing a number in a cell) is one step better. Lab activities in science courses go even further, combining auditory, visual, and kinesthetic inputs. It may seem counterintuitive, but the more you bombard the student with a variety of sensory information, the more they learn.

By stimulating more of the senses and especially by providing strong visual signals (e.g., a graph that updates when a number is changed), we are taking advantage of how our brains

were built. The brain is not, as most people believe, a recording device. In fact, we have a poor understanding of how encoding actually works. Medina (2008, 104) said, “The little we know suggests that it is like a blender left running with the lid off. The information is literally sliced into discrete pieces as it enters the brain and splattered all over the insides of our mind.” If you look at a complicated graph, like an Edgeworth Box, your brain separates the lines from curves and stores them in different places. Color goes somewhere else and so do numbers. Sound, motion, and many other aspects of what we see, hear, feel, smell, and taste are distributed throughout the brain. Neuroscientists are working hard on the binding problem, how the brain manages and reconstructs all of these bits of data.

For a teacher, this understanding of the brain explains why multisensory input is so helpful to learning. The more elaborately we encode information, the stronger the traces in the disparate places in the brain and the more we learn. For example, an optimization problem in a spreadsheet, where the student must manipulate formulas and figure out which variables are endogenous versus exogenous, produces a meaningful and contextual environment that allows for retrieval of concepts more effectively than a mere slide with an equation in a lecture.

Effective use of computers and spreadsheets in teaching does not imply wholesale substitution or elimination of other modes of instruction. Teachers should strive to distribute content in a wide variety of ways to maximize sensory stimulation. Students should avoid massed practice and cramming, which feels like good, hard work, but produces an illusion of knowing that is not true. Steady, repeated, spaced practice and effortful retrieval is the key to studying well. Spreadsheets are perfect for this. It is easy to generate different problems (with varying parameter values) that reinforce concepts. As Brown and colleagues (2014, 75) pointed out, after we anchor a memory, “we must associate the material with a diverse set of cues that will make us adept at recalling the knowledge later.” The physical act of moving the cursor, clicking on a chart element, entering a formula, and seeing the results provide the student with powerful signals that help deeply embed knowledge.

Of course, all of this requires a great deal of work, but we know that “learning is deeper and more durable when it’s *effortful*” (Brown, Roediger, and McDaniel 2014, 3). Retrieval practice that is interleaved and spaced out is by far the most effective way to learn. During a semester of intermediate microeconomics, for example, analyzing a constrained utility maximization model with graphs, equations, and Excel’s Solver and then using these same tools for constrained cost minimization and again for profit maximization (for perfect competition and monopoly) is a perfect application of modern learning theory. The material is tested, which is essentially retrieval practice, so the student gets feedback on mastery and then repeated to entrench the material in the brain. Neuroscientists would point out that the process of repeating the steps in a comparative statics analysis (initial, shock, new, compare) in a variety of applications forces reloading and digs deeper, more durable memory pathways; just like when we recall and retell a story, it gets easier to remember it. As Medina (2008, 146) pointed out, “Memory is not fixed at the moment of learning, and repetition provides the fixative.”

While the puzzle of the mind has always attracted study, it is fair to say that modern scanning and imaging technology has led to an explosion of research on the brain. Professors, as consumers of this output, can apply lessons on learning to improve their teaching. Computers are helpful because they provide more sensory input and context for the student. Using older language, this active learning is more effective than passive listening because information is more elaborately encoded. In addition, the ability of computers to generate many problems to provide repeated,

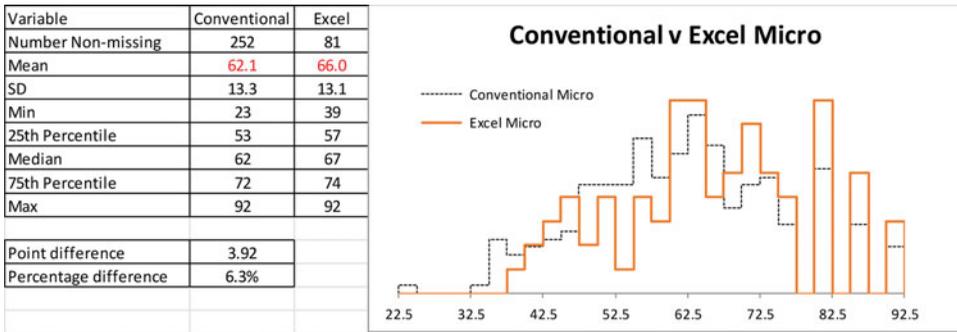


FIGURE 1 Comparing outcomes on MFT by conventional and Excel-based micro course.

