

**Does Stock and Flow diagrams lead to a better
management of credit card ?
The case of exponential growth bias**

An experimental study

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Abstract

Exponential growth bias is the tendency to linearize exponential functions. It means that people underestimate the future value of a growing debt in case of borrowing and future value of a growing investment in case of saving. The bias matters empirically by making consumers have a great tendency to ignore the returns generated by compounding. Consequently, consumers who are biased tend to borrow more and save less. This study aims to provide a toolkit to debias the tendency to underestimate exponential growth variables and helping people to make better financial decision.

We investigated the effect of using stock and flow diagram as external visualization tool for financial problems on perceiving variables that grow exponentially.

In the experiment, we gave three credit card problems for two groups each consisting of seven participants. A treatment group which was provided with a stock and flow diagram explaining those problems in addition to compounding formulas. A control group which was provided with only the compounding formulas. Through a bi dimensional statistical analysis, we tried to assess the bias in term of the magnitude and the direction. We found that both groups underestimate the required time to pay-off a debt. Meanwhile the experimental group overestimated the payment amount in order to pay-off the card debt in three years and overestimated the remaining balance on the card after twenty years of paying a certain amount of monthly payment.

The qualitative analysis of participants methods for obtaining the answers showed that participants in both groups anchor to the required time to pay off the principle of the debt when they try to calculate the required time to pay-off the interest. Stock and flow diagram was useful in obtaining a better mental model by taking into account the accumulation of the interest every year. However, participants in both groups found difficulties when they tried to

calculate a declining stock problem .That made the experimental group overestimate the required monthly payment to pay-off the debt. Furthermore, experimental group was better in considering the consequences of the reinforcing loop between the debt and the interest in the long-term while most of control group participants underestimated the remaining balance of debt .Further research and limitations have been discussed.

Keywords: System dynamics, system thinking, Exponential growth bias, Stock and flow diagrams, credit card usage, Credit card

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" I only intend reform as much as I am able. And my success is not but through Allah. Upon him I have relied, and to Him I return " (Quran 11:88)

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1 Introduction

1.1 Background

Nowadays, Credit card is widely accepted as a mean for purchases. It does provide many benefits for the consumers who are using it. For example, carrying less cash, recording the purchases, Building a credit worthiness history and in general, it makes all the financial transactions easier .Therefore, In USA in 2008, there were 177 million credit cardholders .That represent nearly 80% of the Adult population .This has led to 20.2 billion transactions on credit card with \$1.76 trillion total purchasing volume (Nilson Report, 2010).

Nevertheless, using credit card has its own drawbacks and many consumers misuse their cards. According to the Federal Reserve Board's *2007 Survey of Consumer Finances*, 46.1% of families carry credit debt, with an average debt of \$7,300.

In many ways, the Academic literature has highlighted how cardholders misuse their cards and mismanage their debts. When using credit card, the emotional pain due to spending is reducing in comparison to buying with cash (Soman, 2001) , which leads people to spend more money in the similar purchase situations (Prelec and Simester, 2001). When making payment decision, People tend to anchor to the minimum payment due (Stewart, 2009). Mainly, we can attribute the difficulties of managing credit card to the poor level of financial literacy which the majority of consumers have (Lusardi and Tufano, 2009) .Partially, we can attribute that to the Exponential growth bias .

1.2 The Research Problem

Exponential growth bias is the tendency to linearize exponential functions. It means that people underestimate the future value of a growing debt in case of borrowing and underestimate the future value of a growing investment in case of saving . Eisenstein and Hoch (2005) showed that consumers have a great tendency to ignore the returns generated by compounding. Almenberg and Gerdes (2012) found a negative correlation between exponential

growth bias and financial literacy .Soll, Keeney and Larrick (2013) showed that even people with high numerical skills underestimate the amount of time it takes to pay off a debt and they overestimate the monthly payment required to pay off a debt in three years.

1.3 The Research Question

The effect of External representation as independent variable on exponential growth bias as dependent variable has been tested through experimental study . The study endeavours to answer the motivation research question, which is: *Does the external representation through stock and flow diagram has an effect on Exponential growth bias?*

1.4 The Hypothesis

The general hypothesis is that subjects who use stock and flow diagrams as an external visualization tool for financial problems do not underestimate the variables that grow exponentially in compare to others who do not use stock and flow diagrams.

1.5 The Significance of the Study

The Literature shows how the exponential growth bias contributes to mismanagement of credit card debt .Consequences of that costly error in worst cases can lead to a bankruptcy. Nevertheless, investigating how to avoid the exponential growth bias has been given a little attention by researchers. The importance of this study is to provide a toolkit by visualizing financial problems through stock and flow diagrams. That toolkit can help individuals make better financial decisions and alleviate the exponential growth bias. The implications of the study can be concluded on the followings points. First, is to foster the use of system thinking skills in educational materials by educational policy makers. Secondly, is to use stock and flow diagrams as an explaining tool for teaching personal finance .Thirdly, helping students and consumers to make better decision when they encounter financial problems by using stock and flow diagrams.

In the next chapter the concepts of stock and flows diagram and the causal loops are going to be discussed in the context of system thinking activities.

2 The domain of the Thesis: Stock and flow diagram

When we encounter any situation or taking decision .We build our understanding of the world in term of causality. Our view of causal relationships between the parts in our world facilitates to us formulate explanations for what is going on ,making prediction about what might happen and controlling an event .Causality is the idea that shape our understanding of the world when we trying to make sense of things which happen. Nevertheless, from our childhood we learn that cause and effect relations happen in closely time and space boundaries. If we touch the fire we will get burned instantaneously, if we connect the TV to the electricity we can turn it on. Such simple feedback relations have reinforced our thinking about causal relation has to be close in time and space. Thus, we prone to many defects which could distort our sense of causality .we tend to perceive casual relations as one way phenomena, inference causal relation between things which happens within short duration (instantaneous relationship), ignore causal relations between things which happens not closely in time or space and simplifying problems by focusing only on one cause of them.

However, these ideas might be true in simple feedback situations but it can be strongly misleading in more complex system .Such systems that may consist of many interrelated components, various interacting feedback loop and long-time delay. The root causing of an observed event might be a fully different part of the system and suit far away back in time .When we deal with such system, we try to imply what we have learned about simple system. Therefore, we take actions dealing with the false cause of an event but it is only because it is close in time and space. This could lead us to make the problem worse.

Stock and flow diagram is such a technique, which help you to avoid these defects that have been mentioned earlier. By stepping back far enough in space and time until you can see the underlying interrelated structural relations which are working to produce a specific pattern of behaviour.

Richmond (1991) characterized stock and flow diagram as the third phase of system thinking activities. Figure 2.1 shows system thinking activities which start by defining the parts of the system. Moving rightward along that continuum of activities .Passing by the influence

and structural diagram you become more and more concerned with the implementation of your view of the system.



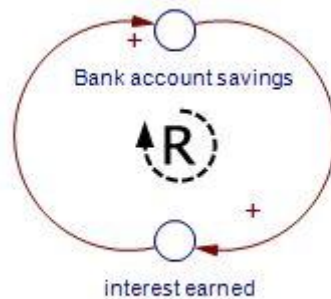
Figure 2.1 System Thinking Activities (Richmond, 1991)

After making the Diagrams that show your view of the relations between parts of the system. Finally, you translate these relations into a set of equations. These equations describe the nature of relation by assigning numerical values, which define the strength, direction and the timing factor of these relations. By simulating these equations on a computer, you can test your hypothesis about the structural relations of the system's components and see if it gives you the expected behaviour or not.

