Romantic Transfer: From Science to Social Ideologies

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Abstract:

The transfer of learning is arguably the most enduring goal of education. The history of science reveals that numerous theories transfer from natural-science to the socio-political realm, but educational practitioners often deem such transfers romantic and rhetorical, ignoring the opportunities and challenges such transfers may hold. In terms of opportunities, romantic transfer encourages students to relate science to events in social life and further to discover new ways to understand social issues and propose social hypotheses. In terms of challenge, romantic transfers are often based on superficial and even imprecise understandings of science and depend on oversimplified labels and metaphors. In many cases, the romantic transfers are imaginative. Although logically romantic transfers are based on analogical resonance, empirically they are hardly proven to be valid. Nevertheless, when students imagine social and ideological implications of the hard science terminologies and theorems, they are at risk for considering the emergent ideologies as proven by hard sciences that are often considered authoritative, objective, and universal. Literal understanding of science-inspired by still unexamined ideologies can lead to maladaptive and even dangerous social actions. Because many of the romantic transfers are interdisciplinary and controversial, teachers may avoid explicit discussion about romantic transfer with students, and do not wish to assume responsibility of doing so. However, the question remains whether avoiding explicit discussion and debates about romantic transfer would inhibit students from spontaneously romanticize science concepts. This dissertation presents four studies that systematically investigate questions of romantic transfer—informal, emergent, and metaphorical boundary transections from natural science to social ideologies that often occur unexpectedly.

My first study shows that participants who scored high in transferential thinking style also scored high in scientism beliefs and that participants who scored high on both tend to give literal interpretations to (religious) text. Following, my second study shows that students who reviewed the conservation of energy in physics are more likely to believe that luck is conserved, a naïve karmic religious idea. My third study shows that students are able to transfer spontaneously from theories in physics to more politically charged contexts. Specifically, students who learned the theory of entropy are more likely to prefer tightened social control, whereas students who learned self-organization theory are more likely to prefer stronger individual agency and relaxed social control. Study-4 involved interviews with the participants from Study-3 and shows that students' narratives about social control are largely consistent with the thermodynamic concepts they have learned. Occasionally, students can critically evaluate the plausibility of their romantic transferences.

This dissertation shows that science instruction implicitly empowers students to make social hypotheses and to engage in moral-civic-political discourse. To consider pedagogies that respond to such an opportunity without falling victim to hasty generalizations, we need both science and civic educations to equip students with the methods to examine self-generated social hypothesis. We also need pedagogies that promote the awareness and tolerance of metaphors to offset the dangers of literalism.

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Preface

I was good at using metaphors when I was very young, particularly, metaphors adopting academic language. I learned it from my grandma, who was illiterate. In my first three years in elementary school, she walked me to school in the morning, picked me up in the afternoon, bought some grocery for dinner and walked me home. There was only one problem. I got detained by my teachers almost every day for mischievous behaviors: I whisper during quite hours, I conceive toys and then throw them at other students, and I play music instruments unpredictably in the middle of math classes. The teachers would detain me, along with other mischievous boys and girls, until our parents came and embarrassingly picked us up from the detaining room. This process was so humiliating to the parents that it guaranteed a good punishment to the kids back home. This had happened again and again in my first years in elementary school, all other parents were too ashamed or exhausted to show up, except for my grandma who showed up every single day.

One day she had a good idea, instead of walking back home with anger and slapping my butt at home. She slapped me in the detaining room and asked me to write a repentance letter immediately. This was happening before any teacher had taught me how to write any essay. All other detainees laughed at me as I was writing my repentance. Then my grandma slapped every other detainee in the room, and asked them to write repentance letters as well. My grandma demanded that we, in the repentance letter, refer to anything we learned in class in retrospective to the roots of our misbehaviors. So I wrote: "I learned in science class today that if you see one cockroach at home there are at least three hundred cockroaches hiding in your home that you cannot see. Similarly, although I only did one bad thing in classroom, there were probably three hundred evil thoughts in my mind. I need to restrain them before I act them out". The teacher loved my repentant letter, asked me to read it in front of the class the second morning, not as a way of shaming, but as a glowing good example. Repentance letters had ever since replaced detaining to become the new punishment at school. I started to write soul searching repentance letters for my classmates, charging with a moderate fee.

Last winter, as I was sinking in the couch in my Cambridge apartment, finishing the discussion chapter of my dissertation that ended with painful reflection and confession of the limitations in my own research, my grandma passed away in Beijing. I have been imaging the moment that I show her my finished work and how proud she would have been, remarkably similar to the moment that I showed her my first repentance letter. For this, I dedicate this dissertation to her.

This dissertation topic and methods are influenced by many of my intellectual mentors. As early as my undergraduate years, I was fortunate to audit a neuroanatomy class taught by Liangbin Wang from biology department. For a whole semester, he did not teach any physiology, but talked long and freely about his metaphysics framework about the structural morphology as a synthesis between biology and religion. Dr. Kurt Fisher's work introduced me to a natural philosophical perspective of education. My earlier advisors, Dr. Jennifer Thomson, brought me to the experimentalist methods in laboratory setting, and Dr. Matthew Schneps brought my experimentalist training to classrooms and outreaching

programs. This dissertation does not exist if without the support from my co-advisors, Prof. Helen Haste, and Prof. Robert Selman. They are the people who steered our joyful conversations to serious research questions, and pulled me from my obsession in cynicism to painstaking actions. Karen Gabe was my supervisor back in my college. She has been my constant source of hope. We don't see each other very often, but we are in each other's prayer list. Prof. John Willett is my statistic guru, he also claims himself to be a great poet; he retired in 2013 and moved to California. I saw him in the airport in San Antonio recently (in the spring of 2017), where he told me that "life is like a step-wise regression". I am glad know he also likes to romantically transfer.

Too often educators emphasize how parents shape the growing-ups of their children, yet too few acknowledge how children shape the growing-worries of their parents. For the past 30 years, I have been training my parents to get used to anticipating the potential troubles I could have made. I had been very intolerant to their worrisome since my teenage years and I did not emphasize their anxiety, until I had my first cat. My folks did not stop worrying about me until I got married to a wonderful wife who keeps me sane and to live under the left-wing liberal assumption that there is a tomorrow.

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CHAPTER I:

INTRODUCTION TO ROMANTIC TRANSFER

If the time should ever come when what is now called Science shall be ready to put on, as it were, a form of flesh and blood, the Poet will lend his divine spirit to aid the transfiguration.

—William Wordsworth (1802)

It was the year 2004. I was in my second year in high school and it was a sunny morning of a moist spring in Beijing. I was sitting in the so-called "advanced" class. The school put its top 50 students in the advanced class and devoted its best resources and most experienced teachers to this class, so that students could achieve the best test scores across the city and bring glory to the school. A young physics teacher in his 30s, who was completely new to us, came in and told us that he was replacing our regular 60-year-old award-winning physics teacher, Mr. Gao, temporarily for just one day, as Gao was out for medical reasons. The replacement's name was Tsu. this was my only encounter with him, but within the next 12 years, Mr. Tsu would become a nationwide, well-known five-star teacher of high school physics with more than 20,000 followers on his Weibo (Chinese Twitter). Back to the morning in year 2004, Mr. Tsu said he brought a physics question that will teach us some really important and useful physics facts.

The question was talking about a circuit on an evenly distributed magnetic field, as shown in Figure 1, and there was a metallic rod "ab" on the circuit. The question asked how the rod should move to have the coil on the rectangle attract the bronze circled wire "c" on the left.

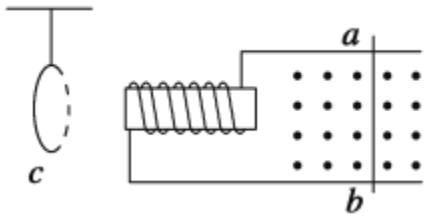


Figure 1. A high school physics test given by Mr. Tsu.

The answer was that the rod "ab" should move away from "c," but steadily decrease its speed, and if "ab" move towards "c" in an increasing speed, it will push "c" away. This was not a difficult question for me in high school, but now as a PhD candidate, I cannot solve it nor explain it as I have forgotten all my high school physics. What makes me remember this question so deeply was that, after explaining the answer in plain physics, Mr. Tsu further explained it in a teasing tone saying, "This is exactly how you should keep your boyfriends or girlfriends on the hook, if you want to attract him/her, you should pretend you are giving him/her more space, or ignore him/her just a little bit." This line of his totally amazed me and literally set off my delayed puberty. For the first time in my boring high school life, I realized science is romantic.

This dissertation concerns how students romanticize science by transferring it to the social domain of personal wisdom.

Romantic Transfer Definition

In the acclaimed Disney animation *Zootopia*, detective Judy the rabbit and her assistant Nick the fox work on a case where numerous predator citizens became aggressive and go mad. Judy, in a press conference, inadvertently suggests that the theory of bio-evolution history, a science theory she had just learned, caused the predators to go back to their savage state. This careless comment, which angers her partner Nick, is a classic example of romantic transference (RT)—being inspired by a science theory to analogize to social phenomenon.

In a separate account, a group of Chinese scientists in bio-engineering published in the journal *PLOS ONE* a research article titled "Biomechanical characteristics of hand coordination in grasping activities of daily living" (Liu et al., 2016), a solid academic paper

discussing the kinetics of human hand structure and movement. In the very last sentence of their article, the authors ended, "In conclusion, our study can improve the understanding of the human hand and confirm that the mechanical architecture is the proper design by the Creator for dexterous performance of numerous functions following the evolutionary remodeling of the ancestral hand for millions of years." The "Creator"' with a capital C so angered nearly the entire academic population that many editors from *PLOS ONE* threatened to resign. As a resolution, the journal retracted the paper, even though forgiving sympathizers argued it was only a mistranslation, or an auto-correction mistake, or a misuse of metaphor in a cross culture context. This is another example of romantic transfer—the attribution of metaphysical or spiritual awe to the intricacy, or magnificence, or universality of the laws of science.

romantic transfer contains three defining components, namely, (a) metaphorical, to transect domains; (b) informal, to romanticize based on a hunch, an inspiring revelation, or an instance of imagination, and not necessarily to follow rigorous reasoning or careful empirical investigation; (c) directional, to transfer from the best "known" and the most "certain" scientific foundations to the most curious but unknown life philosophy. In combination, romantic transference is an informal generalization that carries over accepted knowledge in science via the making of inferences and new understandings into the social domain. The following sections elaborate on the three components.

Metaphorical

There are in general two categories of transfer: applicational transfer and metaphorical transfer. Applicational transfer is the use of knowledge in its abstract form in practical context; only the context has changed, but not the concept domain. For example, teachers may be curious if students can think of Newtonian laws of motion when they are

riding a roller-coaster in amusement parks. In this example, the context has changed from textbook or classroom knowledge to amusement parks, but the concept domains are the same: gravity, inertia, acceleration, etc. The abstract law is only an induction of all the particularities, and each practical context is only an instance that follows the abstract law.

Metaphorical transfer concerns the conceptual leap between different domains, such as from cell membrane to social segregation; from Heisenberg's uncertainty principle in quantum theory to agnostic cynicism about life. This type of transfer operates on metaphorical basis, that people carry over a principle from one knowledge domain to generate a principle in another knowledge domain. This dissertation concerns itself primarily with such cross domain metaphorical transference. Sometimes, metaphorical transfer leads to induction of a more general principle and a scientific breakthrough; sometimes, it remains a metaphor; and sometimes, it becomes a myth, especially when metaphor is taken literally. This leads to the next component of romantic transfer.

Informal

To romance is to be entertained by the inspiration, but much less so by formal and rigorous reasoning procedure or careful empirical investigation. Although romantic transfer has a basis in analogy, it does not always require structural mapping of multiple features as analogy does (Gentner, Loewenstein, Thompson, 2003). Moreover, the implausibility of the inference does not bother it. This informality of romantic transfer creates a safe zone for transfer makers (hereafter transferors). When their transferences are not questioned, they can promote them more seriously, but if questioned, they can retreat and claim it is only a fancy of post-modern poetic imagination. Imagine what Mr. Tsu would respond to concerned parents who questioned him about the kind of passive-aggressive dating advice he gave to their teenage children. Mr. Tsu can simply laugh it off, saying, "Surely, I was joking."

For most people, romantic transfer is a hunch, an inspiriting revelation, or a poetic imagination. In William Wordsworth's (1800) terms, "Poetry is the first and last of all knowledge." Most of the times, a poetic hunch may not turn into a scientific theory. Nevertheless, it may appear to be more convincing than textbook knowledge because it is intuitive and self-generated.