interleaved, and spaced practice is a strong driver of better learning. Finally, computers provide visual stimulation with color, sound, and motion. This is critical because we are absolutely hardwired for visual perception. Our eyes transmit raw inputs, and the brain completely constructs what we perceive (which explains why it is so easy to be deceived by magic tricks and other illusions). For the sighted, a majority of brain resources are devoted to vision, and we pay close attention to color, orientation, size, and especially careful attention to motion. The moment a student changes a cell and a curve shifts on screen, or runs a simulation and looks at a histogram of the results, the learning power is much stronger than listening to or reading an explanation.

I am unaware of any study of the treatment effect of spreadsheet-based instruction. In recent years, however, I have taught one of three or four sections per semester of intermediate microeconomics at DePauw University. Using Barreto (2009), Excel is utilized in every class session and for homework; exams are a mix of pencil-and-paper and computer-based questions. All of our senior economics majors must take the ETS Major Field Test ([www.ets.org/mft](http://www.ets.org/mft)) in economics. Figure 1 compares the performance of students who took Excel-based intermediate microeconomics versus those who took a conventional course on the microeconomics portion of the MFT.

The national SD for the microeconomics portion is 15 for 6,467 examinees (according to the *2014 MFT Comparative Data Guide: MFT Economics*, available on the MFT Web site). Thus, a four-point improvement on an exam taken usually two years after completing intermediate microeconomics represents a roughly one-quarter increase in standard units.

Another way to evaluate the evidence in figure 1 is to convert MFT scores to letter grades. Our department does this so that MFT results can be incorporated into the Senior Seminar course grade. Regressing assigned letter grades (on a 4.0 GPA scale) on MFT scores shows that each MFT point is worth about 0.06 of a GPA point. Thus, a four-point increase in MFT is roughly one-quarter of a letter grade.

The results presented in figure 1 point to a substantial improvement in learning economics with Excel versus conventional methods. Of course, the evidence suffers from a serious drawback: because the students were not randomly assigned, it is impossible to separate the confounding effect of other differences from the use of Excel (or apply the usual inferential analyses that require random sampling). Clearly, Excel was not the only thing that varied across these groups.

A true accounting of the benefits of spreadsheet instruction for learning economics awaits a properly designed, scientific study.

### EXCEL IS “JUST RIGHT”

While everyone could see the revolution happening around them, Bodily (1986, 34) succinctly captured the essence of what was happening: “The spreadsheet was seductive, especially for computer neophytes, because it used programming by example.” There is no real language to learn beyond simple ideas about relative and absolute references. Thus, students can quickly do useful things with little prior programming knowledge. Functions are easily embedded in formulas, and the ability to directly see the data is a great aid to comprehension. There is another level of mastery beyond the basic spreadsheet, and it is at this next stage that Microsoft Excel proves to be an optimal pedagogical choice for economics majors.

By using Excel to deliver content, the student not only better learns economics, but the familiarity gained with the software is of great practical value. We know any student can open a spreadsheet and use rudimentary formulas, but there is enough complexity in achieving advanced proficiency that not everyone can easily master it. On the other hand, advanced proficiency is not so difficult that it becomes a computer science class. Excel is “just right,” hitting the sweet spot between too easy and too hard.

Consider four examples. First, you build the Solow Model, step by step in Excel. You can do this by displaying your screen in a lecture or in a computer lab, with students following each step. In a row, you start with initial  $k$ , capital per worker, which produces  $y$ , output per worker, according to a simple function such as  $y = Ak^\alpha$ . This is split into  $c$ , consumption per worker, and  $i$ , investment per worker, according to  $s$ , the given saving rate. In addition, initial  $k$  is used up depending on  $\delta$ , the rate of depreciation. At the end of the production period (i.e., row), you enter a formula for  $\delta k$ , the net change in  $k$ , which is equal to  $i - \delta k$ . This net change in  $k$  is the steady-state condition. In the next row, you compute starting capital per worker as initial  $k$  (from the cell above) plus  $\Delta k$ . This new level of  $k$  produces  $y$  and so on, just as before. You fill down the cells, iterating and driving the system to its steady-state solution, where  $\delta k = 0$ . You draw graphs of  $k$ ,  $y$ ,  $c$ , and  $i$  over time and play with exogenous shocks to  $s$  and  $\delta$ . In future classes, you add population growth and technological progress. This last addition, however, introduces a severe complication. In the conventional graph of the Solow Model, students can only see variables expressed in effective or efficiency units, and the behavior of actual per worker income, consumption, and capital is invisible; this is a tall barrier to overcome for anyone trying to understand the model. By generating time paths of effective and actual per worker variables, you produce concrete and visual displays so that your students actually learn the Solow Model. The Golden Rule finally makes sense because a time path clearly shows an initial dip in  $c$  when  $s$  increased (assuming it was below its max  $c$  value), but eventually a higher steady-state  $c$  is attained. In addition, you showed how to use cell formulas (and maybe some formatting of characters and cells) and explained how to create graphs with titles, axes labels, and so forth. You are improving the Excel proficiency of your students beyond the basic level, but it is a natural part of your teaching. To see the Solow Model implemented in Excel (and other macro applications), visit [www.depauw.edu/learn/macroexcel](http://www.depauw.edu/learn/macroexcel).