2.1 Causal Loop Diagram CLD

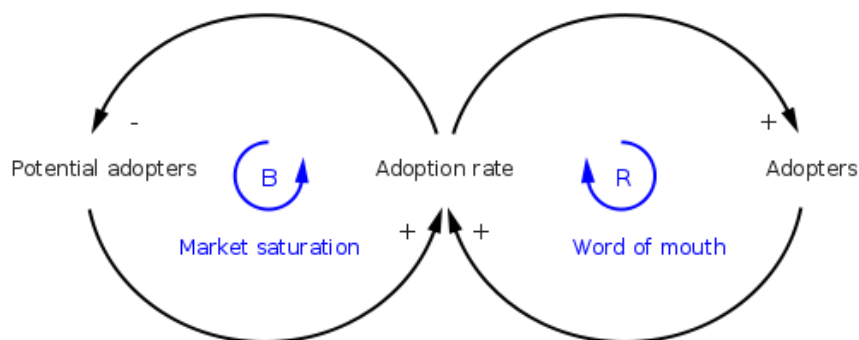
As It is mentioned earlier, second phase of System thinking is the Influence Diagram which is famous by Casual Loop diagram. CLDs are used to describe the cause and effect relations between the elements of the system by visualising how different variables in a system are interrelated (Sterman, 2000). CLDs words represent the variables in the system .The Arrows draw in a circular manner to portray the causal relations. Signs such as + Positive or - negative illustrate the relations between the variables. Positive sign means that the relation is a proportional. Negative sign means that the relation is inversely. CLDs are also containing important feature, which is the representation of the feedback loops. The terminology Loop refers to a closed circle of cause and effect (Ford, 1999). Loops are either Reinforcing loop or Balancing loop .The former means that any change happens to one of the variables through the loop leads to maximize the initial state of the variables. For example, if a variable increases in a

reinforcing loop the effect through the cycle will lead to an increase in the same variable again and the other way around. The latter, Conversely means that any changes in one of the variables in the loop, the effect through the circle will lead that variable to return to its desired state .For example, if one variable increases in a balancing loop the effect through the circle will make that variable to decrease and vice versa .In CLDs the letter R indicates that the loop is reinforcing and the letter B indicates that the loop is balancing.



2.2: shows a reinforcing loop between savings and interest rate.

To illustrate, more, we can see the example of product adoption model in figure 2.3



2.3 product adoption model

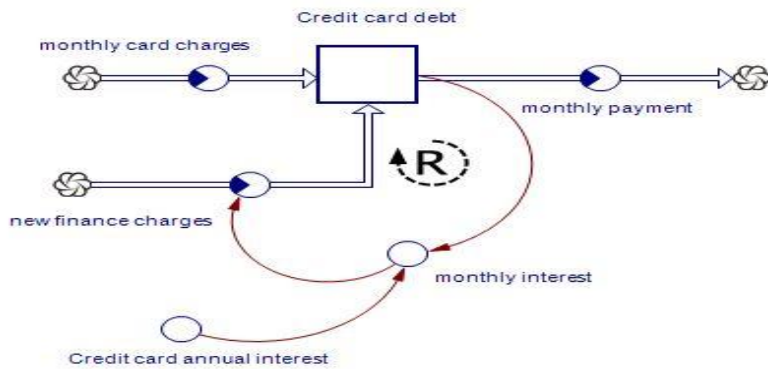
As we can see in this CLD diagram, there is a reinforcing loop between the Adopters and the Adoption rate. which means as more people adopt the new product they give good

recommendation of the model through their word of mouth which increases the adoption rate and so on so forth .Meanwhile there is a balancing loop in the system between adoption rate and potential adapters. As adoption rate increase because of the recommendation of new users, become less potential adopters, leads to negative effect on the adoption rate (market saturation).

2.2 Stock and Flow diagram

Stock and Flows diagrams are essential to the dynamic of the systems (Forrester, 1997). Stock and flow structures are existing in all types of systems ranging from epidemiology to accounting (Sweeney and Sterman, 2000) .To explain what the difference between Stock and flows the example of bathtub system can be used. Bathtub consider as a stock where the water is accumulating. The flows are the faucet and pipes, which fill or drain the stock by the water .The dynamic behaviour of system, occur due to the net changes between the inflow and outflows .If the inflow is more than the outflow the stock will increase. If the inflow is less than the outflow, the stock will decrease. If the inflow is the same as outflow the stock will be the same which represent an equilibrium state of the system .In term of measurement units , stocks are measured at a specific point of time like a snapshot while the flows are measured over interval of time. Thus, flows always measured per unit of time. Another important characteristic differ the flows from the stock is that stock create delay through the accumulation process. Identifying the time lag is important in system thinking. The more lag between a cause and effect, the less probability that the decision maker will realize the causal relation.

Figure 2.4 shows a stock and flow structure of credit card system .The credit card debt is the stock which can be affected by three flows. Two inflows contribute in increasing the debt, which are the monthly card charges as a proxy of purchasing and the new finance charges due to the monthly interest on the debt. The only way to decrease the stock and get rid of the debt is by monthly payment which consider as outflow.



2.4: stock and flow diagram for Credit card system

By portraying the right mental model into stock and flow diagram, you can capture the dynamic of the system first by knowing the relation between the changes in the flows and its effect on the stock, second by identifying the impact of the loops on the state of the system through time. Right calculation of these relations will lead to obtaining the right behaviour of the system and the right expected values for each part on it.

3 Theoretical framework

Individuals can make biased decision due to subjective reality that they create. They create that subjective construction of reality based on their “mental models ” which could be wrong. Biased decision could be also due to the limitations on capacity of information processing " bounded rationality ". In this part, we discuss the concept of biases in general, the research that has been done about the exponential growth bias and how stock and flow can affect it as a tool for external representation.

3.1 Biases

The German philosopher Immanuel Kant has argued that our understanding of the world is a psychological construction determined by the structure of our mind. It's not a literally reflection of objects as they are in real (Martin, 1995). Nonetheless we mostly go without no doubt considering our understanding is the same as reality. When we make decision based on that misunderstanding combined by the lack of possibility that reality might be different from what it appears to us, the inevitable consequence is a bias decision. Nevertheless, we are aware by the final products of our minds (beliefs, feelings, judgments) but in most of the cases we are not aware by the process in our mind that makes them rise up .Thus, decision making and judgments scholars trying in the last fifty years to describe these processes and knowing what goes on inside our head. Aiming to identify and understand the error of intuition judgments which could lead us to improve the decision making process eventually.

3.2 The two system view

Dual process theories or as it known by the two system view provides an explanation for why people commit biased decisions .A main principle of these theories is that the human behaviour is determined by the interaction of automatic and controlled processing (Barrett, Tugade and Engle, 2004) . Stanovich and West's (2000) labelled that distinguish between the two types of cognitive process as system 1 which is the intuition system and system 2 which is the reasoning system .There is a large agreement on the characteristics of each type of these system . System 1 is characterized as fast, automatic, effortless, voluntarily, implicit, emotional

and hard to modify. Control system 2 is characterized as slower, sequential, effortful, explicit and intentionally controlled (Kahneman, 2003).

The mental operations of system 1 is totally involuntary which cannot be turned off .For example, nor you cannot avoid yourself from knowing that $3+3=6$ or thinking of Berlin when the capital of Germany is mentioned .System 1 suggests impressions, intuitions , and feelings for system 2 . System 2 adopts these suggestions with lack of doubt. Consequently, system 2 exert no modification on these suggestions, turn it into beliefs and act upon it .Thus, most of the times, system 2 is in an effortless mode until system 1 experiences difficulty with an issue, then it recalls system 2, asking for its support in term of a detailed processing method that may work out the problem .For instance, this happens when system 1 encounters a multiplication problem such as $16*22$ then it recalls system 2 to use its mathematical skills.

The problem rise up when system 1 has the illusion of solving a problem and system 2 believe its suggestions. Kahneman and Frederick (2002) concluded that the monitoring that system 2 exerts is quite laid-back which let many intuitive judgments comes up. We can see this in the famous experiment of Frederick (2005) to study self-cognitive monitoring when he asked the following question to students in Princeton University and in Michigan University “A bat and a ball cost \$1.10 in total. The bat costs \$1 more than the ball. How much does the ball cost?”. Roughly every subject report primary inclination to answer 10 cents. He found that about 50% of Princeton university and 56% of Michigan university students who have been asked that question surrender to the wrong immediate urge which prove that many of them have not checked their answers before reporting it . That demonstrate that people accustomed to trust their intuition judgment and the moderately control of system 2 over system 1 suggestions.

In other cases , due to limited information , cognitive limitations and constraints on the amount time that people have to make decisions during it, which is so-called bounded rationality (Simon ,1972), people depend on their intuitions by developing shortcuts or rules of thumb to reduce the complexity of the problem which they encounter rather than moving to system 2 mode .This happens specially when using a sophisticated strategy has more cost than the potential benefits of the accuracy .People use these heuristic to ease the cognitive load but sometimes that leads them to severe and systematic errors (khanemann and Tversky ,1973)

In the previous paragraphs, it is stated that poor decision making associated with intuition. Nonetheless, we cannot underestimate the importance of system 1 by saving a lot of time and energy for us. You are driving your car and all you need to know is the way to the intended place. You are on automatic pilot. No need to think a lot. Moreover, Klein (2007) argued that when some decision makers follow their intuition they perform better than when they use analytical process. Haselton, Nettle and Andrews (2005) suggested that biases are not design flaws but design features which help individuals to take decisions when there are constraints on effort or time or when there is a lack of motivation .Yet intuition thinking has its own liabilities in the form of errors and biases.