Even if romantic transfer is informal in its reasoning style or proof procedure, it does not prevent such transfer from being taken seriously. Chemist Denham Harman had a thought "out of the blue" (as he admitted himself in an interview in 2003) that oxidants (free radicals) cause aging just like oxidants can erode rubber in chemistry, or just like ionizing radiation can be deadly. Harman (1995) admittingly made the chemistry-to-human transfer by saying: "I realized that free radicals could account for all the phenomena that I knew about because they were irreversible reactions. At that time there was no datum to indicate they were going on in the human body, but it was quite obvious that they had to go on because it was just the nature of chemistry". Therefore, Harman reasoned, antioxidants, such as vitamin C, must be effective in preventing aging. For half a century, the pharmaceutical community took this metaphor very seriously, and so did consumers. By year 2013, antioxidants have enjoyed a $2.1 billion market that is projected to reach $3.1 billion by 2020 (Scudellari, 2015), although scientists in early 2000s have shown antioxidant theory to be no more than a myth (Bjelakovic, Nikolova, & Gluud, 2013; Ristow et al., 2009). Other scientific theories, such as evolution theories, were not aimed at transferal implications, but were nevertheless passionately rejected (e. g., by creationists) or embraced (e. g., by social Darwinists) by the public for its theological or social implications.

Alfred N. Whitehead (1962) once considered the learning process to be a three-step procedure: to romance, to master, and to generalize. In many cases of the informal transfer,

the learner is captured by the mysterious and reduceable nature of the laws of science, has not mastered the full scope of the target concept, and yet is eager to skip the mastery step and move on toward generalization. Thus, in Whitehead's terms, we can understand romantic transfer as equivalent to romantic generalization minus the necessity of mastery.

Directionality

Romantic transfer in this study specifies a unidirectionality in that knowledge is transferred from hard science to social or civic domains. Cognitive linguistics has extensively studied the directionality of metaphor from concrete source domains to abstract target domains (e. g., Lakoff & Johnson, 1980). Most of the metaphors in our languages follow such directionality (e.g., love is a rose), and metaphors that follow such directionality tend to be more comprehensible. The reason, simply stated, is that we use familiar objects to describe unfamiliar objects and visible objects to imagine invisible ones. Such a rule of metaphor can be used to explain the transference in either direction between the domains of science and mundane life, depending on which domain is deemed "concrete." It is commonly assumed (Lakoff & Johnson, 1980, 1993; Ortony, 1993) that the life domain is more concrete, with so many life events embodied, visible, and familiar to us, whereas science concepts are abstract and distant. Expectantly, reflections in the life domain can be transferred to the science domain by science experts or learners, to make difficult science more comprehensible or to inspire new science hypothesis for further investigation (for thorough reviews see Dunbar & Blanchette, 2001; Gentner & Jeziorski, 1993; Nersessian, 1999; Thagard & Croft, 1999). I would name them as *enlightened* transfers in that, similar to the Age of Enlightenment, such transfers evoke scientific rationalizations of nature. Since the goal is to have a deeper understanding of nature by the science professionals, it does not

stop by an inspired hunch, or a simple example for illustration, but further formulates hypotheses, tests, modeling, and theorization.

The opposite direction, from science domains to lay domains, although seemingly unlikely, is congruent with metaphor theories as well. The reason is that, although science deals with the unknown, scientific knowledge delivered in most of the school settings is the best "known" and the most "certain." The "laws of nature" have been proven true by the most intelligent, represent the simplest and most parsimonious form of pure and universal formula, and are the most certain factually. Although the scientific principles are difficult to comprehend in depth, their superficial conclusions are usually succinct, authoritarian, and easy to remember. Considering the amount of time each student spends repeating the same physics law in classrooms and homework, it is possible that one may take scientific knowledge as essential, familiar, and certain and, therefore, place it in the source domain. Life wisdom, social events, civic opinion, and political stance, on the contrary, do not have a clear right answer. They are probably the things that matters the most, but are abstract and uncertain. Opinions are often mutually or self-contradictory, observations are noisy, predictions are unreliable, authority is doubtful (e. g., genius is found in physics, not in morality). To use the best known scientific laws to understand the most curious but unknown life philosophy is consistent with the rule of metaphor that maps from known to unknown. Multiple scholars, such as Gardner (1985), Pinker (1999) and Gigerenzer (2000_, have argued that without the computer metaphor as a mental model, and terminologies that carried over from computer science, contemporary scholars can hardly image and talk about human mind. Even though barely any scholar literally believes that human mind is precisely a desktop or laptop, they are content with this innovative metaphor for practical use. In fact,

through the history of psychology, people always use the most innovative and intricate technology of their age to metaphorize human mind.

I specify this particular direction of transference, from natural and physics science to life philosophy and civic ideas, as *romantic* transference, in contrast to *enlightened* transference. Apart from borrowing this term from Whitehead, another reason for the term "romantic" comes from the Romantic period, an era in Western history that superseded the Age of Enlightenment. The "Romantic" assigned a high value to intuition and imagination over rationality, and places the experience of awe inspired by nature as a way to achieve mental and moral health. The simple fact that science fictions (e.g. Frankenstein) grew out of Romantic period is a testament that Romantics understand and, most importantly, fantasize about science and technology. Intellects in the Romantic period looked for moral, spiritual, humanistic, and poetic inspiration from nature (or, more specifically, from science as a study of nature), and deem the end goal of observing nature to be acquiring the inspirations, but not necessarily the logical proof or empirical examination.

Richard Dawkins (1995) made an interesting observation of a less romantic, but more pragmatic, reasons of transfer (although he did not use the same terminology):

> Physics is difficult, so there's a great industry for taking the difficult ideas of physics and making them simpler for people to understand; but, conversely, there's another industry for taking subjects that really have no substance at all and pretending they do—dressing them up in a language that's incomprehensible for the very sake of incomprehensibility, in order to make them seem profound. (p. 23)

Dawkins might have been very harsh for literary or humanist scholars who were trying to borrow lexicon from physics science, and he might not have much tolerance for the safe zone created by the previously noted informality of the transference, but his line nicely

distinguishes the two types of transfer, one trying to borrow lay language to ease or deepening understanding in science, the other trying to borrow scientific language to support and theorize lay ideas.

Romantic Transfer in Science

Inventors of scientific theories sometimes reluctantly, and passively, respond to the extension of their theories to another domain. Few years after Newton published *Principia*, scholars (e. g., Richard Bentley, 1692) questioned *Principia's* religious implication. Newton, concealing his unorthodox anti-Trinitarian position until his private letters and manuscripts were revealed after his death, reassured theologian scholars that his book intended to inspire the intellectual community to meditate on God's law more closely (Iliffe, 2015). He further proposed that the cosmos was the divine analogue of human sense and reasoning and the analogy between the infinite power of God who moved the universe and the finite capability of humans to move their own bodies. Darwin was even more reluctant to participate or respond to the transference generated by the public, namely social Darwinism. Instead, he relied on his scholar friends, such as Thomas Huxley (1896), to argue that human society is driven by different mechanisms from the world of biology.

Many other scientists, however, have more actively, and often more passionately, extended their theories to the social domain. Niels Bohr, the founding father of quantum theory, conceived the *complementarity principle* in 1927. Encyclopedia Britannica (2015) explains this principle by stating, "It is impossible to observe both the wave and particle aspects [of an atomic dimension] simultaneously. Together, however, they present a fuller description than either of the two taken alone." The complementarity principle, though controversial and elusive, has remained an influential thought in both science and philosophy in early twentieth century. Bohr (1937) intended his theory to be, as summarized by Beller (1998,

p30), "an overarching epistemological principle applicable to physics, biology, psychology, and anthropology, a substitute for the lost religion, should be taught to children in elementary schools." Bohr's colleagues, venerated scientists in quantum physics such as Max Born and Wolfgang Pauli, concurred with Bohr. Pauli (1948, as quoted by Gieser in 2005) named the unification of quantum reality and spirituality to be "the most important and extremely difficult task of our time," while Born (1962, p.107) called for quantum philosophy to help humanity "toward a deeper understanding of social and political relations." Heisenberg (1958) hoped that quantum physics, empirically verified, would have major social and personal consequences "[just as] the changes at the end of the Renaissance transformed the cultural life of the succeeding epochs" (quoted from Beller, 1998). Bohr, nevertheless, never laid out the philosophical implications of the complementarity principle in a transparent language. Many philosophers of his time tried to speculate and rephrase his philosophical implications, but Bohr accused almost every one of them to be misreading him. Such a high aspiration to scientize religion and philosophy in the early twentieth century was replaced by a cold phase in the 1950s, exemplified by Richard Feynman, who believed physicists should not question or comment on philosophy (Farmer, 1995).

There is a particular type of scholar who is expert in a discipline in science and transfers the knowledge of the discipline into social and humanistic disciplines. Such a person was Vilfredo Pareto, an engineer by training who worked in railroads and iron companies, bringing the concept of equilibrium from engineering to economics and sociology disciplines. Peter Burke (2016) named them academic nomads, and John Brockman (1995) called them the third culture intellectuals. With the first culture dominated by literary scholars, and the second by the scientists, Brockman called for the need to celebrate a third culture, where scientists translate their knowledge to construct knowledge in

social and political matter and directly talk to the public just like literary scholars always do. The latter two decades of twentieth century witnessed the rise of the third culture scholars, such as Roger Penrose, Richard Dawkins, Daniel Dennett, and Steven Pinker. It also revived the hope for the unification across disciplines and more than 200 have been published annually, between 1980 and 2000, in the single category that contemplates the connection between science and religion. Russell Jacoby (1987) once worried about the increasingly specialized academics with narrowed visions and the diminishing intellectuals sharing a public interest. Brookman (1995, p. 19) claimed that third culture scientists are the "new public intellectuals."

Romantic Transfer among Teachers, Students and Lay People

In September 2016, *Nature* published a short news article reporting the escalated dispute over the CRISPR (clustered regularly interspaced short palindromic repeats) patents, a genetic editing technique, and one of the greatest scientific breakthroughs in the 2010s:

> Geneticist George Church has pioneered methods for sequencing and altering genomes… and is probably the world's leading authority on efforts to resurrect the extinct woolly mammoth.
>
> Now, a battle over who owns the patent rights to a revolutionary gene-editing technique could hinge, in part, on whether Church's scientific skill could be considered 'ordinary'.
> …
> In 2012, a team [from Berkeley] reported that they had reprogrammed CRISPR to cut isolated DNA at sites of their choosing. Then, in early 2013, several groups [Zhang from MIT Broad Institute and Church from Harvard] reported that CRISPR also worked in living eukaryotic cells, including human cells.
>
> Since January, the two sides have been making their case in filings to patent judges. [MIT Broad] asserts that Berkeley's initial patent filing described using CRISPR in prokaryotes such as bacteria, but did not sufficiently describe the procedure in eukaryotes such as mice and human cells. That distinction is important: CRISPR's most lucrative applications are likely to be in medicine, and several biotechnology companies have already licensed patents from either Berkeley or the Broad.
>
> Berkeley argues that the application of CRISPR to eukaryotic cells was obvious and that "persons of ordinary skill", such as a postdoc with relevant expertise, could have

> made the leap…The Broad countered that these scientists are all leaders in their field and could hardly be considered "ordinary.'" (p. 1)

This dispute, complicated by the most advanced microbiology terminologies, eventually counted on who could make the "leaps" (from ideas originated from research in bacteria cells to application in human cells), and if making "leaps" requires extraordinary expertise. Broad insisted it requires the greatest academic genius, whereas Berkeley thought that such leaps were attainable by any ordinary person. In the following section, I consider how ordinary teachers and students make the leap, namely romantic transference.

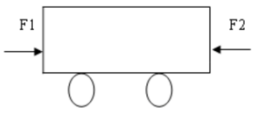
In a comprehensive analysis of the ideologies hidden in Norwegian high school science curricula and textbooks, Sather (2003) identified multiple frequent ideologies underlying the presentation of scientific frameworks, ideologies such as materialism, liberalism, and skepticism. More education researchers have explicitly called for a "broader scope" (Reiss, 1999) in the curriculum design in science education that would bring about a "philosophical turn" (Matthews, 1999) and a "cultural border crossing" (Aikenhead & Jegede, 1999) to deliver "companion meaning" (Roberts, 1998) in "beliefs and values" (Poole, 1995) for the promotion of liberal ideas and democratic society (Carson, 1998).