Next, you are teaching consumer theory and want to maximize utility subject to a budget constraint. You can show how to implement this problem in Excel by entering a formula for a

typo  
 $\Delta k$  is net  
 change  
 in  $k$

Cobb-Douglas utility function and values for exogenous variables (including prices, income, and utility function exponents). Next, you use Excel's Solver to find the optimal solution. Finally, you perform comparative statics analysis by changing income and tracking optimal consumption or derive a demand curve. The student is learning consumer theory and Excel (and math if you present the Lagrangian and solve it; Excel's Solver displays the Lagrangian multiplier in its Sensitivity Report). You can, of course, do this problem in Mathematica, Matlab, or many other packages with numerical optimization algorithms, but you must first teach students how to use the software. This is not so with Excel. Students know enough to get started, and the advanced proficiency is relatively easily acquired in the context of learning of economics.

By exposing students to Solver, you have opened a window to the world of add-ins, files that provide additional functionality not included in the core Excel software. Some (like Solver) are proprietary, but many add-ins are freely available. Barreto (2001) offered an add-in that works with Solver to easily perform comparative statics analysis. Barreto and Howland (2006) provide add-ins for a variety of econometric applications, including Monte Carlo simulation, probit and logit, P value calculations (including the DW statistic), and much more. Many economists use FRED data, but not everyone knows that there is a FRED Excel add-in that instantly pulls data into Excel without the need for a browser. It is freely available at [research.stlouisfed.org/fred-addin](http://research.stlouisfed.org/fred-addin), and a variety of FRED data applications are at [www.depauw.edu/learn/macroexcel](http://www.depauw.edu/learn/macroexcel).

A third example is from econometrics. You implement the Classical Normal Linear Model in Excel. The data generation process is given by  $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$ , with  $\varepsilon_i \sim N(0, \sigma^2)$ . You create values for the betas and sigma and name the cells. You set up a column for the  $x$  variable (which is fixed in repeated sampling) and another column to draw the epsilons. You embed `RAND()` in `NORMINV` like this, `=NORMINV(RAND(),0,sigma)`, to produce identically, independently normally distributed random draws. Your formula for  $y$  is then `beta0 + beta1*x + epsilon`. You draw a graph of  $y$  on  $x$  and hit F9 to recalculate the sheet and show that  $y$  is a random variable because it includes epsilon. The amount of bounce in  $y$  depends upon the value of sigma. You use `LINEST`, an Excel array function that reports estimated coefficients, standard errors (SEs), and other regression diagnostics. You use the Monte Carlo simulation add-in (see Barreto and Howland 2006) to explore the sampling distribution of  $b_j$ . In future classes, you invent other linear estimators (e.g., average of slopes between two successive points) and race them against the ordinary least squares (OLS) estimator displayed by `LINEST`. You are now demonstrating the Gauss-Markov Theorem. You can show that the estimated SEs are biased in small samples, but consistent, so that as  $n$  increases, the expected value approaches the exact, true SE. You break the identically distributed error term requirement by inducing heteroskedasticity (making each epsilon a function of its  $x$  value) and then violate independence by making  $\varepsilon_i = f(\varepsilon_{i-1})$ . Using simulation, you can show the coefficient estimates remain unbiased (although OLS is no longer the best linear unbiased estimator), but estimated standard errors are now inconsistent. Throughout the course, you are implementing the data generation process in Excel and removing the barrier of abstract thinking. This concrete and visual representation is a powerful way to teach. You are also expanding the student's stock of knowledge about Excel, using advanced functions such as random number generation and array formulas.