Our hypothesis is that stock and flow diagram can make two main contributions on attempting to avoid the bias. First, it gives the decision maker the right mental model of the system which can make him question his beliefs and his previous mental models which are in system 1 before adopting it by system 2. Second, making the strategy which they are using less costly by easing the cognition load .The literature behind those hypotheses is going to be discussed later in this chapter after reviewing the literature of the exponential growth bias.

3.3 Exponential growth bias

Exponential growth bias is the tendency to underestimate the future value of a variable growing exponentially when assessing it intuitively. Exponential growth bias can explain financial decision behaviours such as the tendency to underestimate the interest given other loan terms in case of borrowing and the tendency to underestimate a future value of an asset in case of investments .The bias has its consequences empirically. Individuals who are biased tend to save less, borrow more and prefer short maturities (Stango and Zinman, 2009). In this part, we discuss previous literature showing empirical evidence of exponential growth bias and summarize the stylized facts that one can conclude from all of previous work to date.

Eisenstein and Hoch (2005) they did a lab experiment studies and found that most of people naturally anchor to simple interest when they are facing a problem containing a compounding interest which lead them to make large error when they calculate the outcomes of a compounding process. They found also that these errors increase outstandingly as the time

frame become more longer or the interest rate become more higher. Next, they endeavoured to decrease the bias by providing a training for the participants on the rule of 72. They found that the error has decrease by a 50 percent. They concluded that people's accuracy estimations of compound interest problems can be improved significantly by short training procedures.

On the borrowing side, Stango and Zinman's (2009) analysis data which was drawn from Federal Reserve surveys between 1977 to 1983. The surveys have done by asking the respondents to estimate interest rate in specific situation given by the amount of principle, maturity time and repayment stream. They demonstrated that 98% of consumers make mistakes when they assess the interest rate. In china, Song (2011) did a field experiment to test the effect of financial education treatment on pension contribution. He found that the intervention does help the subjects partially to correct their fundamental misunderstanding of compounding interest concept and increasing their contribution level. Nevertheless he found that some household subjects end up saving at a higher level than the implied by the benchmark model. Concluding a similar result, McKenzie and Liersch (2011) showed that highlighting the benefits from the exponential growth of savings make the participants willing to save more for their retirement's plans. Almenberg and Gerdes (2012) used a representative sample of Swedish adults and found that exponential growth bias is negatively correlated with standard measures of financial literacy

Goda, Manchester and Sojourner (2012) they did a field experiment to measure the effect of informing people about how their pension contribution today can shape their future retirement income. Followed by a survey, they found that the subjects of the experimental group have increased their contribution to the pension by 85\$ more than the control group during the period of the study. Levy and Tasoff (2014) used a representative sample of US population and demonstrated that the magnitudes of the bias and asset accumulation are negatively correlated. Concluding that exponential growth bias is a significant predictor of people saving behaviour. Nevertheless they found that age and education are uncorrelated with the bias, indicating that experience doesn't help to reduce the magnitude of the bias. Furthermore, they have done a lab Experiment in order to assess the effect of a graphical intervention in order to making the exponential growth more salient which could be used to achieve the correct responses, they found that the bias was robust and the intervention have no effect on the performance. They have reasoned that by the overconfidence of people about the magnitude of their errors which makes them unlikely to seek help.

Soll, et al. (2013) they tested the difference between people who have a strong numerical skills and people who have a weak numerical skills. They found that regarding the numerical skills all people underestimate the time required to eliminate a debt but The underestimation was more stronger for people who have low numerical skills. Moreover, they found that less numerate people tend to underestimate the monthly payment required to pay off a debt .Conversely, high numerate people tend to overestimate the monthly payment.

The above findings shows that Exponential growth bias negatively correlated with financial literacy and financial education treatments .Making people less biased although it can lead some individuals to overestimation. However, the lack of financial or arithmetical knowledge about exponential growth seems an implausible justification. Fernandes, Lynch and Netemeyer (2014) they did a meta-analysis and found that financial education like any education , decays over time , moreover , they found that large intervention programs with intensive instructions have slight effects on financial behaviour 20 months or more after the intervention .In addition , solving interest rate problems include more than simple calculations . Even though , there are formulas to solve these problems but it would be challenging even for most of numerate individuals to derive it on their own

In addition to know the right formulas, one needs to know the situations when he can apply his knowledge. It has been found that even highly mathematical skills they will execute errors if they don't know the rules that come to their mind directly not applicable in a given situation (Kahneman and Frederick, 2005).

In term of system thinking, inputs to such financial decision include the balance as a stock and the annual interest rate which determines one of the flows. The decision maker decides the new purchases he wants to execute or debt payoff amount which will affect his balance for the beginning of next month. Analysis of the relationship between stock and flows is not easy even in simple situations such as bathtub (Cronin, Gonzalez and Sterman, 2009).But financial decisions are even harder. It's a multi-period one when the changes in the flows of payment or charge change the principle over time and the effect of the interest makes it more complicated.

3.4 How does stock and flow diagram can has an effect on Exponential growth bias?

Many things can distort or bound our decision making process such as, our selective perception, overestimating of how much we understand about the world, overconfidence on our mental model, emotions, subconscious and constraints on time. Therefore, instead of making rational decision which lead us to the optimization, people tend to use a wide range of heuristics and rule of thumbs either consciously or unconsciously. As a result, when we face a problem we try to simplify it, focus only on one cause of the problem rather than taking into account the many others variables that are relevant that lead us to draw too narrow and short view of the problem (Dorner,1980) and misperceive the feedback (sterman,1989). In this section, the mental model concept are going to be discussed in addition how the external representation plays a role on correcting it.

3.4.1 The Mental models (The internal representation)

If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of the past events in dealing with the present and future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it (Craik, 1943.ch5,p.61).

When we deal with the world around us we don't carry a person or community. What we carry are images and assumptions based on our experience knowledge and expectations. That mental representation not only shapes our conception of the world but also determines how we deal with that world and how we take actions. Two people may have different perception of the same event due to different mental models in their minds. Thus different decisions may be taken as a result of these different perceptions.

Many system thinking scholars have discussed the function of mental models in forming perception of complex systems.

Forrester (1961) in his work *Industrial Dynamics* introduce the concept of mental model as

“ A mental image or a verbal description in English can form a model of corporate organization and its processes. The manager deals continuously with these mental and verbal models of the corporation. They are not the real corporation. They are not necessarily correct. They are models to Substitute in our thinking for the real system that is represented ” (p. 49).

In his opinion the main limitation of mental model is that it is hard to simulate its dynamic consequences . He argued that even a skilled investigator his intuition is unreliable to foresee dynamic behaviour for a simple feedback of five or six variables related to each other .He elaborate the concept and define it as *“ The mental image of the world around us that we carry in our heads is a model one does not have a city or a government, or a country in his head. He has only selected concepts and relationships, which he uses to represent the real system ”* (Forrester ,1971, p.112) .

Forrester (1971) characterized a mental model as it is fuzzy, it is incomplete. It is imprecisely stated .in addition , It is changing over time even during a single conversation .Other system Thinking researcher have added to the list of characteristics of mental model .For example, Meadows , Meadows and Randers (1992) and Sterman (1994) suggested that mental models are over simplified in comparison to the complexity of dynamic systems. Doyle and Ford described it as *“ A mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system ...whose structure is analogous to the perceived structure of that system ”* (1998, p. 17). Many of experimental studies have confirmed these limitations (see, e.g., Dörner, 1980; Sterman, 1989). Changing or improving mental models in order to make it closer to the reality is an objective in order to people can make better decisions. Thus, there is a need for a tool that can facilitate and improve our mental models. External representation through stock and flow diagram is such a tool that can facilitate perceiving complex dynamic system.