One application of romantic transfer in curriculum is to interpret social political issues through the lens of natural science principles. American physicist Alan Lightman, the first professor at MIT to receive a joint appointment in the sciences and the humanities, gave the following homework to his students in 1992:

> One statement of the second law is that a physical system naturally evolves toward redistributing its energy equally among all its parts. Zachary Hatch, of the class of 1991 of Princeton University, has proposed that the historical dissolution of empires - which political power is first consolidated into large, centralized regimes and then ultimately dispersed into many smaller ration-states - can be understood on the basis of the second law of thermodynamics. For example, the end of World War II brought the end to Hirohito's Japan, the modern version of the feudal empire that had existed for hundreds of years. China, too, saw its several-thousand-year-old dynasty fall and be replaced with a socialist state. Recently, we have witnessed the

> disintegration of the Union of Soviet Socialist Republics. Do you think this application of the second law is justified? If so, what corresponds to the energy of the system? What is the political or social process that corresponds to molecules' bumping into each other and thereby redistribution and sharing the total energy? Does such a process have the needed element of randomness? What corresponds to a state and a configuration of the system? Would the second law, if applicable, preferentially lead to a capitalist or a socialist society? If true, how would this theory reconcile itself with the formation of empires?

Another example is the following test item (translated) from Chinese Entrance Exam (for high school students to enter colleges):

> The following graph reflected the development of national capitalism in contemporary Chinese history, F1 is friction, F2 is thrust force, the situation that F1>F2 occurred in ( )
>
> 
>
>
> A. After the Sino-Japanese War of 1894
> B. During Liberation (civil) War
> C. First 10 years under Nationalist government
> D. During World War I

In both examples, it is expected that students have basic understanding in both the political affairs and physics science (thermodynamics or Newtonian law), and use physics to "solve" politics. There are great volumes of literature that show students actively and implicitly making sense of their worldviews based on their science learning experience (Kilbourn, 1980; Hansson et al., 2015; Hofmann & Weber, 2003; Keranto, 2001).

In a study of students' conceptualization of nature, Cobern et al. (1999) reported two worldviews of nature that are prevalent among ninth graders from science courses: The first is that nature is logical, ordered, and has patterns that can be fully understood eventually; the second is that nature is so complex and intricate as to imply a Godly design. Both views are common, though different, worldviews and both are consistent with science courses. Other research has shown that students (11-15 years old) who adopt the first worldview are likely to hold strong beliefs in scientism and to demonstrate a less favorable attitude towards

Christian religion (Francis, Gibson, & Fulljames, 1990; Fulljames, Gibson, & Francis, 1991). Taber et al., (2011), nevertheless, reported that students (14 years old) do not always choose one over the other as they can actively reconcile (science can support faith) or manage (chose or inhibit one position depending on context) the two worldviews. Fleming (1998), in a study of college students in a pre-professional science track (e. g., pre-med), shown that since science (or professors) is always proven to be right, the students have gradually developed "faith" in science or in their professors, just as craft apprentices have faith in their mentors.

Besides the transference from science to spirituality, the student populations actively map science concepts onto the domain of social and civic ideas. In a study of college students' perceived social consequence of evolution theory, Brem et al. (2003) reported both enthusiastic and concerned responses. The enthusiastic respondent believed that evolution theory has positive outcomes, quoted as an example, "It's up to them [people] to shape their actions according to their own personal, moral or philosophical beliefs, but it would be a bonus if teaching evolution helped people to accept one another easier!" The concerned respondent worried that evolution may promote social-Darwinism, racism, elitism, and selfish moral values. In addition to science models, engineering prototypes, with its emphasis on "control," are also prevalently borrowed in social and civic discourses (Edge, 1990; Nelkin, 1979; Volti, 1992; Winner, 1977; Zuboff, 1988). Zaino (2008) showed that a pedagogy that traces and constructs the mechanical metaphors behind social and organization control benefits students' deeper understanding of the political system. Edge (1990) quoted a VOX magazine interview in 1969 during a big student demonstration in Washington DC, as middle-aged bystanders talked about demonstrations as a healthy "letting off steam." One student leader addressed the crowd, "You've heard they say we're

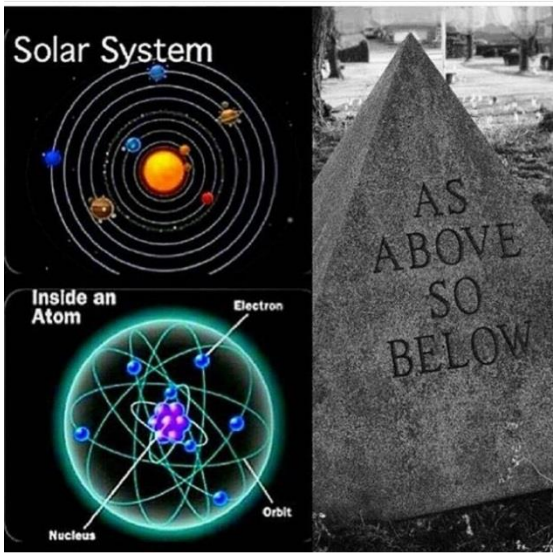
the safety valve – but I say they're dead wrong. We are the explosion!" Such is an example of youth adopting engineering and technology metaphors to reframe civic discourse.

Recently, Hadzigeorgio (2005) have called for a "romantic understanding" of science in science education, that cultivate an esthetic and philosophical taste of science knowledge. Specifically, he and colleagues intend such an romantic approach to promote (a) emotional sensitivity toward nature; (b) acuity to one's own sense and experience; (c) holistic experience, (d) appreciation of mystery and wonder, (e) transformed worldview, and (f) a philosophical understanding of science (Hadzigeorgiou & Classen, 2012; Hadzigeorgiou & Schulz, 2014). Hadzigeoriou et al (2011) provided an example in which they used a romantic and story-telling way to introduce the works of Nikola Tesla. The story tells Tesla's personal ambitions, humanistic ideals, social responsibility and frustrations. In the story, Tesla was portraited with heroic qualities such as strong will-power, ability to work unseasingly without sleep for 3 days and nights and rebellion against Thomas Edison. The story created a sense of wonder in its description of the marvels of alternating current electricity that astonished the world in World Exposition in Chicago in 1893 and transmitting electrical power from Niagara Falls to Buffalo City in 1895. Hadzigeorious et al (2011) showed that students who learned about electricity through the story of Tesla demonstrate more interest and deeper understanding in electricity than those learned electricity from a plain lecture. In addition, more students from the Tesla group developed transferential thinking, open-mindedness and a sense of wonder (Hadzigeorgiou & Garganourakis, 2010). For example, one of the student responded: "the more I read about his [Tesla] life and his way of thinking, for example the idea of the Earth as a huge battery with one pole on the ground and the other one in the ionosphere, the more I become impressed."

Constructivist scholars have long argued that there exists a parallel mapping between the development of scientific ideas in history and the conceptual growth within individual minds, as if the history of science recapitulates itself in a learner's mind. In Piaget's (1970, p13) words, "The fundamental hypothesis of genetic epistemology is that there is a parallelism between the progress made in the logical and rational organization of knowledge [in history] and the corresponding formative psychological processes." Piaget pushed this analogy even further and intended to study the development of knowledge in children to trace the ontology of knowledge itself. Many researchers have performed empirical studies of the parallelism hypothesis. Wandersee (1986) showed that students conceptual growth about biological processes to be in parallel to the development of the theory of biological processes in history. Eckstein and Kozhevnikov (1997) showed that students' development in the concepts of projectile motion proceeds by stages, each in parallel to a corresponding historical stage. Tsai (2000) summarized the interplay between history of science and students' learning trajectories, for example, that students' knowledge acquisition is affected by existing conceptions just like scientific observations are driven by prior theories. Students go through conceptual changes to challenge their existing misconceptions and mental models just as science grows through series of revolutions and paradigm shifts. Further, students exchange and validate science ideas in a complex social, cultural, and psychological context just like scientific knowledge is a product in the social, cultural, and psychological context and needs to go through a series of social negotiations. For such reasons, constructivist psychologists, for half a century, have been advocating for a learner-as-scientists model of education (Ausubel, 1968; Bereiter, 1994; Cobb, 1999; Sridevi, 2008; Major & Mangope, 2012). Interestingly (with a sense of irony), the recapitulation theory itself began as a romantic transfer that originated from the revelation that the evolution history

recapitulates itself through the sequential development from embryo to adult. Such theory has been largely discredited by biologists, but its modern revision has regained popularity, exemplified by the 2014 PBS documentary series: Your Inner Fish, Your Inner Reptile, and Your Inner Monkey. For reasons similar to the opposition to recapitulation theory in evolutionary developmental biology, researchers in science education called for caution against the recapitulation theory in learning epistemology—although it is a seductive hypothesis, one should not take sequential mapping rigidly (Lythcott, 1985; McClelland, 1984). My presumption on this issue is that science is fundamentally human activity. The history of science lays out the limit, habit, intuition, delusion, and frustration of human mind, demonstrated by science professionals. Lay learners are very much likely to experience the same processes for the simple reasons that we are all human and bounded by the same limitations and habits of mind. If scientists habitually apply their knowledge to provide alternative social perspectives, to give reason to human society, to prove or disapprove religious ideas, it is not unthinkable that ordinary science learners are tempted to do the same.

For purposes of this introduction, I consider science beliefs as discourse that lay people share in the context of communicating with each other for entertainment or for informal learning. Figure 1.2 is an example of romantic transfer propagated by an astro-photographer's Instagram account (Kodiak_89, 2016, December) that has more than 18,000 followers.



♥ 736 likes

kodiak_89 #truth #knowledge #wisdom #philosophy #science #astronomy #sacredgeometry #Zen #peace #love #universe #Gratitude #Namaste #meditation #meditate #happy #happiness #evolve #wakeup #unplug #freeyourmind #higherconsciousness #PinealGland #astrology #enlightment #fearless #WeAreOne #OneLove #revolution #nature.

Figure 2. An example of romantic transfer, screenshot from an Instagram account. The left side is the shared image; below are the hashtags given by the account users.

In this post, the account user collaged three images to present a revelation: that the structure of atom is like the structure of the solar system, which is a "proof" of "as above so below," a Hermetic religious idea that the Earth reflects Heaven. The user also assigned hashtags (shown below the figure are the hashtags that indicate the user's interpretation of the post). It appears that the user considered the post to be the interface of science, philosophy, religion, and wisdom.

In the comments below the post, there were other Instagram users who were not fully convinced by the revelation and commented,

> Electrons aren't in orbits, they're in orbitals. Orbital is just the probability of finding an electron within an atom in a particular space. This model was suggested by Bohr I believe, but it's been disproven already, but its sadly is still the most marketed model. I usually like your posts, but I'm sorry, this is so wrong.

Another commenter said: "As above so below doesn't mean that, not even close, don't be deceived. God bless."

There were other commenters who were aware of the invalidity of the atom model, but could appreciate the analogy, stating, for example, "That model of the atom is outdated, but the point of the post still stands."

There were also other commentators who felt inspired and who commented, "Man, I've always said that atoms were mini solar systems way back when I was in my teens, now I'm seeing this stuff is crazy!" Another inspired commenter said, "Huh, never thought of that actually, amazing idea!"

Finally, there was another intriguing type of commenters who took the transference even further by commenting,

> When you remove an electron from an atom you create a positive ion. That is God removing the rib from Adam (atom). When you take the electron you removed and put it in another atom, you create a negative ion. That is God making Eve from the rib. The message is, all life come from the splitting of the atom.

These different types of responses nicely summarized the reactions to romantic transfer from lay consumers. There are critical defenders who are not easily humored by the transfer and tend to defend the most technical interpretation of knowledge within its domains. There are more tolerant appreciators who are aware of the invalidity of the leap, but can still appreciate the intelligence behind a good transfer. There are keen followers who enjoy the transfer, inspirited, and feel they become wiser persons because of the inspiration. There are also pioneers who make even further transfer to demonstrate or share their wisdom or humor. If we as researchers assume the duty of delivering the scientific proven

knowledge and correct any misconception, we may become the critical defenders, and fail to detect the wisdom and humor behind the romantic transfer and, moreover, fail to observe different types of science consumers who make sense of science in unexpectant directions.

Psychology Study of Romantic Transfer

Psychologists who study transfer are driven by three types of questions that consider (a) why transfer is logical, (b) the ease of transfer, and (c) the nature of people likely to transfer.

Why Is Transfer Logical?

Romantic transfers are fundamentally metaphors. Classical metaphor theorists have been fascinated by the question as to what makes "speaking something as something else"—an absurd linguistic practice—so logical and appealing (Boyle, 1954). Multiple theories have tried to explain how to make sense of a metaphor, such as to understand metaphor through its correspondence (Black, 1993), from its context (Ricoeur, 1975), or from its extended mental space (per *blend theory* from Grady, Oakley, & Coulson, 1999). Gentner's (1980) structural mapping theory, through multiple generations of revision (Gentner & Jeziorski, 1993; Fauconnier & Turner, 2008), has been successful in operationalizing the analogical nature of transfer. In brief, several features from the base domain are mapped to the target domain to build the analogy; afterwards, an additional feature from the base is transferred to make an inference about the target domain per the established rule of analogy. The more features required to be mapped, the more rigorous is the analogy, and the more potential target domains are deemed unfit and, therefore, filtered out. When there are, only a few features requiring mapping, the criteria are more relaxed, and the more target domains are deemed as plausible.