Simulation and resampling methods to teach statistics is not a new idea. Simon (1969, 283) was one of the first to recognize its potential in the classroom:

The instructional method simply skips backwards over three hundred years of mathematical history; all problems are solved with experimental Monte Carlo methods rather than by analysis, just as gambling odds were estimated before the invention of probability theory. This method not only allows students to solve problems immediately—and probably with a better chance of a correct solution than after considerable conventional instruction—but, best of all, it forces explicit consideration of the process of constructing an appropriate model and of conversion of scientific questions into statistical questions.

Yes, best of all, any model implemented in a spreadsheet (optimization or equilibrium, deterministic or stochastic) must be broken down and the pieces explicitly made clear. This process of recasting and reorganizing the material from its textbook or mathematical exposition gives both teacher and student an alternative way to work with the model.

The final example concerns elementary data analysis in an economics course, assuming no regression analysis. You get data in Excel and teach students how to compute averages, standard deviations, and other summary statistics, including histograms. You draw graphs of relationships between variables and discuss dispersion, including correlation coefficients. Most importantly, you show students how to create Pivot tables, cross tabulations of variables with frequencies, averages, or other statistics. Like charting, creating a Pivot table is easy, but it has enough complexity so that doing it right and correctly interpreting the results requires some training and effort.

These four examples show how Excel can be used at a level beyond that of the basic spreadsheet. Students acquire skills using advanced Excel functions, become adept at installing and managing add-ins, and can access, manipulate, and analyze data. It is this level of proficiency that employers crave. Thus, while Excel is helping students learn economics content, which may be the primary objective of the professor, students quickly grasp the importance of the utilitarian, vocational aspect of learning Excel. This serves as a strong motivator for hard work and study.

In 1993, with the release of Excel version 5.0, Microsoft began a switch from an Excel-specific macro language to Visual Basic. This enabled a much more powerful macro environment with a huge library and object-oriented programming. This is the more advanced, expert level of Excel. Articles and books using Excel to convey concepts (e.g., Barreto 2009; Barreto and Widdows 2012; Benninga 2010) often utilize macro-enabled workbooks. The user is placed in a more controlled environment with scroll bars, buttons, and other objects that are used to deliver content. Some teachers reject this approach because they worry the student is simply clicking in a rote way without creating anything. This is a concern, but some models or processes are so complicated that creating them from scratch takes too long (e.g., Barreto and Raghav 2013).

Others reject Excel in favor of sophisticated statistical packages such SAS, Stata, or R. There is no doubt that Excel is not a substitute for these products. It is a testimony to the power of spreadsheets that so much data analysis can be done in Excel, but for advanced empirical analysis, it is inappropriate. This speaks to Excel's proper place in the curriculum as a basic tool for all economics majors, a few of which go on to learn more advanced software.

## CONCLUSION

It is not surprising that teachers use spreadsheets, given their established base on millions of personal computers and on online platforms such as Google docs and Microsoft's OneDrive.com

portal. Modern cognitive science explains how concretizing and visualizing are the source of the teaching power of spreadsheets. Providing a rich, multisensory environment and giving students the opportunity to practice and repeat concepts are applications of best practice teaching from scientific studies of learning.

Modern learning theory is not needed to know that more involvement by teachers and students leads to better outcomes. Using Excel to teach economics forces the professor to spend time and effort on planning and delivering material. Similarly, students are more likely to be fully engaged when working with Excel. Viewed in this light, Excel is simply a way to increase the quantity and quality of inputs into the learning production function.

While one might agree that computer-based instruction is effective and valuable, there are a variety of software options from which to choose. Microsoft Excel has a “just right” quality. It does not require extensive training to use it, but there are enough features and skills needed that not everyone can instantly master it. The advanced features (e.g., array formulas, Pivot tables, and add-ins) used while implementing a model in Excel give students practical skills that have real value in the marketplace. Excel’s gradual learning curve eases students into quantitative work and offers a path to more sophisticated data analysis software. Excel’s powerful Visual Basic programming language enables the creation of macro-enabled workbooks where developers can implement complicated models. In fact, Google spreadsheets continue closing this gap, offering JavaScript for macros and the development of what Google calls add-ons (analogous to Excel add-ins).

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### NOTE

1. Excel Web sites that provide helpful starting points include [serc.carleton.edu/econ/spreadsheets/econ.html](http://serc.carleton.edu/econ/spreadsheets/econ.html), [www.depauw.edu/learn/econexcel/](http://www.depauw.edu/learn/econexcel/), and [www.economicsnetwork.ac.uk/themes/excel](http://www.economicsnetwork.ac.uk/themes/excel).

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