3.4.2 *The role of External representation*

The optic nerve contains over 1 million fibers, while the auditory nerve contains only 50000. Thus, Vision is vital to our biological being and one of the most vital source of information about the world is sense of vision (Adams and Victor, 1993). As biological being we are not only have the ability to see what comes within the sight but also to see the unseen. It's not about seeing the tiny bacteria or the far galaxies, nowadays the new technology solve these limitations of the human being sight. But the unseen here refers to the abstract world which the new optical technology cannot represent to us. Indeed we need a cognitive technology which Pea (1987, p. 91) define it as “*any medium that helps transcend the limitations of the mind . . . in thinking, learning and problem solving activities*”. Such technology might elaborate visual means to seeing the concepts and the ideas. Visualization as Jackson (2002) describes it goes beyond the physiological sense of the eye. Arcavi (2003,p.217) define it as “*the ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds, on paper or with technological tools, with the purpose of depicting and communicating information, thinking about and developing previously unknown ideas and advancing understanding*”. Thus, by Visualization we can see the abstract world .

A widely used method for conceptualizing a problem is to translate it into a visual graphical representation. That is considered as external representation of the problem in the form of symbol and graphs which is different to the internal representation (mental model) .For solving a problem, a spatial organization of the information and data can facilitate transformation of the idea .Furthermore, they remain much longer period of time more than representing ideas in spoken language which is there only in the moment of speaking. Therefore, external representation is considered as external memory which off-loads individual cognition (Larkin and Simon, 1987). Still, each person has his own interpretation of the visual representation.

It has been shown that external representation not merely function as memory aid but the form of representation is so essential to cognitive tasks such as problem solving, decision making, reasoning which they guide, constrain and determine cognitive behaviour . This happen by focusing on what information in the external representation can be perceived and how these information affects problem solving and decision making (zhang, 1997). Chambers and

Reisberg (1985) suggested that external representation provide people with skills and knowledge which are not available from internal models. For example, Larkin (1989) argued that diagrammatic representation empower individuals to make inferences faster and recognize characteristics easier .Furthermore, different forms of external representation can cause different cognitive behaviour. For instance, Kleinmuntz and Schkade (1993) showed that different information display forms (graphs tables and lists) affect decision process. The form, organization and sequence of the information which are displaying facilitate some decision strategies and hold back others .Thus , different information display lead to variation in the anticipated effort and accuracy related to each available strategy .Whereby the decision maker making a trade-off between maximizing the accuracy and minimizing the effort as a costs benefits analysis. Additionally, organizing the information has an influence on information acquisition which strongly has an effect on information evaluation.

System Dynamics stock and flow structure is a method which emphasizes different information by capturing the time delay , accumulation through Stock and the feedback loops in the system either reinforcing loops such as the case of compounding or balancing loops. In addition to recognizing the characteristics of system's parts such as variables, stocks and flows. That may improve the performance of decision making in dynamic environment since that information presented in that way will smooth the progress of the acquisition of the mental model, ease the cognition load and make the decision process less effortful. For example, Students showed better understanding of Gross Domestic Product when they had access to the stock and flow diagram of the economy (Wheat, 2007)

In this paper, we are aiming to find how stock and flow diagram can improve individuals' perception of a financial situation including exponential variables better. Problems which have been used in this study are similar to the work of Soll et al. (2013) in their paper *Consumer misunderstanding of credit card use, payments, and debt: causes and solutions*.

4 Experimental Design

4.1 Research method

4.1.1 Design

The experiment consisted of two conditions .The control condition and the experimental condition .The control condition is where participants were given three questions without a stock and flow representations , which served as a baseline for the performance .The experimental condition is where participants were given the same three questions but with a stock and flow representation for each question.

By comparing the performance of the unrelated groups in these two condition , we were able to test the influence of the stock and flow external representation as independent variable on the exponential growth bias as dependent variable .The performance in the three questions is used as a proxy for the exponential growth bias .

4.1.2 Participants

Overall, there were 14 students agreed to participate in the experiment, 7 in each condition .There were 7 women, 5 in the experimental condition .All participants were first year students of master of system dynamics- University of Bergen, Norway .Participants were from various educational backgrounds and various nationalities .4 of them have studied personal finance before, 2 were in each condition . They decide voluntarily to participate in the experiment. No financial incentives have been used. Participants were allocated to conditions randomly.

4.1.3 Procedures

The experiment was conducted at the University of Bergen campus in April 2014.Participants took part in the experiments in the same time. Each participant received the experiment sheet containing an introduction about the task and the instructions that they should

follow such as they were allowed only to use simple calculators. The sheet also provided both groups with the compounded interest formulas. They had to fill some information about them in the beginning of the task such as the gender, educational background and if they studied personal finance before or not .They had to solve the questions and write a brief explanation about how they got their answers. After they had solved the task, they delivered the sheets back. After finishing the task, some of them were asked verbally to explain more about how they got their answers if it wasn't clear in their writing. The participants of the control group were asked also individually after the task if they tried to use stock and flow diagrams when they were solving the task.

4.2 The problems

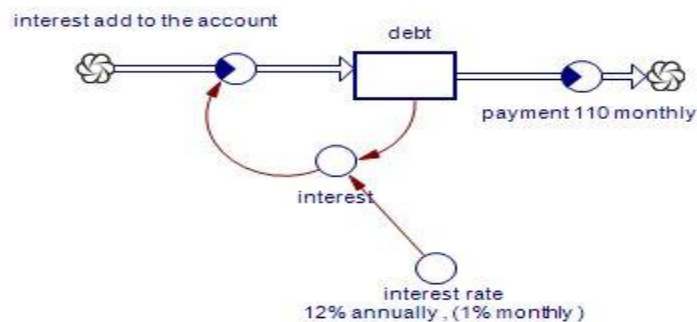
In this section, the three problems, which have been given to the participants are going to be Presented combined with stock and flow diagrams.

So the case was as follows:

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

4.2.1 Problem 1

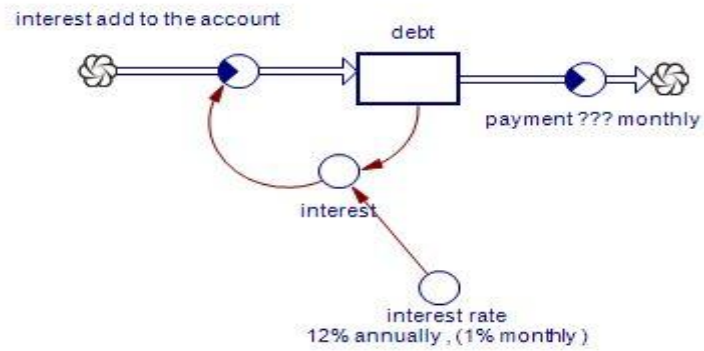
(Required Time) *How long would it take to pay off the card with a constant monthly payment of \$110?*



4.1First problem representation

4.2.2 Problem 2

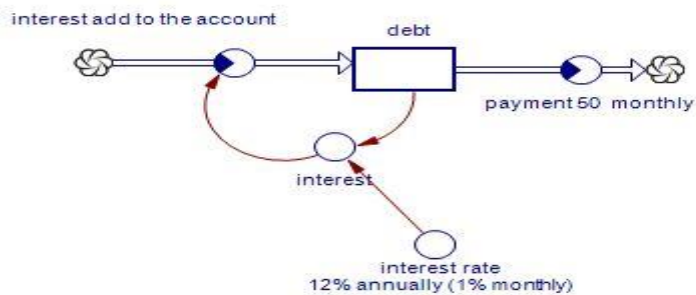
(Payment Amount): What must the constant monthly payment be in order to pay off the card in three years?



4.2 Second problem representation

4.2.3 Problem 3

(Remaining Balance): Assuming a constant monthly payment of \$50, what would the balance be on the card after 20 year?



4.3 Third problem representation

4.3 Hypotheses

In this section, we are discussing the various methods that participants may use to deal with the problems in addition to stating the correct answer for each problem. Furthermore, formalizing the hypothesis in the end of the section.

4.3.1 Problem 1

*(Required Time)How long would it take to pay off the card with
a constant monthly payment of \$110?*

We propose in this case, that people will start by zero rate solution , by divided 10000 over 110 they will get 91 months to pay off the debt which is about 7.5 year .Then each person try to adjust his answer depend on his own understanding of the system . for example some people will calculate the interest for only one year so $10000 \cdot 0.12 = 1200$,then by divided $1200/110 = 10$ months , thus he will add 10 to 91 given 101 months . A person who has a deeper understanding will take in his consideration that the interested is added every year so he will calculate interest for the 7.5 years .thus given that $(1200 \cdot 7.5)/110 = 81$. Thus, by adding 81 to 91 it would give 172 months. It is tricky to follow up with the interest that accumulates over the added months, the interest that would accumulate on the months added to that, and so on. so we hypothesized that individuals with stock and flow diagrams will have the sense that time would increase as more interest are added to the stock of debt .The correct answer for this problem is 241 months .