The above theories help us to understand how can we make sense of existing romantic transfers, and how we determine if a romantic transfer is appropriate. However, these theories do not extend to the question of how romantic transfers are generated. One contribution of the conceptual metaphor theory (Lakoff & Johnson, 1980, 1999) through its systematic analysis of metaphors behind different languages (Croft & Cruse, 2004; Kovecses, 2002, 2006) is to demonstrate that our conceptualizations of abstract concepts are motivated by metaphors or prototypes that are available (Gibbs, 2011; Lakoff & Turner, 1989). In other words, the available prototypes in the source domain may shape our construction in the target domain (Boroditsky, 2001; Gentner, Imai, Boroditsky, 2002) and we may actively use new metaphors to reconstruct the target (Boroditsky, 2000).

The process of constructing and reconstructing based on metaphors is termed *framing* in political and media studies (Tankard, 2001; Weaver, 2007). To frame is to select or transpose some aspect of reality to highlight or promote intended interpretation and recommendation (Entman, 1993). The theory of framing emphasizes the agenda behind the agent, not the validity of the frame. In fact, the frame can be entirely invalid, the correspondence between the two mapping domains can be very "thin," but the agent can still choose to use the frame to shift the discourse. Even if the receivers are aware that the frame is invalid, they often think and reason within the frame. Lakoff (2004, 2012) gave an example to illustrate the power of the frame: Employers tend to describe pension as benefit or welfare for retirement, even if the employees understand that pension are in fact delayed payment that employees deserve and are owed. Employees are reluctant to talk about it or ask for it once they are framed to think that a pension is "extra" payment for not working.

In addition to its function in conceptualization and persuasion, metaphor is also a tool for creative thinking or, in Aristotle's terms, a "sign of genius." It enlightens us to

discover new aspects of the target domain or bring about a change in basic assumptions. Per Kovecses (2005), creativity originates from (a) within the source domain, by extending the source space and map unused features to the target domain for new inferences; (b) a different source domain, by replacing the previous source to reframe the target for new conceptualizations; and (c) retrieving from a conventional source domain to rediscover unused features. Schaefer (1970), for example, proposed using metaphor creation task as a psychological measurement of creativity, and following psychologists (de Barros et al., 2010; Dias, 2005; Nogueira, Dias, & Primi, 2003; Primi et al., 2006) have validated such a measurement to be closely related to creativity thinking skills.

Scientific breakthroughs are often accompanied by new metaphors, such as using human communication ("message," "reading," "transcribing") to understand DNA (see detail in Bump, 1985). New ideas in social science are deeply rooted in metaphors as well and many directly come from physics science, such as the quantum theory of education (Maccia & Reyolds, 1963) or chaos theory in curriculum design (MacPherson, 1995). The simple fact that the founding father of sociology (as an academic discipline), Auguste Comte, originally termed the discipline as "social physics", is a testament that social science has being borrowing metaphors from physics science since its own conception. However, as MacPherson (1999) argued, despite initial excitement for their creativity, seldom have any of the transferred theories become successful without major modifications. The reason, he claimed, is that social scientists often neglect the distinction between application and metaphor. This converges with the distinction (see the Metaphorical and Directionality section) between applicational transfer (which directly apply an abstract knowledge to practical use) and metaphorical transfer (which leap from abstract knowledge in natural science to abstract wisdom in social life), as well as between enlightened transference (which

does not stop at metaphor level but investigate deeper to the essence) and romantic transference (which is content at the metaphor level but sometimes taken seriously).

Ease of Transfer

To my best of my knowledge, experimental psychology studies have not explicitly examined the psychological factors that ease the process of romantic transfer. However, abundant psychological studies (a burst of literature in the last decades of twentieth century) have examined the transfer in learning in general. Psychologists are motivated to prove the existence of transfer to demonstrate that subject learning is either applicable to practice or an enhancer of latent skills. Thus, psychologists have been focused on the useful or correct transfers, but not the romantic and problematic ones. Nevertheless, a brief review of the psychology studies of transfer is helpful to reflect on the general factors that may be applicable to all types of transfer. In the next two paragraphs that review the psychology literature, the term transfer is not confined to romantic transfer, but is generically defined as applying knowledge across two or more different contexts. Often, the contexts are closely related to each other, such as between two programming languages.

Transfer of learning between boundaries is not easy, as far as experimental psychologists are concerned. Although, psychologists are eager to prove the existence of a latent skills that is useful in different contexts, findings have been more negative than positive (Alexander & Murphy, 1999). Taking computer language learning, for example, (for other subjects, see Bennett et al., 2000; Clements, 1985; Dalbey & Linn, 1985; Gick & Holyoak, 1980, 1983; Perkins, 2009), in the study of near transfer within domain, researchers have found students failed to transfer between different computer programing languages even if the underlying architecture of the two languages was largely the same (Perins & Kartin, 1986); in the study of far transfer across domains, researchers have found

learning computer programming does not make one become better at systematic reasoning and problem solving (Clements, 1985). Nevertheless, considerable literature has concluded that transfer does happen (Campione et al., 1995; Medin, Goldstone, & Gentner, 1993; Pedone, Hummel, & Holyoak, 2001; Schwartz, Bransford, & Sears, 2005; Schwartz, Sears, & Chang, 2007)). For example, Bassok and Holyoak (1993) showed that subjects who learned abstract algebra were able to transfer to new contexts, such as physics and finance. More recent studies have shown that students can recognize principles that arise in different domains, such as feedback loops, and can explain phenomena in both physics, chemistry, economy, and society (Chi & VanLehn, 2012; Goldston & Wilensky, 2008; Goldstone & Day, 2012). Ball (2011) showed that students can transfer the diffusion-limited aggregation principle (a process by which particles undergo a random walk to form aggregation with tree-like structures) that they learned from lectures about copper sulfate to the formation of lungs, snowflakes, and even civilization. As shown in the above mutually conflicting findings, there is not conclusive agreement in the extent that transfer may occur (Barnett & Ceci, 2002), and multiple recent reviews articles about the transfer of learning (Lobato, 2006; Larsen-Freeman, 2013; Mestre, 2005) have concluded that transfer is both ubiquitous and rare. If we revisit the example from Figure 2 (the "as above so below" case), we may notice that most of the studies cited were looking for useful and correct transfers, which may be rare indeed; however, people tend to make romantic transfers regardless the transfers' correctness. Possibly, researchers should not reframe their scope within the domain of useful transfers, but broaden the scope to detect potential "useless" or controversial transfers, which demands the researchers to be even more imaginary than ordinary learners.

This inconsistency—namely, that transfer of learning is both rare and ubiquitous, also leads researcher to ask if there are certain types of transfer that are easier to take place

than others, or if knowledge organized in a certain structure is more likely to transfer. Based on multiple studies and reviews, it appears that transfers are likely to happen when domain independent abstractions are delivered (Bransford et al., 1999; Catrambone & Holyoad, 1989; Perkins & Salomon, 1989; Reed, 1993; Singley & Anderseon, 1989). In practice, this suggests a pedagogy to decontextualize the problem-solving process to find a general pattern or theory (Chen & Daehler, 2000; Genter, Loewenstein, & Thompson, 2003; see review in Lobato, 2006; Reeves & Weisberg, 1994). This conclusion makes perfect sense within the framework of structure mapping theory. If the message is summarized and reduced to one salient line independent of the context, it is that fewer contextual features are deemed necessary as part of the structure mapping criteria. Because of the relaxed criteria, more potential target domains are considered plausible by learners and, thereafter, transfers are made easier and even "epidemic" by the relaxed criteria. Recall Harman's justification for his hunch about the free radical (oxidization) theory of aging: "I realized that free radicals could account for all the phenomena that I know of… [including] human body… it was quite obvious… because it was just the nature of chemistry". In this line, one only needs to assume that human body (as well as every other thing that one knows of) abide by chemistry, to successfully make the mapping and carry out the (epidemic) transfer.

Template effect, label effect and prototype effect

The above conclusion—namely, decontextualization and simplification, is particularly viable for transfers based on science theory, because the laws in science are often deemed universal, context independent, and parsimonious. For example, science textbooks have shown that genetic mechanisms can explain the morphology of flies, green beans, bananas, and eye-color, but are not dependent on any of the specific species. One can easily conclude that "everything is about the gene" and transfer it to the domain of human culture.

A classic one sentence summary of a science concept comes from the famous American geneticist Theodosius Dobzhansky's (1974) essay titled, "Nothing in biology makes sense except in the light of evolution," known as "The Dobzhansky Template." Randy Olson (2015) suggested that if every scientist could summarize his/her research using the Dobzhansky Template, that work would get the attention of the granting agency. Let's call it template effect. Luna (2015, p. 391), in his comments on science, said this template maybe "a bit far-reaching" for granting agencies, but "would be appropriate in a setting such as at a dinner party or a community outreach event." Imagine that the Dobzhansky Template is widely used in community outreach events. It is highly probable this will bring about romantic transfer among the lay public. it may quickly attract attention and engagement, but also possibly lead to generalization. The template effect may sound rather extreme, but this form of summarization seems to be trending in the education of science, technology, engineering, and mathematics (STEM). Cooper and his co-authors (2015) recently published a proposal in *Science* to transform STEM learning by reducing the overwhelming amount of content to core ideas and "crosscutting concepts" that are widely applicable to different context and area of studies, such as evolution and conservation of energy. Again, for the same reasons discussed above, core ideas are easy to cut across disciplinary boundaries. Most researchers (including Cooper and colleagues) may be only concerned for interdisciplinary study within STEM subjects when they discuss crosscutting concepts, but we should be reminded of a recent report in *Nature* by Van Noorden (2015) that interdisciplinary academic articles are predominantly published in the field of sociology, art, and humanistic studies, and such are the areas of study from which scholars are most likely to make reference to articles from remote disciplines (such as natural science). Thereafter, to reduce STEM education to its core may have surprising and unintended outcomes for non-science majors.

The template effect is not yet the most extreme case of simplification. The history of science has shown how romantic transfer can originate from a simple label—*the labeling effect*. Expectantly, because of the over-simplification of single labels and extremely relaxed criterial for the mapping plausibility, the labeling effect has led many to misread science in the social domain. One of the examples is *relativism* as a moral and political theory. The popularity of relativism in the twentieth century partially owes to Einstein's theory of relativity (Baghramian & Carter, 2016). Inspired by Einstein's theory, linguist Benjamin Lee Whorf developed the Sapir-Whorf hypothesis, namely, the idea that different languages shape different thoughts, which Whorf referred to as "linguistic relativity" (Heynick, 1983). Gelbert Harman (1996) explicitly built a morality relativism based upon Einstein's relativity saying, "According to Einstein's theory of relativity even an object's mass is relative to a choice of spatio-temporal framework…. I am going to argue that moral right and wrong … are always relative to the choice of moral framework" (p.3). However, the essence of Einstein's theory of relativity does not support relativism's claims, not only because it is a constant law, but also because the theory was intended to explain the counterintuitive fact that the speed of light is constant for different observers. Even more ironically, Einstein originally wanted to name the theory as "the Theory of Invariance," which could have led to a completely opposite social ideology. Another example is Darwinism. Darwin in his original work did not choose the term "evolution," but instead "descent with modification," because he was explicitly trying to avoid implying progressivism ("high," "lower," "improvement"). Nevertheless, his theory became popular as Herbert Spencer chose "evolution" as the catchier and briefer synonym for "descent with modification." The subtle replacement of wording introduced the implication of progress, which engendered Social Darwinism and jeopardized Darwin's careful choice of words (Gould, 1992, p34-38). In both cases—the

theory of relativity and theory of evolution—social scientists carried over a superficial label from natural science to support or inspire social theories that were not even analogical to original scientific theories.

The template effect and label effect together do not fully explain why science is particularly prone to transfer because we seldom only receive a one-sentence or one-label instruction, nor do we only remember a one-sentence or one-label summary. Instead, we learn much associated knowledge to explore the full map of the domain. This calls for another explanation, namely the prototype effect. Prototypes facilitate and expedite human reasoning. A prototype can be a long story that contains a lot of information, different from the one-sentence effect. However, prototypes are also well-packaged information. They have a set of salient features for other incidences to map onto and they also provide an easy solution that similar incidents can follow. The great danger of human civilization is that we have too few prototypes, and new prototypes do not emerge and become popular easily. For a person with a standard public education, there are only a few role models to follow, only a few wars or treaties to teach them about international relationships, only a few social activists to frame civic conflicts, and only a few villains to categorize the spectrum of immorality. One weakness in using social prototypes to make social arguments is that every prototype is constrained by its historical and geographical context. It is easy to experience the accusation of a misplaced generalization because a situation may have changed. For example, in response to the recent populist events happening in many countries in the world, many people have worried that these events presage neo-fascists ideologies (mapping to fascists and national socialists prototypes). However, such worries are quickly refuted (Roodujin, 2016) by reasons such as "fascists and national socialists are no populist, because

they are not democratic. Populists are". In short, social prototypes are often old and they update slowly and are confined by their particularities.

In contrast, science prototypes have the potential to counteract all such shortcomings. Steward Brand (1995) once said,

> Science is the only news. When you scan through a newspaper or magazine, all the human interest stuff is the same old he-said-she-said, the politics and economics the same sorry cyclic drama, the fashions a pathetic illusion of newness, and even the technology is predictable if you know the science. Human nature doesn't change much; science does, and the change accrues, altering the world irreversibly.

What Brand noted was a lack of new prototypes from social affairs, but that new prototypes, mental model shifts, are emerging from the science community. In other words, if there is a field that can deliver new prototypes to suggest alternative perspectives, it is likely to be science. Not only is science updating frequently, it is also considered to be context free, universal, and authoritarian. Thus, science remains a renewing source of transfer.

Who Are the Most Likely to Transfer?

One answer, mentioned earlier, is that students who hold strong a belief in scientism are more likely to transfer, because they assume that everything can be reduced to a set of unified and parsimonious scientific theories. In turn, students who have been shown the feasibility of transfer between subjects will develop an appreciation that any discipline can potentially enlighten another discipline through science (Chi 2005; Chi, Slotta, & deLeeuw, 1994).

Recently, scholars have been calling for the study of learning beliefs and motivation behind transfer (Perkins & Salomon, 2012; Pugh & Bergin, 2006). The most direct evidence comes from Belenky and Nokes-Malach (2012), who showed that students with a mastery-learning orientation towards math learning are more likely to transfer regardless of the

instruction approach, because they are motivated to prepare for future application. Greeno et al. (1993) demonstrated that students who believed themselves to be contributing to the creation of new knowledge and new solutions are more likely to transfer.

A different type of learning motivation, namely, self-development orientation, is less discussed in literature but merits brief mention. Feng Youlan (1900), a Chinese philosopher in early twentieth century, was the first to identify two distinct learning beliefs between Western and Eastern cultures, with Western culture believing that learning is the mastery of the subject and skill, and the Eastern culture emphasizing personal development into a wiser and more holistic being living in synchrony with the laws of nature. Jin Li (2012) applied this distinction to the study of education and suggested that the two learning styles exist in both cultures and that a self-development-oriented learning style tends to lead a learner toward transference, because such a learner actively feeds subject knowledge into a personal worldview. Indeed, psychology experiments have shown that students who set intrinsic learning goals are more likely to engage in metacognitive learning comparing to those who set extrinsic goals (Pintrick, 1999). Interestingly, a recent report concerning interdisciplinary indexing, calculated by the number of academic articles that cite literature from another domain, ranked China at the top rank, followed by India and Taiwan (Van Noorden, 2015), which suggests that the practice of boundary crossing is prevalent in Eastern cultures (at least in academia).

In a summary, when learners hold a belief or exist in a culture that encourages conversion of subject learning into personal wisdom, they tend to consider a valid prior assumption to apply to multiple life occasions. Furthermore, when a science subject is introduced or summarized with single sentences, a learner may tend to assume that the single line is sufficient as a mapping criterion (e.g., The Dobzhansky Template). When science

knowledge is packaged into a prototype that is universally applicable, people tend to question less its potential to be a misplaced generalization.

Philosophical Discussion About Romantic Transfer

In an address to American Association for the Advancement of Science, later published in *Science*, Dewey (1910) expressed the concern that a science education that focused on subject matters of fact was only relevant for the few who would turn into science professionals, but was not adequately training the public. He envisioned a science education that focused on method. By method, he went beyond the laboratory setting and the mathematical analysis; he meant a method as habit of mind. For Dewey, the endeavor of science education is to foster a habit of mind that makes transferences, seeks patterns, takes science as a perspective for life, and generates new personal knowledge. Further, he opined that transference should not fall victim to fallacy because the learner should understand the conditions and evidence that leads to theory. However, Dewey worried that, in reality, "science teaching not only have not protected men and women who have been to school from the revival of all kinds of occultism, but to some extent has paved the way for this revival." An example of romantic transference from Dewey can be seen in the thought, "If radioactivity (sending out invisible waves of particles) is a proven fact, why is telepathy (sending out invisible waves of thoughts) not highly probable." Such romantic transference is common among "literary idealists," who are exposed to the fact in science (e.g., radioactivity) but not to the method and reasoning. A scientific habit of mind should not only transfer a guess, but also examine such guesses with scientific inquiries.

Whitehead (1967) in the *Aims of Education* described the learning growth in each subject in three sequential stages:

1. Romance, early intrigued encounter with a subject that is "half disclosed by glimpses and half concealed by wealth of material" (page 17)
2. Precision, an in-depth and systematic understanding of the concept domain and increasing mastery of skill
3. Generalization, to apprehend the abstraction in the concept domain, transfer it to other domains, and formulate a more general domain independent principle.

What if the three stages do not follow a strict sequence, and a learner starts to generalize in parallel to romance, skipping the mastery and precision within the subject domain? He/she will be inspired by making connection and seeing patterns. However, the inspired wisdom may be an over generalization, because the subject domain is understood in face value, not deep understanding, or in Dewey's term, as a superficial fact but not as a method. Without a deep understanding of the scientific methods, the students will have less information to determine the boundary of a science principle in the source domain, to assess the plausibility of the transfer, and to empirically test their generalized hypothesis in the target domain.

Caveat to Romantic Transfer

Dewey (1910) was concerned that the idea of radioactivity pave the way for misconceptions about telepathy. An example that is a valid analogy based from the source domain of science fact, but not supported by (empirical) science method. A contemporary example, as mentioned earlier, is the case of antioxidant. The scientist community have reached a near consensus through empirical investigation and been out-crying that it is a misconception myth. Nevertheless, it did not slow down the market of antioxidant because this is oxygen erodes flesh, apple, or rubber is a solid and compelling science fact, and

people carry this prototype as to the problem of human aging, and consider the transference as truth.

The conception of telepathy and antioxidants are examples of negative transfer, namely, transfers that overgeneralize prior learning in an inappropriate situation (McNeil, 2008; Ross, 1987). Schwartz, Chase, & Bransford (2012) argued that the occurrence of negative transfer is due to teachers' and students' overzealous temptation to transfer. In Whitehead's (1967) terms, students may romantically generalize without mastery of precision.

However, to be fair to the students, one should not forget that scientists who took telepathy seriously had the luxury of testing it in their labs, while students do not have such time or resources. It has not been known until this decade that, while telepathy remains impossible, there exists between-brain (in mice or in humans) electroencephalogram synchronization (Hasson et al., 2004; Hasson et al., 2012; Jääskeläinen et al., 2008; Kauppi et al., 2010; Nummenmaa et al., 2012) that was originally inspired by the very raw and romantic transfer notion. As another example, while recapitulation theory has been discredited ever since the mid of 19th century, scientists have had the luxury to study the genetic structure and expression that later led to various modified versions of recapitulation theory. From this perspective, it is not wrong for students to transfer romantically, a practice that is common among scientists in hypothesis speculation and formulation. Students, however, are in a disadvantage position in that they cannot easily set off further investigations to test their romantic transfer, partially because they do not have the necessary methods and equipment, partially because they are content with the romanticism (the informality component of romantic transfer).

Traditional conceptual change theories have assumed that students hold misconceptions prior to formal learning, that learning brings about new information that

challenges the misconceptions, and that, eventually, misconceptions resolve into conceptual changes to accommodate new evidence (Biemans et al., 2001; Linnerbrink & Pintrich, 2002; Posner et al., 1982). Recent research in misconception, however, challenged the assumption in conceptual change theory that misconceptions are pre-formed. A series of studies of students' misconceptions of force and motion, conducted by Rowlands, Graham, and Berry (1999, 2005, 2007, 2013), have shown that students generate misconceptions spontaneously as they apply the concept in a new context. This group of researchers demonstrated that students who had solid prior understanding of Newtonian laws in explaining horizontally moving airplanes unanimously gave the wrong answers to the direction of force for vertically moving balls (e.g., claiming the force is upwards when a thrown ball is going up and is zero when thrown ball is at instantaneous rest). Rowlands et al. explained that the students' understanding of contact forces (e.g., engine and brakes on airplanes) is not so obvious with the force at a distance (e.g., gravity); instead students spontaneously constructed a modified notion of force that has accounted for what they perceived as the dominant features of the motion. The new notion of force had become a metaphor rather than a true, analytical understanding of Newtonian force—the ball is moving upwards as if there is a lifting force applied on it. The moral of the story is that, even with subtle changes of contexts within the same domain, if students cannot directly fit their (correct) understanding of a concept from a prior context into a new context, they reconstruct the meaning of the concept to accommodate to the new context, so that they can claim "it is still force, only working slightly differently in vertical movement." Such a reconstruct-as-you-go resolution is even more apparent and viable when the change of contexts is no more subtle but is more significant, such as in romantic transfer from science to social domains. People can simply slot in the scientific lexicon, but reconstruct the meaning of the lexicon fitting it to the social

context. Sometime the reconstruction of meaning is so distorted that the lexicon does not bare any resemblance to the original meanings inherited from the domain of science, as if the new meaning is a misconception from a hard science point of view. In Rowlands et al.' view, this is not a pre-formed misconception, but a new misconception that is generated spontaneously as students transfer to new contexts. One classical example is the previously noted linguistic-relativism as it was inspired by Einstein's theory of relativity. Linguistics borrowed the lexicon, but reconstructed the meaning.

The greatest threat to romantic transfer is literalism, which is also one of the greatest threat to all doctrines, be they scientific or religious. It is a joyful mental exercise to transfer romantically if the transfers are taken as a metaphor, but once taken literally, transferrors are exposed to the dangers of misplaced generalization, such as social-Darwinism. This is particularly true for science and religion, the two doctrines that are considered or expected to be universally applicable and to transect boundaries. Thus, it is not surprising that a lot of revelations in the modern age transect science and religion, for example, the "as above, so below" discussed previously for Figure 2. As Elizabeth Boyle (2005), who was an enthusiastic and poetic communicator between science and religion, nicely put it, "Those scholars who exploit metaphor can sometimes replace biblical literalism with a physical literalism that is no more 'true' than the illusion it is intended to supplant. The more attractive the metaphor, the more acute the danger of literalism" (p. 5).

A question remains as whether those who hold strong beliefs in scientism are in any way like those who hold strong beliefs in religion? On one hand, we see a biologist such as Jerry Coyne (2015) provide a long list of reasons for why science and religion are incompatible; on the other hand, we see Francis Collins (2007), describing why faith in God and faith in science can coexist within humans harmoniously. Scientists, among all

professions, are particularly good at believing in a theory that cannot yet to be proven. Edge.org (2004), a science website, reported, under the title "Scientists take a leap," the survey it conducted sampling 120 secular scientists in year 2004. The survey found the scientists named over a hundred concepts that they firmly believe were true even though they could not produce evidence of that truth. It is amusing and inspiring to read the following comment from Brian Goodwin (1995), in which he suspected Richard Dawkins, one of the strongest atheist advocates, was secretly religious:

> For him [Richard Dawkins], Darwin was a revelation. Dawkins was a zoologist, an ethologist, and then suddenly Darwin got to him, and he thought, My God, this is the truth, and everybody should know this truth! He became something of a preacher.
> …
>
> To give a very brief summary of the way he presents neo-Darwinism in the The selfish Gene and The Extended Phenotype … (1) organisms are constructed by groups of genes, whose goal is to leave more copies of themselves; (2) this gives rise to the metaphor of the hereditary material being basically selfish; (3) this intrinsically selfish quality of the hereditary material is reflected in competitive interactions between organisms, which result in survival of fitter variants generated by the more successful genes; (4) then you get the point that organisms are constantly trying to get better, fitter, and—in a mathematically, geometrical metaphor—always trying to climb peaks in fitness landscapes.
>
> The most interesting point emerged at the end of The Selfish Gene, where Richard said that human beings, along amongst all the species, can escape from their selfish inheritance and become genuinely altruistic, through educational effort. I suddenly realized that this set of four points was a transformation of four very familiar principles of Christian fundamentalism, which go like this: (1) humanity is born in sin; (2) we have a selfish inheritance; (3) humanity is therefore condemned to a life of conflict and perpetual toil; and (4) but there is salvation.
>
> What Richard had done is to make absolutely clear that Darwinism is a kind of transformation of Christian theology… I suspect that Richard was at one stage fairly religious, and that he then underwent a kind of conversion to Darwinism, and he feels fervent that people ought to embrace this as a way of life. (p. 89)

I cannot assess if Goodwin's account truly describes Richard Dawkins' psychological activity, but if we ignore Dawkins' name, or replace his name with anyone else's, Goodwin's account nicely illustrate how a person can (1) take science theories (or religious doctrines) as

metaphors; (2) map these metaphors to other domains for wisdom and revelation; (3) realize the universality of the metaphor and consider it as a literal truth; and (4) preach the personal truth as a new discovery and ignore the fact it is still a romantic transference.