4.3.2 Problem 2

(Payment Amount): What must the constant monthly payment be in order to pay off the card in three years?

People can use the compounded interest formula so they get the future value of 10000 \$ as principle with interest rate 12% for time period of 3 years (36 months) that would give them 390 \$. But people with stock and flow diagrams can see that the principle is declining over time so they will decrease the amount of money as they will notice that the added interest will become lower .other solving strategies could be add 1200 \$ as interest for one year to the principle then divided the sum over 36 months it would give 311 \$. Other person will take in his account that the interest must be added for three years so he will add (1200×3) to principle and divided the sum over 36 which would give 377\$. The correct answer for this problem is 332 \$.That answer takes into consideration the principle of compounding and that the stock of debt is declining over time.

4.3.3 Problem 3

(Remaining Balance): Assuming a constant monthly payment of \$50, what would the balance be on the card after 20 year?

Most people will notice that as the amount of payment is less than the interest so the debt will grow higher but people who can see from the stock and flow diagram the reinforcing loop between the interest and the stock of debt will notice that the stock of debt would grow exponentially instead of linearly. People who would solve this problem from a linear perspective only would try to found the difference between the interest and the payment each year which would be $1200 - 600 = 600$ \$ then by multiplied 600 for the 20 years and add the output to the principle that would give 22000. The correct answer is 60000.

4.3.4 Hypothesis formulation

The main hypothesis is that there will be significant difference between the two groups regarding the exponential growth bias. Two kinds of measurement used to assess the bias, the magnitude and the direction and the direction of the bias. The magnitude is measured by the deviation from the correct answer taking into consideration the negative values. The direction of the bias is either overestimation or underestimation. Thus, for each problem the hypothesis will be as follows:

Regarding the magnitude

The alternative hypothesis is that there will be difference between the Experimental and the control group in term of the magnitude of their estimations.

$$H_{1_0}: \mu_1 = \mu_2$$

$$H_{1_a}: \mu_1 \neq \mu_2$$

μ_1 is the mean of the deviations from the correct answer for the Experimental group.

μ_2 is the mean of the deviations from the correct answer for the control group.

Regarding the direction of the bias

H_{2_0} The null hypothesis

The direction of the bias is independent on the stock and flow diagram.

H_{2_a} The alternative hypothesis

The direction of the bias is dependent on the stock and flow diagram.

5 Results

5.1 Problem 1

Table 5.1 shows the estimations made by both group and their deviation to the bench mark. Magnitude of the bias is equal to the reported value (data) - the correct answer (241)

Experimetal group subjects	Data	magnitude of the bias
A	101	-140
B	101	-140
C	200	-41
D	173	-68
F	200	-41
G	101	-140
H	150	-91

control group subjects	Data	magnitude of the bias
K	110	-131
I	wouldnt paid	...
M	101	-140
N	120	-121
P	80	-161
Q	102	-139
R	180	-61

Table 5.1 Estimations by both groups and their deviations

Table 5.2 shows group statistics

	treatment	N	Mean	Std. Deviation	Std. Error Mean
p1	Experimental	7	94.42	45.91	17.35
	Control	6	125.50	34.24	13.98

Table 5.2 Group statistics

Table 5.3 shows the result of the two-sample t-test used to test H_{10}

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	1.96	.18	1.36-	11	.20	31.071-	22.82	72.06-	9.91
Equal variances not assumed			1.39-	10.8	.19	31.071-	22.28	71.14-	9.00

Table 5.3 Independent Samples Test

The statistic $0.18 > 0.05$ in Leven's test means that we can assume variances to be equal .With $\alpha= 0.1$, H_{10} cannot be rejected , As Experimental group estimations can not be shown to be significantly different from the control group estimations .

Both groups underestimate the required time to pay off the debt. Thus, H_{20} can not be rejected.

5.2 Problem 2

Table 5.4 shows the estimations made by both group and their deviation to the bench mark. Magnitude of the bias is equal to the reported value (data) - the correct answer (332)

Experimetnal group subjects	Data	magnitude of the bias
A	350	18
B	390	58
C	400	68
D	377	45
F	365	33
G	333	1
H	350	18
control group subjects	Data	magnitude of the bias
K	330	-2
I	801	469
M	311	-21
N	123	-209
P	390	58
Q	390	58
R	320	-12

Table 5.4 Estimations by both groups for the second problem and their deviations

-Statistical analysis including outliers (The estimated value of 801 considered to be outlier)

- Table 5.5 shows the group statistics including the outlier value

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
p2	Experimental	7	34.42	23.99	9.06
	Control	7	48.71	205.89	77.81

Table 5.5 Group Statistics

Table 5.6 shows the result of two-sample t-test used to test H_{10}

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
p2 Equal variances assumed	3.25	.09	.182-	12	.85	14.28-	78.34	153.92-	125.34
Equal variances not assumed			.182-	6.16	.86	14.28-	78.34	165.80-	137.23

Table 5.6 Independent Samples Test

- Statistical analysis excluding the outlier value

Table 5.7 shows the group statistics Excluding the outlier value .

Treatment	N	Mean	Std. Deviation	Std. Error Mean
p2 Experimental	7	34.42	23.99	9.06
Control	6	21.33-	98.25	40.11

Table 5.7 Group Statistics

Table 5.8 shows the result of the two-sample t-test used to test H_{10} excluding the outlier value .

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
p2 Equal variances assumed	2.59	.13	1.46	11	.17	55.76	38.14	12.74-	124.27
Equal variances not assumed			1.35	5.51	.22	55.76	41.12	25.43-	136.95

Table 5.8 Independent samples Test

In both cases with outlier and without outliers, the statistics .09 , .13 > .05 in Leven's test means that we can assume variances to be equal. With $\alpha= 0.1$, H_{10} cannot be rejected as The experimental group estimations for the required monthly payment to pay off the debt in three years cannot be shown to be significantly different from the control group estimations.

The direction of the bias

Table 5.9 shows the direction of the estimations made by both groups.

	estimation		Total
	overestimation	underestimation	
treatment Experimental	7	0	7
Control	3	4	7
Total	10	4	14

Table 5.9 Problem 2, Direction of the estimations

Table 5.10 shows the results of chi-square tests used to tests H_{20}

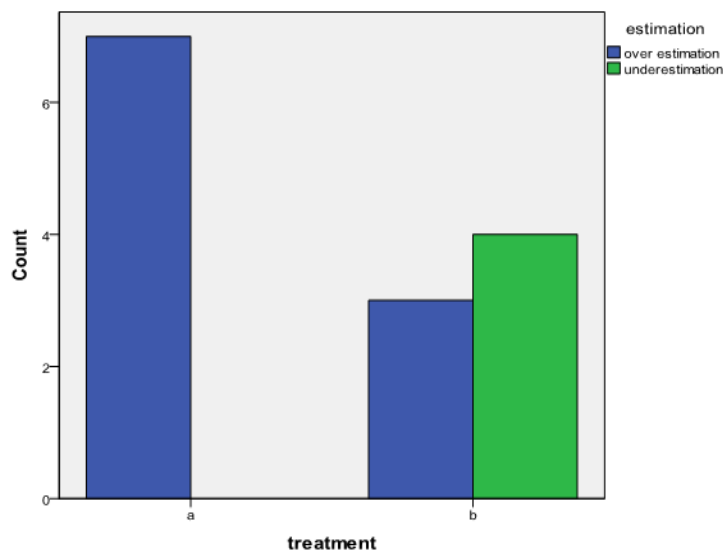
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.600 ^a	1	.018		
Continuity Correction ^b	3.150	1	.076		
Likelihood Ratio	7.191	1	.007		
Fisher's Exact Test				.07	.035
N of Valid Cases	14				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.00.

b. Computed only for a 2x2 table

Table 5.10 Chi-Square Tests

As expected count is less than 5 for 2 cells, Fisher's Exact test is considered to be used .With $\alpha = 0.1$,the significance level of $0.07 < 0.1$ means that there is enough evidence against the null hypothesis H_{20} . As all the participants in the experimental group overestimated the required monthly payment .Conversely, to the participants in the control group, 4 of them underestimated and 3 overestimated. The following graph shows that.