Four decades ago, in his work *Myths, Model and Paradigms*, Ian Barbour (1974) identified model and metaphor as the common ground betwen scientific and religious communities. What Bohr's planet-like-orbit model of atom and a biblical model of personal God both achieve is reconstructing or reaffirming of one's world view. The metaphor is especially reconstructive when the metaphor is fresh, be it in science or in religion, because, "It immediately sparks our imaginations…as viewed through a concrete grid or screen" (McFague, 1988, p. 33). In McFague's words, "A model is a metaphor with staying power…that has gained sufficient stability and scope so as to present a pattern for relatively comprehensive and coherent explanation" (1988, p. 34). The Trinity model in Christian theology, for example, not only explained the concepts of Father, Son, and Holy Spirit in a parental relationship, but also, according to Augustine, consonances the psychological attributes such as memory, understanding, and will in the human mind (Southgate et al, 1999). Both science and religion require a connection (or a balance) between being conclusive and heuristic. To be conclusive, the connection should effectively summarize and explain existing observations and documents and, to be heuristic, it should inspire so that it can accommodate new observations. Model and metaphors enable the connection, and set up the common ground between science and religion. For such reasons, Southgate et al (1999) reiterated, "Science, like theology, needs to be seen as the activity of a community of motivated believers, holding core assumptions and testing out new possibilities" (p. 22).

Yet, this does not necessarily indicate that scientists who use metaphors are secretly religious or are prone to be religious. The scientific and religious communities have subtle

yet important differences in their pragmatic uses of metaphors. Kuhn (1970) pointed out that scientists rarely teach their students the classic text. Old models may be briefly reviewed, but are quickly superseded by advanced or revolutionary models. In religion, however, old models and metaphor are tenacious and serve to stabilize rather than mobilize world view and to assimilate rather than accommodate to new data. Although both science and religion models are being used to test new possibilities, scientists in comparison consider models as temporary and are always ready to replace existing models. Nevertheless, there are occasions that scientists replace temporary models to be "faithful" to other core assumptions. For example, Pauli proposed the existence of the neutrino in 1930 in order to "save" the first law of thermodynamic (conservation of energy) 36 years before the neutrino particle was observed. For another example, Penrose (1979) and other theoretical physicists (e.g., Goode & Wainwright, 1985; Newman, 1993) have proposed various theories to "save" the second law of thermodynamics in extremely conditions, such as in Big Bang or a black hole, that appear to violate this law (see details in Curiel, 2016), and yet their theories have not been empirically proven or tested.

Polkinghorne (1996), a theoretical particle physicist, tried to distinguish scientists use of metaphor from ordinary imaginative metaphor based on a linguistic point of view, namely, that "when scientists use apparently metaphorical language—as in talk of 'black holes' or the 'genetic code'—they are using these terms as picturesque shorthand for ideas they can more readily and more adequately convey in precise scientific language, and they are not using them as imaginative resources for the generation of ideas in a truly metaphorical way" (p. 20). His remark is an important reminder that scientists, although being aesthetic in their choice of "nicknames," are not overly romantic in their understanding of the essence of concepts in their own minds.

However, Polkinghorne's emark does not "do justice to the way metaphors determine what can and cannot be thought" (Southgate et al., 1999, p. 22). In fact, his remark revealed the seldom examined playground that cultivates the romantic transfer among lay people. Scientists created the beautiful and mysterious labels that are not imaginative and not even metaphorical for themselves, but are imaginative and metaphorical for the lay person. Lay persons heuristically process metaphors and produce romantic transfers. If we assume that science and religion are the two ends of a spectrum for the management of metaphors, then romantic transfer floats somewhere in between. Although originating with science theories, such constructions cannot be conveyed by lay persons in precise science languages and equations. For lay persons, a line of scientific text starts as a metaphor for science and ends as a metaphor for life wisdom. What determines the position of a romantic transfer in the spectrum (between scientific hypothesis and faithful doctrines) is whether lay persons take this romantic transfer literally or metaphorically. If they consider the romantic transfer as only a temporary worldview, one of the many lenses in their lens boxes, and are ready to swiftly switch the lens, then such lay persons are closer to the scientist camp. Although these lay persons have already romanticized the science concept and do not constrain their imaginations as do scientist experts, they at least treat this romantic worldview as a temporary hypothesis, not believing it as the ultimate truth but ready to modify or even discard it if it contradicts data in real life. Alternatively, if lay persons consider the romantic transfer as a fundamental theory proven by science and hold it in awe as a universal law, these lay persons are closer to the religious camp. For them, this romantic transfer is one of very few fundamental laws of nature and life that has endured the test of science and time and cannot be easily disapproved or replaced (just like scientists so faithfully believe in the first and second law of thermodynamics). As of today, we can

assume that most scientists do not conveniently take science theories at metaphors of other domains, if we believe Polkinghorne's remark to be valid. We also know that a few scientists, perhaps a minority, such as Bohr and Harmann, take science theories as metaphors of other domains very seriously and passionately. What we do not know is how seriously lay persons treat their own transfers.

One implicit assumption behind the thesis of romantic transfer is that lay people can discover new ways to understand the human society through science theories. However, this assumption may not hold, and, in fact, two directions between science theories and personal beliefs are possible: (1) people can generate alternative perspectives depending on the science framings (science theories → inspire new personal beliefs), but (2) they can also use science to support their preexisting beliefs, use science to push for their preexisting social agenda, or succumb to preexisting biases in their interpretation of science (preexisting personal beliefs → seek science theory). Here we should be reminded of the informal nature of romantic transfer, that there is no such thing as the "correct transfer"; all transfers are subjective speculations and, therefore, many preexisting factors affect the speculative process and outcome. For example, astrophysicist and public science advocate Neil deGrasse Tyson (2013) once said in a Big Think documentary film,

> So those who see the cosmic perspective as a depressing outlook, they really need to reassess how they think about the world. Because when I look up in the universe, I know I'm small, but I'm also big. I'm big because I'm connected to the universe and the universe is connected to me.

It is apparent that Tyson maintains a different interpretation of the cosmic "messages" from those who have more melancholic or darker worldviews, but his interpretation is biased (in a healthy way) by his prior experience, aesthetic taste, and motivation (e. g., to encourage more people to have an interest in astrophysics and not to

scare them away). Nevertheless, urging others to "reassess" their worldview of the cosmos may not effectively bring them to the "correct" answer, since there is no correct answer, but only a romantic transfer that is perceived as compelling by an expert in astrophysics.

Taking another example that is more politically charged (thus, more controversial), in response to the increasing anti-immigrant movement in the U.S. and Europe, a popular meme named *Schrödinger's Immigrant* has been circulating online. This meme borrowed the famous thought experiment from quantum physics (*Schrödinger's Cat*) that a cat can be both dead and alive in a quantum scenario, and claimed that the problematic immigrants purported by right-wing propaganda to be too lazy to work were simultaneously stealing others' jobs. This analogy was intended as a mockery to the preposterous claims of xenophobia and to inspire the left wing and neutral bystanders. Thus, for the meme creator, the purpose was to prove the point using a science concept. From the perspectives of sympathetic left wing and neutral bystanders, this meme inspired them a new way of responding to xenophobia. Meanwhile, many in the right wing directly refuted the plausibility of the analogy. However, more interestingly, as the meme gained its popularity, the right-wing activists gradually claimed the ownership of the meme and used "Schrödinger's Immigrant" to justify their own anti-immigrant beliefs: that if something as dubious as Schrödinger's cat is possible in quantum physics, it is certainly possible to have Schrödinger's immigrant in the society; and that it is the flawed social welfare system that is enabling such a dubious immigration paradox. Furthermore, the right-wing activists applied the analogy back to the left wing by saying, "They [pro-immigration folks] at once praise the great contribution our self-sufficient migrants make to this country while simultaneously implying they need to have enshrined in law extra help with things like benefits, employment, and diversity quotas to compete with the native population" (Dillion, 2015). Thereby,

"Schrödinger's Cat," a quantum physics theory, is both pro-immigrant and anti-immigrant simultaneously, depending the agenda of the user. The science theory in this case does not change the mind of strong ideological holders, but rather becomes the rhetorical support for their existing ideologies.

Such a bidirectionality—namely, that science may inspire new ideas, and in the meantime, old ideas may find new scientific "proof", pose a tautological challenge to anyone who intends to disentangle the relationships. To test either direction of the effect, (or one direction as in this dissertation), we need to assert experimental control in the study design. Specifically, for two randomly split groups learning different science concepts, if the two groups reach different answers for the same social or ideological question, this will constitute strong evidence for the first direction—that science can inspire new social ideas.

For such reasons, I included four studies to investigate this question. Study-1 is a correlational study that explores (a) who are most likely to transfer and (b) the relationship between transferential thinking style, scientism beliefs, and literalism. Study-2 and Study-3 are randomized experimental studies that examine whether students learning different science concepts can spontaneously transfer to different social ideological implications. Study-4 is an interview follow up to Study-3 to derive a deeper understanding of students' mental models based upon their own words. The general study design, rationale, and measurement are explained in Chapter II. Each of the studies occupy Chapter III, IV, V, and VI. The final chapter (Chapter VII) offers a general discussion of the findings.

Both Dewey and Whitehead encouraged the idea that learners actively transfer science knowledge to life wisdom, and most science teachers would have agreed. Yet, both Dewey and Whitehead assigned prerequisites, such as a precise mastery or method training, as an a priori to transference to evaluate the outcome of transference and to avoid falling

into a naïve misconception. Most science teachers would have agreed as well. However, in practice, a science teacher would, on the one hand, encourage students to relate science to life and, on the other hand, would ask them to postpone transference until they fully understood the subject matter and method. A physics or biology teacher would acknowledge that a science topic is inspiring but at the same time would avoid teaching beyond the boundary of science for fear that (a) the student is still a beginner, (b) does not have enough knowledge or expertise to comment on other domains, and (3) of being held personally responsible for teaching controversial ideas. This creates an imagination vacuum for students, leaving their romantic transference unsupervised.

I would argue that a prerequisite in science education in addition to method training and mastery of precision is explicit debate, discussion, reflection, and comparison regarding intuitive transference in the early romantic stage of learning. "Can you think of anything else that follows evolution theory? Let's talk about that." Before we take this step forward (the "let's talk about that" part), I would carefully examine the assumption that is fundamental to this argument, namely, that students will actively and spontaneously make romantic transference (the "can you think of anything else" part) and determine whether, as Dewey had worried, science has unavoidably paved the way for revelation? Only by evaluating the extent and prevalence of spontaneous romantic transfer can we start to debate the next step.

A Review and a Preview

The romantic transfer that motivates my studies in this dissertation is puzzling for four reasons. First, one recurring discussion in my previous passages focuses on the informality of romantic transfer, which omits a grey area between a scientific justification and an imaginary folklore. Many people, including most scientists, use metaphorical language as a shorthand for a complicated idea; many others, such as lay persons, romanticize science

for their own joy aware of its boundaries; some others, including both scientists and lay person, may take the transfer more seriously as a personal doctrine that is justified or implied by science. If, as Aristotle had suggested, mastery of metaphor is a sign of genius, then the follow up question is whether people who make romantic transfers are masters of metaphors? Or, on the contrary, are they literalist? Could it be possible that people romantically transfer because they believe hard science to be the source of truth and reduce social topics to science theorems like a fundamentalist believer rather than as a metaphorical consumer? Both scenarios are reasonable. For example, Mr. Tsu might consider the physics question about electromagnetic effect only to be a humorous metaphor for teenager romantic relationship, whereas Dr. Harman took the chemistry model of oxidization seriously as the fundamental reason behind human aging. A slightly different version of this question is whether people make a far-leaping (and most the romantic transfers leap far) transfer when they are, in general, sensitive or not sensitive to metaphors?