Graph 5.1: Bar chart shows the direction of the estimations . A is the experimental group , B is the control group .

5.3 Problem 3

Table 5.11 shows the estimations made by both group and their deviation to the bench mark. Magnitude of the bias is equal to the reported value (data) - the correct answer (60000).

Experimetnal group subjects	Data	magnitude of the bias
A	108925	48925
B	84462	24462
C	80000	20000
D	22000	-38000
F	28000	-32000
G	10200	-49800
H	500000	440000
control group subjects	data	magnitude of the bias
K	1000	-59000
I	20000	-40000
M	201	-59799
N	13440	-46560
P	50000	-10000
Q	200	-59800
R	60000	0

Table 5.11 Estimation made by both groups for the Third problem and their deviations

Table 5.12 shows the group statistics for the third problem.

treatment	N	Mean	Std. Deviation	Std. Error Mean
p3 Control	7	59198	171916	64978
Experimental	7	-39308	24781	9366

Table 5.12 Group Statistics

Table 5.13 shows the result of the two-sample T-test used to test H_{10}

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
p3 Equal variances assumed	3.50	.08	1.50	12	.15	98506.57	65649	1.85	2.15
Equal variances not assumed			1.50	6.249	.18	98506.57	65649	2.81	2.25

Table 5.13 Independent samples Test

The statistics $.08 > .05$ in Leven's test means that we can assume variances to be equal . With $\alpha= 0.1$, H_{10} cannot be rejected as the Experimental group estimations for the balance of the debt after 20 years cannot be shown to be significantly different from the control group estimations .

The direction of bias

As there is a reported answer exactly as the correct the answer, the researcher has chosen to treat it statistically twice one as overestimation, other as underestimation. Excluded it from the result was in favour of the alternative hypothesis but it hasn't been reported here.

-Considered as overestimation

Table 5.14 shows the direction of the estimations made by both groups .

		estimations		Total
		over	under	
treatment	Experimental	4	3	7
	Control	1	6	7
Total		5	9	14

Table 5.14 Problem 3 direction of the estimations

Table 5.15 shows the results of chi-square tests used to tests H_{20}

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1- sided)
Pearson Chi-Square	2.800 ^a	1	.094		
Continuity Correction ^b	1.244	1	.265		
Likelihood Ratio	2.947	1	.086		
Fisher's Exact Test				.266	.133
N of Valid Cases	14				

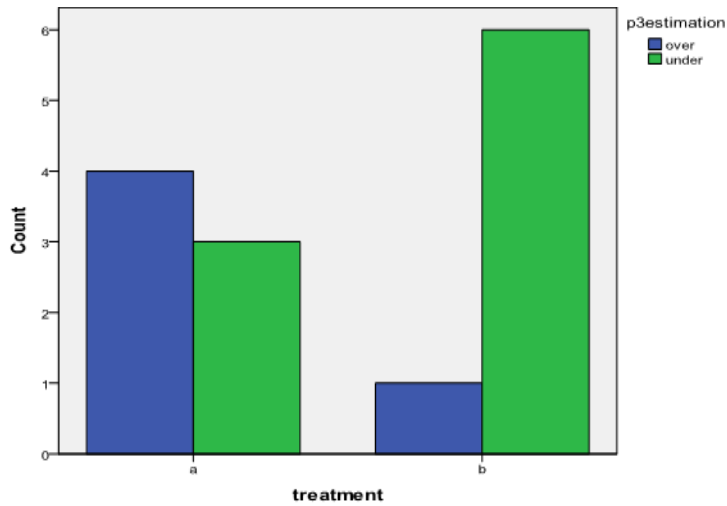
a. 4 cells (100.0%) have expected count less than 5. The minimum expected count is 2.50.

b. Computed only for a 2x2 table

Table 5.15 Chi-Square Tests

As expected count is less than 5 for 4 cells, Fisher's Exact test is considered to be used .With $\alpha = 0.1$, There is not enough evidence against the null hypothesis H_{20} .

The next graph illustrates the direction of estimations.



Graph 5.2: direction of the estimations . A is the Experimental group , B is the control group .

-Considered as underestimation

Table 5.16 shows the direction of the estimations made by both groups.

		Estimations		Total
		Over	Under	
treatment	Experimental	4	3	7
	control	0	7	7
Total		4	10	14

Table 5.16 Problem 3 direction of the estimations

Table 5.17 shows the results of chi-square tests used to test H_{20}

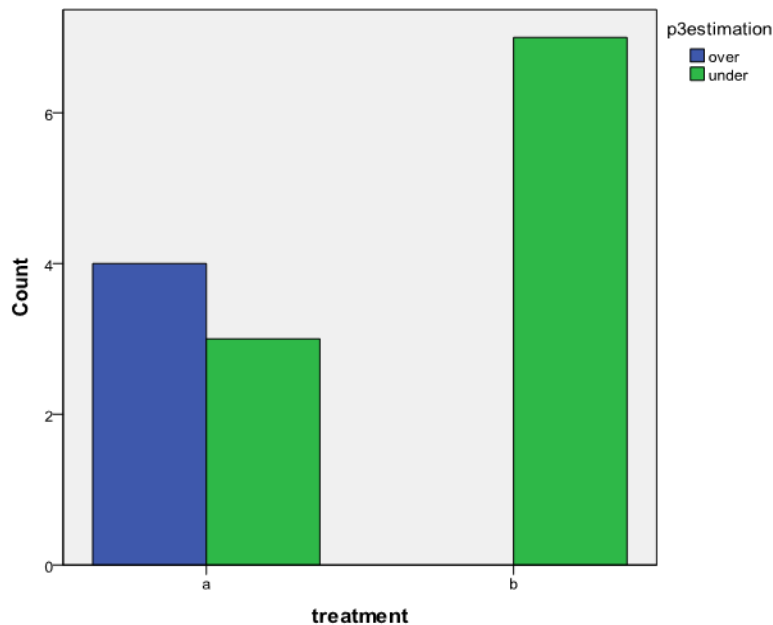
	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.60	1	.018		
Continuity Correction ^b	3.15	1	.076		
Likelihood Ratio	7.191	1	.007		
Fisher's Exact Test				.07	.035
N of Valid Cases	14				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.00.

b. Computed only for a 2x2 table

Table5.17 Chi-Square Tests

As expected count is less than 5 for 2 cells, Fisher's Exact test is considered to be used .With $\alpha = 0.1$, the significance level of $.07 < 0.1$ means that there is enough evidence against the null hypothesis H_{20} . As all the participants in the control group underestimated the balance of debt after 20 years .Conversely, to the participants in the experimental group, 4 of them overestimated and 3 underestimated .The next graphs illustrates that.



Graph 5.3:the direction of the estimations . A is the Experimental group , B is the control group .

6 Discussion

6.1 Problem 1

According to the reported answers, all participants in both groups start solving this problem by dividing the principle 10000 over the monthly payment 110, given 90 months. Then, all tried to adjust according to his perception of the interest. Some add interest for only one year, others add for the whole 90 months. Nevertheless, many of them treat the interest linearly. Two participants from the experimental group noticed the reinforcing loop and what they tried to do was to add estimated number of months to cover the interest payment. So one person add 50. the other one¹ start by the premises that it would take approximately 100 months to cover the principle and added 100 months more to account for the interest. Hence, although these people might have thought about the reinforcing loop of the interest but they didn't imagine that the time required to cover the generated interest may it takes more than the required time for covering the principle. Those results are similar to Soll, et al. (2013) conclusions when they found that regardless of numerical skills, people tend to underestimate the required time to pay off the debt.

There was one different approach, by taking into consideration the relation between the stock and the flows and how the net flow contributes to the stock declining. The participant² who took that approach started by subtracting the monthly interest 100 \$ from the monthly payment 110 \$. That gave 10 which assumed to be the contribution in declining the stock. So by dividing 10000 \$ over 10 \$ per month, that gives 1000 month. However, she found out that the number was too high intuitively. That made her to notice that as the stock decreases, the interest decreases then the amount of the contribution to decline the stock is increasing over time. So she decided to take average debt reduction and raise the number from 10 to 50. By dividing 10000 over 50, gave her 200 months.

¹ See Experimental Group Answers - participant D in the Appendix Page 46.