Anecdotally, Martin Luther and Huldrych Zwingli were both religious reformists of the sixteenth century. They agreed on far more theological matters than they disagreed on; however, they never managed to reconcile their disagreement over allowing a closer coordination in their reformation movement. In one primary disagreements, Luther believed the bread and wine in the Eucharist were literally Jesus' flesh and blood, while Zwingli believed that they only signified flesh and blood. This disagreement in metaphorical or literal interpretation of biblical text resulted in the failure of the Marburg Colloquy to bring the two Protestant leaders to unity. As a thought experiment (or say Gedanken experiment, a term used by Einstein), 1) assuming Zwinglian and Lutheran are similar in all other personal traits except for metaphor and literal tendency in text interpretation measured by the "wine-blood task" and 2) imagining both lived in a modern secular society that looks to science for

knowledge, is one group more likely to make transfers (higher transfer tendency) than the other? (Historians may not agree with the assumption that the Lutheran are more literal than the Zwinglian, especially considering that Zwingli insisted that the Christ's body is only at the right hand of God and Luther accused Zwingli as a literalist on this doctrine. To simplify the argument, I assume the assumption holds.) Moreover, is one group more likely than the other to look to hard science as the ultimate explanation for everything (i.e., scientism)?

Study-1 is an attempt to investigate this question partially. I substituted the "wine-blood task" with a task with which that participants in my sample were more familiar. The task was to interpret a short excerpt from the Taoism "Bible," Tao Te Ching. The excerpt read, "The ultimate goodness is like water." This expression has been widely adopted in Chinese fortune telling and is the foundation of Feng Shui (in which Feng means wind and Shui means water), which insists that water and water-based objects can bring good luck and good merit. This expression, in comparison to the "wine-blood task", is less ambiguous in that the sentence explicitly contains the word "like" and should be considered a simile, but in Feng Shui practice, the importance of water is considered more literally. Study-1 intended to distinguish the strong literal and strong metaphorical interpretation in the "goodness-water task" and to compare participants' scores on a scientism scale and a tranferential thinking scale. The scales did not measure if participants actively practiced scientism or transfer, but asked their agreeability to these statements. In short, this is a simple correlational study to examine if people who make metaphorical or literal interpretations of this one line of Taoism text differ by their agreeability to scientism and transferential thinking styles.

The result, in brief, showed that strong literal interpreters scored higher than strong metaphorical interpreters on both the scale of scientism and transferential thinking style. Several more complicated patterns—taking in account the inward motivation of learning,

mindfulness of one's own mental activities, basic physics test scores, age and gender— are shown in a path analysis. (See details in Chapter III.)

The second puzzle concerns the causality of the transfer: Is it the case that learning a scientific theory can inspire a person to generate social ideologies, or if it is confounded by other unobserved factors. Recalling the Schrödinger's "immigrant" example, it is evidently correct that people can willfully use science as a post hoc support for their existing social beliefs. The major threat to the causal claims is the self-selection bias, such that some people actively seek and borrow science concepts to justify their existing ideologies to push for their own agenda while people who do not have a passionate social ideology or agenda do not seek for scientific or any other form of justification. In an observational study, it is likely that one can only observe the first group (active seeker for science justification) in the population. Such a selection bias leads to the failure of disentangling the direction of causal effect. To answer the direction of the effect requires a randomized control trial (RCT) experiment, in which participants are randomly assigned to two groups learning different science concepts. After the intervention, participants need to answer questions that assess their social ideologies. The treatment effect depends on whether the two groups differ in their social ideologies in their posttest, and whether their differences are consistent with the expected implication based on the science interventions that they receive. If one assumes (and confirms with evidence) that the randomization has successfully balanced the characteristic between the two groups in average, we should be strongly confident (compared to a non-RCT, purely observational, or correlational design) that the science concept somehow "changes" the social ideology of the participants. I intentionally choose the term "change" to indicate that the RCT studies investigate the causal effect by design. (It is always possible to argue that the randomization may have failed to balance the unobserved variables, or that

the sample may not be representative for a larger population, and, therefore, that people should always be cautious about the internal and external validity of the causal effect, but I want to make it explicit that the RCT design of the study is to investigate purposefully the potential causal effect even if we should be cautious with the conclusion and interpretation.) Nevertheless, the term "change" is carefully chosen for another reason, namely, that "change" does not exclusively mean generating an idea from scratch;, the meaning also includes the possibility that a treatment only reinforces certain social ideologies in participants' minds. It is possible that both groups share the same ideology, but one intervention reinforced this ideology more than the other intervention. In fact, my studies cannot tell the difference between reinforcement (reinforcement effect) and generating a brand new social theory (generation effect). Adding questions about existing social ideologies in the pre-test can potentially differentiate the two scenarios, but it would prime the participants to think about social ideologies before receiving the science instructions and also would provide a hint to the participants that the science lecture is related to social ideologies, which would jeopardize my argument that the transfers, if observed, are spontaneous and not imposed by the researchers. Therefore, my experiments set a less ambitious goal that does not differentiate between reinforcement effect and generation effect.

To avoid giving any further hints to the participants to the effect that the science instructions are associated with the social ideological test items in the post-test, I separated the occasions for intervention and the posttest in a way that participants could be told that the two parts were completely separate events existing for totally different purposes. The details of the experiment design are located in Chapter II.

In brief, in my first experiment, I randomly assigned participants to two groups: One group (treatment group) received a lecture about the conservation of energy (first law of

thermodynamics) and the other group (control group) received a lecture about Nash equilibrium. Three days later, both groups answered a questionnaire that contained a list of items that suggested the conservation of luck, a raw and naïve idea that is related to morality, karma, and religion. The results were that the conservation of energy group was more receptive to the conservation of luck, as details show in Chapter IV.

Based on the result from the first experiment that showed that students are able to transfer from physics concepts to the moral and religion domains, it would be interesting to investigate the third puzzle, namely, whether students are able to transfer science concepts to a domain that is more politically charged. In addition, it would be interesting to answer, thereby, the fourth puzzle, namely, whether participants talk differently about social political issues after being exposed to a new scientific concept. Such a question demands another RCT study that allows for potential connection between physics theories and political ideologies, and it also demands a follow-up interview to observe the participants' own narratives.

In response to such necessities, I carried out another experiment (Eperiment-2) that randomly assigned participants to two groups. One group learned about entropy (second law of thermodynamics), denoting a thermodynamic system is destined to become messier and increasingly disorganized unless there is input of external higher ordered energy. The other group learned another thermodynamic theory known as self-organization theory, which denotes an open system shaping its own patterns, such as snowflakes, independent of external design. Such systems can form a highly organized and intricate pattern that external design cannot achieve. In the post-test, participants answered questions that probed their preference in social control: Should a society have more bureaucratic control from external agencies (consistent with theory of entropy), or should one expects a social system to shape

its own order and discipline without external control. The result largely confirmed the hypothesis that participants are more agreeable to the social control ideologies that are consistent to the implications of the science concepts that they receive. Moreover, in the follow up interview, participant spoke of social control in narratives in ways that were aligned with features of the physics theories that they studied, such as the expected change over time and the origin of order. Interestingly, however, none of the interviewees directly used the nomenclature of science, such as entropy, thermodynamics, or self-organization; nor did they quote the entropy or self-organization theories to justify their social reasoning. Instead they used their own words to make the justification, but their justifications were analogically consistent with the physics theories they had received and they shared strong similarities within their group, but differed significantly across groups. See detailed results from Chapter V and VI.

The implications of the above results are discussed at the end of their respective chapters and in the general discussions of Chapter VII. To briefly preview, I argued that there is strong evidence that students are able to transfer spontaneously from the science domain to social, moral, and political domains. I do not advocate for a pedagogy that encourages the practice of romantic transfer, yet I have shown that the mere avoidance of talking about it would not prevent students from making the transfer romantically. Thus, explicit discussion is necessary. However, enthusiasm and concerns coexist in retrospect to the opportunities and challenges implicit in romantic transfer. Does science education offer opportunities to bring about the discussion of alternative social ideologies, or does science education pave the way for social programming and misconceptions? I discuss such implications in Chapter VII. I argue that these two seemingly contradictory positions (romantic transfer is inspiring versus romantic transfer is erroneous and dangerous) are not

necessarily contradictory. They are both placed in the loop of scientific discovery. A lot of argument focused on who possesses or determines the correct understanding and interpretation of knowledge from science, but neglect the fact that the outcome of romantic transfer is a new hypothesis in social science, and such argument should undergo the same steps of scientific discovery. The real opportunity that romantic transfer provides is to allow for student-generated social hypotheses and, therefore, to invite the introduction of social science methods that are as rigorous as the hard science methods.

In the chapters that follow, Chapter II is a methods chapter. It consists of two parts. Part one reiterates the research question, the challenges, and the rationale for the research design by which I address these challenges. Part two describes the methodological procedures, including the sample, allocation and details of the interventions. It also describes the measurements, including the exact wording and psychometric properties of each survey. Chapter II can be considered as the compilation of the method sections from each of the four studies. Readers can use Chapter II as a reference chapter to which to return for technical details as they peruse the study. The gist of the Chapter II has already been summarized in the above paragraphs in the Review and Preview section.

Chapters III through Chapter VI present Studies 1 through 4. Each chapter briefly reviews the research question, design, and measurements and is largely self-contained. Each chapter reports the data analytic strategies in detail and naturally transitions to the result report. Each chapter reports the results in detail and discusses them in a concise manner. The discussions within each of the chapters focus on the interpretation of the findings and speculate upon theoretical explanations, but they do not comment on the implications for educational practice (but see Chapter VII for such discussion).

Chapter VII summaries the key findings and generally discusses the educational importance of the thesis and its implications for practice. It also reflects upon the limitations of my dissertation project and anticipates future studies to examine theoretically speculations that I have postulated based on my findings.

CHAPTER II:

RESEARCH DESIGN, RATIONALE, MEASUREMENT

We are all connected; to each other, biologically; to the earth, chemically; to the rest of the universe, atomically.

–Neil deGrasse Tyson (2009)

In this two-part chapter, part 1 explains the motivating questions, challenges and general study design by which I propose to meet these challenges. Part 2 describes the specific design, procedure, interventions and measurements in detail. In specific studies presented in Chapter III, IV, V and VI, I rebrief that applicable methodological and measurement issue.

Part 1

Driving aims

As stated by the end of Chapter I, this dissertation is motivated by four puzzles which translate to the following driving aims:

(1) What are the characteristics of students that have the tendency to transfer science concepts to social domains, specifically, whether those who romantically transfer tend to take texts literally or metaphorically?

(2) Does an intervention that teach students about science concepts lead to greater spontaneous transfer from science knowledge to social ideologies?

(3) Similar to aim (2), does an intervention that teach students about science concepts lead to greater spontaneous transfer from science knowledge to political charged social ideologies?

(4) Specifically to (2) and (3), do students learn different science knowledge spontaneously transfer to different positions on social ideologies? Do different science knowledge intervention have different effects on spontaneous transfer?

(5) Whether and in which narrative students adopt the science concepts to justify their reasoning in the social domain in such a cultural context? What kind of narratives derived from the science concepts adopted do students use to justify their reasoning in the social domain.

Challenges and Rationale

Question 1

The first question concerns itself with the relationship between multiple variables, namely, whether people who are more or less sensitive to metaphor the same people who hold scientism beliefs and simultaneously are more agreeable to transferential thinking. It is very difficult to manipulate any of the variables, such as scientism beliefs, transferential thinking and sensitivity to metaphor, in randomize control experimental setting. Therefore, I only intend to explore the relationships in a correlational study using questionnaires to measure attitudes. The affinity for transferential thinking and scientism beliefs was relatively easy to measure. It only required test items that were reliable and that probed multiple aspects of the respective constructs. This could be done by piloting the test items and establishing the reliability of the measurement using Item Response Theory (IRT) models (see Measurement section in Part 2).

A major challenge in this question was to measure participants' sensitivity to metaphors, and this measurement had to allow for both metaphorical and literal responses (just like the Blood-Wine task) to categorize participants into two groups. There did not exist an appropriate measurement to the best of my knowledge. To create a task that was like the Blood-Wine task but that was appropriate and relevant to my target sample (Chinese freshmen year college students in China), I created a Goodness-Water task. The task, as

introduced in Chapter I, invoked a classic Taoism scripture that reads, "The ultimate goodness is like water," which is also the foundation of Chinese fortune telling—FengShui—whereas Feng means "the wind" and Shui means "the water." The task related this Taoism scripture to people's FengShui practice that requires water or water-based objects (e.g., fish tank, plants) in living spaces to have good fortune and good morality. Participants need to respond if they believe this scripture should be interpreted in the strict literal sense that insist of real water or should rather be interpreted as a simile, a metaphor, and a symbol signifying some deeper principles of goodness. Because the scripture contains the word "like," it identifies explicitly as a simile and presents a strong signal that this line should be read metaphorically. Therefore, the literal interpretation of this text can be considered a proxy for low sensitivity to metaphorical cues in text.