² See Experimental Group Answers - participant F in the Appendix Page 48.

The conclusion, stock and flow diagram cannot be shown to have an effect on perceiving the required time to pay off the debt. As even with different approaches to solve this problem and various mental models of perceiving it, all participants anchor to the required time to pay off the principle. The highest estimations for the required time that must be added to take into consideration the interest was the same as the required time to pay off the principle.

6.2 Problem 2

Statistically we couldn't see significant difference in terms of the magnitude of the answers as the significance value of T-test is 0.17 in case of excluding the outlier. That could be due to two reasons. First, as it was mentioned before in the hypotheses section that the range of the answers taking into account the expected different approaches is between 311 and 390. Thus, maybe the range is not so big to show differences. Second, according to Eisenstein and Hoch (2005) they stated that the error increases outstandingly as the time frame becomes longer but in our case it is only three years. As a result, it may be that there was not enough period to show significant differences in terms of the magnitude.

However, regarding the direction of the bias, we found enough statistical significance difference against the null hypothesis. That difference came into view clearly from the descriptive data by seeing that there were no participants from the Experimental group who underestimated the monthly payment for paying the debt in three years. On the other hand, four participants on the control group underestimated the required monthly payment. The reason is that the stock and flow diagram help the participants in the experimental group to notice that the interest must be added for the whole three years. Thus, some of them used the compounding formula, others use simple interest formula to calculate the additional interest that must be added to the debt. Meanwhile in the control group, three of the participants have used the compounding formula. Others tried to take into account the additional amount to contribute in paying off the interest but they didn't have a clue for how long they should calculate it.

We can conclude that the stock and flow diagram was helpful to obtain a better mental model for that problem which is reflected on the experimental group answers by taking into account the interest for the whole period. That has been proved also statistically (significance value by Fisher's test is 0.07), as it has been shown that stock and flow diagram make a significant difference between the two groups in term of the direction of their estimations for the monthly payment required to pay off the debt in three years.

6.3 Problem 3

Although most of control group participants underestimated what would be the balance after 20 years but I have to mention that two persons³ used the equation wrongly. Consequently, that give them too small value about 200 \$. Their approach was calculating the value of the stock using the compounding formula then subtracting the total payment for the whole twenty years. If they used the equation correctly, that would give them overestimated value actually as a result of not taking into their consideration the deducted amount of the stock each month. Although, that can show us, that they didn't doubt their small value and they had overconfidence on the output of the equations they used.

Nevertheless, in term of the magnitude, the experimental group estimations mean is higher than the control group estimations mean, although it cannot be shown to be significantly different through the statistical analysis (significance value by T-test was 0.15). However, statistically there is a significance difference between the two groups in term of the direction of the bias (significance value by Fisher's test is 0.07). No one in the experimental group has reported an estimated value smaller than the initial value of the debt. That give us insight into how the stock and flow diagram has made the participants in the experimental group aware of that the stock will increase. In addition, by the mere exposure to the visualized reinforcing loop they even raise their estimations reaching to 500000 on one of the cases⁴.

We can conclude that stock and flow diagram has an effect on the estimations for the remaining balance after 20 years. That has been proven statistically through the significance difference between the two groups in term of the direction of the bias.

³ See Control Group Answers - participants M and N in the Appendix Pages 55 and 56.

⁴ See Experimental Group Answers - participant G in the Appendix Page 49.

6.4 General discussion and Findings

It has to be mentioned that many factors can affect the answer of those problems .For example , studying personal finance or financial mathematics helps to perceive the right mental model for those problems ,The numerical abilities helps to decide which mathematical formula should be applied and how to use it correctly , system thinking skills facilitates the simulation of system behaviour on the minds of participants by noticing the relation between the stock and the flows in addition to the dominating loop in the system . Such differences have an effect on participant's answers. Furthermore, in such small sample, those individuals' differences might give confusing statistical results.

Before doing the experiment, there were some degree of fear that there wouldn't be any difference at all between the two groups as a result of that both group are students of system dynamics and that might make both group think in term of stock and flows. Although, apparently stock and flow diagrams had two impacts .First, by correcting mental model through the external representation. For example by noticing that the interest must be calculated for the whole period. Second, by easing the cognitive load when solving the problems. We can see that from some of the answers of control group's participants by relying only on the formulas, they haven't questioned the final output of their calculations. On the contrary, some participant on the Experimental group did question their answers and tried to correct it. The possible explanation is that they had expected certain behaviour for the stock and flow structure which they being exposed to it. That made them questioning their results if they found it not matching with the expected behaviour.

It has been noticed from participants answers that even if they see the dynamic changes of the system, many of them usually approach solving the problems in a linear way .That is consistent with Cronin et al. (2009) conclusions that poor performance in Stock and flow problems is a robust phenomenon even with well-educated people. Nevertheless, all the participants in our experiment are system dynamics students so the lack of the knowledge of stock and flow relation is the not the problem but is that they didn't activate such knowledge .The reason might be that they used simple heuristics to overcome the cognitive burden of the calculations.

For example, when the stock of debt is declining over time, when they tried to calculate the interest they calculated it based on one value of the stock. That value in most cases was the initial value. They didn't take into consideration that as the stock is declining over time so the interest must be declining too.

Nevertheless, Experimental group participants had a better sense of the reinforcing loop consequences in the long term and have raised their estimations as a result of that.

6.5 Limitation and further research

Due to constraints on time and financial matters, the researcher has chosen system dynamics students to participate in the experiment. Nevertheless, testing the effect of stock and flow diagram on individuals from other backgrounds could be interesting also. The small sample size also has had an effect on the statistical analysis of the second and third problem. As we found in the second and the third problem significance difference in term of the direction of the bias. It is expected to be less variation with bigger samples so we can see also significant results in term of the magnitude. Also using longer time frame for the first and the second problem could show significance differences. Defining the various levels of participants' mathematical skills should be taking into considerations in further research. The motivation for the participants to take part in the experiment was totally altruistic. There were no monetary incentives. Nonetheless, based on the observation on the event, most of the participants take it seriously. This Study endeavoured to test the impact of stock and flow diagram on the exponential growth bias, although, further research might take into consideration the impact on the accuracy of the estimations for the variables that grow exponentially.

The ideal research design could be by having a sample from the same population who are equally in term of financial knowledge, numerical skills and have never study system dynamics before. Dividing them into two groups. Experimental condition which will receive financial literacy program based on stock and flow diagrams. Control group which will receive financial literacy program based on traditional method. Then making a test to assess the difference between the two groups in reasoning financial dynamic problems.

7 Conclusion

Regarding the first problem of determining the required time to pay off the debt, both group underestimated it. The observed explanation of that by going through the reported answers is that, participants anchor to the required time to pay off the principle of the debt. Their estimations for the required time to pay off the interest couldn't exceed their estimations for the required time to pay off the principle. This issue could be elaborated upon by further studies. Regarding second and third problem, we found that subjects provided with stock and flow diagrams obtained better mental models for the financial problems they encountered by taking into consideration the accumulation of the interest to the stock of debt over time. Although, both groups experience difficulty when they try to relate about the dynamics between the stock and the flows in the case of declining the stock of debt as a result of payments outflow. That led the experimental group to overestimate the required amount of monthly payment to pay off the debt. The experimental group was also overestimating the balance of debt as a result of the reinforcing loop between the stock of debt and the interest added to that stock. Conversely to the control group who most of them underestimated the increasing stock of debt. In general stock and flow diagrams were helpful to not underestimate the exponentially growing variables.

The sample of participants was so small which had an effect on the statistical significance. We aimed only in this study to see the effect of stock and flow diagram on the exponential growth bias but further studies may also take the accuracy of estimating those variables into considerations. Furthermore, the level of mathematical skills has influence on relating about variables that grow exponentially. Further research should differentiate the impact on various levels of numerical skills by stock and flow diagrams.

8 Appendix

8.1 Information about the participants

Information about participants including the gender and their studies before system dynamics

Experimental group Participants	Gender	Background
A	F	Accounting
B	M	Engineering
C	F	IT
D	F	Political science
E	M	Geography
F	F	Science
G	F	International Business

8.1 Experimental group Participants information

Control group Participants	Gender	Background
H	M	Industrial Engineering
I	M	Banking
J	M	Engineering
K	M	Criminology
L	F	-----
M	F	Business Administration
N	M	Marketing

8.2 Control group Participants information

8.2 Instructions

Instruction for both groups

- 1) The questions are about using a credit card. Answer each question and include a brief description of how you got the answer.
- 2) We do not expect you to give exact answers to the questions. We are more interested in the thinking that goes into your answers. So, it's OK to give approximate answers (your best estimations)
- 3) If you need to use a simple calculator to get your answers, that is OK.
- 4) The formula for calculating compound interest is given if you need it .

The Compound Interest Equation

$$P = C (1 + r/n)^{nt}$$

where

P = future value

C = initial deposit

r = interest rate (expressed as a fraction: eg. 0.06)

n = # of times per year interest is compounded

t = number of years invested

Simplified Compound Interest Equation

When interest is only compounded once per year ($n=1$), the equation simplifies to:

$$P = C (1 + r)^t$$

8.1

8.3 Experimental group answers

Participant A

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions .

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

	<p>Your Answer</p> <p>105 month,</p> <p>80</p> <p>101.8</p>
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2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer</p> <p>390.2578</p> <p>390.2578</p>
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3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer</p> <p>84462.9307</p>
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Experimental Group Answers -Participant B

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

<p>Handwritten notes in Arabic: "المبلغ الذي كان عليه" and "بالتالي".</p>	<p>Your Answer</p> $0 = 10000 \left(1 + \frac{0.12}{12}\right)^{12t}$ $0 = 10000 (2)^{12t}$ $0 = 10000 \left(1 + \frac{0.12}{12}\right)^{12 \times t}$ $0 = (10,100)^{12t}$ <p>101 months</p>
---	--

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer</p> $0 = 10000 \left(1 + 0.12\right)$ <p>\$390</p>
--	--

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer</p> $20 \times 12 = 240 \text{ months}$ $= 10000 \left(1 + \frac{0.12}{12}\right)^{240}$ $= \$108,925 - 12 = 56$
--	--

Experimental Group Answers - Participant C

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

	<p>Your Answer</p> <p>Total credits = 10,000 + 1,200 (Interest included)</p> <p>210 months = $\frac{11,200}{110}$ (Total payment / monthly payment)</p>
--	---

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer</p> <p>333 dollars per month.</p> <p>$\frac{11,200}{36}$ (Total credit debt payment / 36 (months in 3yr))</p>
--	--

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer</p> <p>$50 \times 20 = 1000$ dollars</p> <p>$11,200 - 1000$</p> <p>10,200 (Balance)</p>
--	---

Experimental Group Answers - Participant D

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions .

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

	<p>Your Answer About 200 months. I didn't have a calculator so I estimated that it would take approximately 100 months to pay the original debt so I doubled that to account for the interest rates</p>
--	---

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer About 350 400 dollars. You then pay 4800 per year which would pay off the debt, Probably in less time than 3 years. I approximated the debt would be ca. 12000 at 3 years and divided by 3 years approximately</p>
--	--

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer About 1 80,000 \$. I knew it would at least tripple but since it is exponential growth I put a higher number.</p>
--	--

Experimental Group Answers - Participant E

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

	<p>Your Answer</p> <p>With 0% APR it would take $10000/110 = 90,9$ months $\sim 7,57$ years The APR for this period is 19,090 which will take another 82,64 months TOTAL = 173,54 months</p>
--	---

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer</p> <p>$10000 + 1200 \times 3 = 13600$ to be paid $13600/36$ months = 377,77/month</p>
--	---

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer</p> <p>The amount after 20 yrs = $10000 + 24000 = 34000$ The amount paid is $50 * 240$ months = 12000 The balance is 22000.</p>
--	---

Experimental Group Answers - Participant G

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions .

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

	<p>Your Answer ~ 150</p>
--	------------------------------

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

	<p>Your answer $3 \times 12 = 36$ 10,000 / 36 + add some to cover interest rate 350</p>
--	--

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

	<p>Your answer very very big ☹️ $10,000 - 5 = 9,995 \cdot 12\% \cdot 1000$ exponential growth of debt. interest rate after 1 year In 20 years should be ~ 500,000</p>
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8.4 Control Group Answers

Participant H

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

$$P = C(1+r)^t$$

$$0 = 10000(1+0.12)^t$$

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

$$(1+0.12)^t = 0$$

$$\frac{[10000 - 110t]}{1.12^t} +$$

$$(-110t) / 1.12^t$$

close to 75 month years = 180 months

$$\frac{180}{12}$$

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

36 months

Almost \$20

$$\frac{10000}{36}$$

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

$$P = 10000(1+0.12)^{20} - 500(1+0.12)^{20}$$

$$= 10000 \left[\frac{1 - (1+0.12)^{-20}}{0.12} \right] - 500 \left[\frac{1 - (1+0.12)^{-20}}{0.12} \right]$$

(just trying to think of a formula)

at $t=20$, $C_{20} = 10000 = C_0$

Around 60000 \$

Control Group Answers - Participant I

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions .

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

~~Around 100~~ Around 110 months

→ calculated considering 12% APR interest rate.

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

Around \$330/Month

→ Considered apr. interest for 3 years.

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

Around ~~\$10,000~~ 10,000

→ Taking into account the compounding effect of interest rate,

Control Group Answers - Participant J

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions .

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

~~180 months~~ 180 months

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

\$ 390 / mo

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

\$ 50.000

Control Group Answers - Participant K

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

It would not be paid ever because the increase of the interests are higher than the actual payment.

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

$$A = C(1+r)^t \Rightarrow 10,000 = C(1.12)^3 \rightarrow \frac{10,000}{(1.12)^3} = C \quad \text{equation}$$

$$C = 9615.4 \Rightarrow \frac{9615.4}{12} = 801.28$$

Monthly payment should be 801.28 \$/month

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

$$\begin{aligned} \text{total payment} &= 50 \times 12 \times 20 = 12000 \$ \\ \text{total interest (without reduction)} &= 10,000 \times 0.12 \times 20 = 24000 \end{aligned} \quad \left. \begin{array}{l} \text{SD} \\ \end{array} \right\} 24000 - 12000 = 12000 \$ \text{ not paid}$$

Approximately, it would be 20,000 \$ (adjusting for the decrease of the actual interests)

Control Group Answers - Participant L

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

$$\frac{10,000 \times 12}{100} = 1200 \text{ - Interest}$$
$$\frac{110 \times 12}{100} = 13.2$$

~~10~~ × 12

It will take 10 years

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

$$\frac{110 \times 12 + 110}{100} = 123.2 \text{ us dollars}$$

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

$$\frac{50 \times 12}{100} = 6 + 50$$
$$= 56 \text{ us dollars}$$
$$(56 \times 12) = (672 \times 20)$$
$$= 13,440 \text{ us dollars}$$

Control Group Answers - Participant M

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

aprox with 101 months almost equivalent
to 8 yrs & 4 months

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

aprox. \$311.⁰⁰

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

There still be a debt
of aprox. \$200.⁰⁰

Control Group Answers -Participant N

Consider a consumer with \$10,000 worth of credit card debt and an APR (annual percentage interest rate) equal to 12%. In each case, assume that the consumer is no longer using the card. Answer the following questions.

1) How many months would it take to pay off the credit card debt if you paid \$110 each month?

$$P = C \left(1 + \frac{r}{n}\right)^{nt}$$

$$\Rightarrow 11,268.2503 / 110 = 102 \text{ months}$$

$$\Rightarrow \left[\frac{10,000 \left(1 + \frac{0.12}{12}\right)^{12}}{110} \right]$$

$$\Rightarrow \left(\frac{10,000 \left(1 + \frac{0.12}{12}\right)^{12}}{110} \right)$$

$$= \underline{\underline{354 \text{ months}}}$$

2) What monthly payment would be required to pay off the credit card debt in exactly three years?

$$P = C \left(1 + \frac{r}{n}\right)^t$$

$$= 10,000 \left(1 + \frac{0.12}{12}\right)^3$$

$$P = 14,049.28 //$$

Monthly payment to required to pay off in three years is;

$$14,049.28 / 36 = \underline{\underline{\$390.258}}$$

3) Assuming a constant monthly payment of \$50, what would the balance be on the card after twenty year?

$$\left[\frac{10,000 \left(1 + \frac{0.12}{12}\right)^{20}}{12} \right] - [50 \times 12 \times 20]$$

$$12,201.9 - 12,000$$

$$= \underline{\underline{\$201.9}}$$

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