This task is a novel attempt to approximate participants' sensitivity to metaphor, but it is not without limitation. One concern is that this task may only reflect participants' baseline affinity to Feng Shui, which would eventually threaten the internal validity of the task. I did not consider it to be possible to completely avoid such a shortcoming in such a simple task, but I tried to respond to this concern by making the wording of the task focus on the interpretation of the text rather than on attitude toward FengShui practice and by avoiding the metaphorical interpretation for arguing against FengShui, but rather only suggesting a symbolical understanding for the deeper meaning of water in the FengShui framework.

The literature review in Chapter I also mentions the possibility that inward learning motivation and meta-cognitive skills may influence the inclination to transfer. Therefore, I also needed to include measurements of learning motivation and mindfulness (i.e., a

measurement of one's awareness and a monitoring of his/her mental stat) in a broader analytic model. It is also possible that participants' attitudes vary by their other background information. For example, participants' scientism beliefs may be explained by their understanding of STEM subjects; therefore, I also needed to control for their physics test scores and other academic test scores in addition to their age, gender and major. For such objectives, I designed Study-1, overviewed below.

Study-1

Participants answered to an extensive survey. The survey consisted of three parts: basic information, a mini-case study, and a list of scales about beliefs in multiple topics. The basic information included gender, age, major subject, and mindfulness (using mindfulness scale). The mini-case study discussed a fable excerpted from an ancient Chinese Taoism text, the *Tao Te Ching*, commonly considered the "Bible" of Taoism, that was written by Laozi, a saint of Chinese history, around 580-500 BC. The fable contains a simple line reading, "The ultimate goodness is like water." In the case study, different people had different interpretation of this old text. Some took it literally, believing water itself is goodness and insisting on have water-based object at home to bring good fortune and good morality; some took it as a metaphor, believing water has some characteristics that can teach us about goodness. After reading the case, participants needed to answer to what extent that they agreed with each of the two interpretations (see Measurement in this chapter for the full case and the questions). This case study's intent was to identify the participants who took a fundamentalist approach to interpreting old (biblical) text and those who took a metaphorical approach

The list of belief scales includes scientism, transferential thinking style, and inward learning motivation. Scientism indicated the extent to which the participants believed natural

science, and only natural science, would give the ultimate explanation to all things, and that natural science should be the new faith for people in modern society. Transferential thinking style indicated the extent to which participants considered that incidents in different domains share common roots, that almost everything was related, and that learning in one domain could inspire the understanding of other domains. Inward learning motivation indicated the extent that participants believed that to learn was to make oneself a better, stronger, more moral, and holistic being, rather than simply acquiring a skill (see the Measurement section in this chapter for wordings of items).

Question 2 and 3

The second and third questions were concerned with the causal effect of learning science concepts on students' social, moral, and political ideologies. The hypothesis was that learning a science theory will lead a student to generate or reinforce a social ideology that is consistent to the analogical implications of the science theory. This hypothesis also assumed that the romantic transfer process occurred spontaneously without explicit hints.

The first challenge posed by this motivating question was that a correlational or observational study cannot fully examine the direction of the causal effect, because there would be unobserved confounding factors and self-selection bias. To make a stronger argument for the causal link, I needed to randomly assign participants to different science concepts.

The second major challenge was to choose the science concepts to be delivered to each group. The science concepts required the following properties: First, the science concepts for each group had to be equivalent in level of difficulty. Second, if a science concept was considered to be a metaphor for a social ideology, it should have had a clear and unambiguous implication based on analogy; science concepts should not have multiple

ambivalent interpretations for the same social topic. Third, the different science concepts assigned to different groups should have *different* implications on the same social topic.

For such reasons, I chose the conservation of energy for the treatment group and Nash equilibrium for the control group in the first experiment. Both concepts touched upon the concept of balance, with conservation of energy emphasizing the zero-sum balance and with Nash equilibrium emphasizing balance at maximization. The hypothesized romantic transfer is that participants from the conservation of energy group were more likely to believe that many other things in life, in particular, luck, is zero-sum conserved, and whether people need to save and convert luck as if saving and converting energy potentials.

In the second experiment, to investigate more politically charged ideologies, I chose entropy and self-organization theory. Entropy is a thermodynamic theory that denotes an enclosed system unavoidably becoming chaotic unless orderliness is restored using external energy (e. g., diffusion of gas). Self-organization theory is another thermodynamic theory that denotes an open environment developing into systematic patterns without external intervention (e. g., snowflakes). Both concepts come from the family of thermodynamic theories, but on their face, they make different predictions for the order of a thermodynamic system. Inherently, the theories are not mutually exclusive, as I explain in the Chapter I, but students from each group were only introduced to the theory to which they were assigned. The target romantic transfer involves whether the participants from the different groups have different expectations of social order and different preference in social control. I hypothesized that the entropy groups would prefer a tightened social control whereas the self-organization group would prefer a relaxed social control.

The third challenge was to prevent the students from being primed by the teacher or administrator to relate between social ideas and the science concepts. Specifically, students

should *not* have been primed to relate to social ideas during science learning and students should *not* have been primed to relate to science concepts when they were responding to questions in the social realm. I tried to separate the timing for the lecture intervention and the questionnaire measurement, and described the two steps to participants as unrelated events. The lectures were designated as part of the annual schoolwide science festival, the questionnaire was designated as being for social studies and surveys as being for the student organizations.

The fourth challenge was that social and political ideologies were largely sensitive and private, which could prohibit participants from giving honest answers. Ideologies were also dominated by the current social political system. If everyone gave the politically or ideologically correct answer, there would be a ceiling or floor effect that could not be disassociated by any comparison. This challenge demanded that the social questions used in this study would not have a clear right or wrong answer and that they would not be ideologically sensitive in a way that would inhibit candid responses. In practice, I avoided directly asking students to report their own political stances, instead creating case studies to ask if the participants agreed to "others" actions.

For such reasons, I designed Study-2 and Study-3, overviewed below, to address questions 2 and 3.

Study-2.

In Experiment 1, students were *randomly* assigned to two groups. The experiment group reviewed conservation of energy, a high school physics concept; the control group received a lecture about Nash equilibrium. Two days after the lectures, students answered a set of questions as to whether luck is zero-sum conserved (i.e., what goes around comes around), a

naïve religious idea that was like karma and was common in Chinese culture (see Measurement section for the detailed wording of items).

Study-3.

In Experiment 2, students were *randomly* assigned to two groups. One group learned entropy, a thermodynamic theory that denotes an enclosed system unavoidably becoming chaotic unless orderliness is restored using external energy (e. g., diffusion of gas). The other group learned self-organization theory, a thermodynamic theory that denotes an open environment develop into systematic patterns without external intervention (e. g., snowflakes). Neither concepts had been introduced to students in high school or freshmen year and, thus, were considered new knowledge. After the lecture, on two separate occasions, students were asked about (a) their opinion in four case studies (posttest 1) and (b) the amount of donation they were willing to make to a student-self-governed club (volunteer social work club) that was preparing to launch in their school (posttest 2).

In posttest 1, the four case studies were (a) whether Massive Open Online Courses (MOOC) should assign head teachers to help students organize the knowledge structure, (b) whether the government should intervene in the Uber market, (C) which of two parties deserves support where one promotes strong citizens and small government and the other promotes strong government over citizens, and (d) should government intervene in the online small business environment (e. g., ebay sellers).

Case A. MOOC was a new and trendy concept in China and many universities were experimenting with MOOC classrooms. MOOC provided a platform and resource for students to freely explore; however, it was also the weakness of MOOC that the looser control led to a higher dropout rate, which raised the question as to whether MOOC should assign head teachers. The case study suggested that the head teacher could help students

organize the knowledge structure, and help students keep a steady learning pace. The participants needed to respond if they agreed that it was necessary to have head teachers in MOOC.

Case-B. Uber had entered the taxi market in several big cities in China as of 2015 when my studies were carried out. This new business entry raised heated debate on news media about its safety, legitimacy, and regulation. Uber, however, had not yet entered the city of my experiment site. Therefore, Uber was a new conceptual problem, yet a practical and relevant one, for participants in my experiment. Because the participants had not experienced Uber, they could only reason about the case as a hypothetical question, and could not have been not overly biased by their user experience. (It was reasonable to assume most people who had used Uber would be biased in support of Uber because of its cheaper but superior service compared to traditional taxi service.) However, participants were unavoidably biased one way or another because of their previous experience in other random incidents; these experiences could only be balanced via randomized assignment.

Case C. The political party was a hypothetical case, and happened in a hypothetical country. Because such questions were politically sensitive in China, placing the case in a hypothetical country would encourage honest answers. In the prior five years, there had been a great deal of social debate in China between "nation step in, citizen step out" and "citizen step in, nation step out" in terms of who should have more political power. Therefore, a case as such, although hypothetical, was still relevant to the Chinese context. The two parties in this case each represented one of the two ideologies: stronger citizen power over the government, or stronger government power over the citizens.

Case D. The online small business (also known as micro-business) was a hotly discussed topic in China. Taobao, equivalent to a Chinese Ebay and Amazon, was the most valuable

brand in China. However, it was of concern that online sellers on Taobao sell fake or imitation product to deceive customers (not unlike similar concerns for Amazon and eBay in the U.S.) This raised the question, which had been discussed in media, as to whether the government should intervene in the online market.

Case A concerned the organization of knowledge and learning plan. Case B and Case D concerned government intervention in free markets, which for Case B was unfamiliar and for Case D was to the participants. Case C concerned the power relationship between citizens and the government. All four cases were related to order and control, but specified in different domains that to which participants might potentially transfer romantically (see the Measurement section for the complete cases and questions).

The volunteer club was indeed on the calendar for the school of my sample. The school administration was planning to have students manage the club to the greatest extent possible, with minimum interference from school administration. In preparation for the club, the school administration sent out questionnaires to a large sample of students to ask them about the type of social work for which they were interested in volunteering. I had the permission (a) to insert and have access to one question (posttest 2) that asks students how much they were willing to donate as a membership fee to this student-self-governed club, (b) to ensure that participants from Study-3 did, in fact, receive this questionnaire two days after the treatment, and (c) to have access to the student IDs to map their answers from posttest 2 to posttest 1 and the pretest. In such a design, I was able survey students outside of the "umbrella" of the experimental context to minimize priming.

The science topics were common, useful, and not politically charged. The social questions were not ideologically sensitive, were in completely different subject domains from the science concepts, and did not have an absolute answer. Students were told (by the school

administrators who helped organized the event) that the science lectures were intended for evaluating new curriculum designs and that the follow up questionnaires or interviews were only for social survey.

Question 4

The fourth motivating question consisted of observing how the participants' own narratives justified their social beliefs. I was primarily interested in observing Whether participants used the vocabularies from the intervention, and if participants adopted narratives that were consistent with the implications of the science concepts that they had studied. I designed an interview that asked participants to explain their preferences in two case studies: the Uber and student club. In order to avoid participants being primed by wording in the survey, participants included in the interview study were not included in the posttest surveys. The following section provides an overview of Study-4.

Study-4.

Study-4 was a semi-structured interview study, recruited 12 Participants who received interventions from Study-3 (entropy versus self-organization). The interview asked participants to justify their preference to the regulation of Uber and governance of volunteer club, similar to the questions asked in the posttest surveys in Study-3. In case the participants notice the interview was related to the lecture they had received, the 12 participants in the interview study were not given the posttests in Study-3. The interview was carried out 3 days after the intervention. In the semi-structured interview, I read the cases aloud, such as regulation of Uber or the governance of a volunteer club, to the interviewee. Afterwards, I guided the conversation with a sequence of overarching questions. The actual questions were asked in Chinese in a colloquial manner. In their essence, the questions focused on (a) students' preference, (b) their justification for both sides, (c) their reasons

concerning the key source of order and disorder, (d) their prediction of what would happen if there was, or there was not, external intervention. As the conversation unfolded, I asked follow up questions to encourage the participants explain their opinions in further depth (see the Measurement section for the complete wording of overarching questions).

Rationale for Target Population

The last major challenge in this study was to decide the target population. The study would be of greater practical interest if it was carried out with participants who came from a culture that discouraged explicit discussion about alternative ideologies. This would help us understand whether science can be a tool for introducing and exploring alternative ideologies and whether students can make the transfer spontaneously without instruction and supervision from their teachers. It was also necessary to carry out the study in a location where Uber has not yet introduced itself, as I expected people who are familiar with Uber will predominantly welcome Uber over traditional taxis. I decided to target Chinese freshmen-year college students as my sample because in China today, it is nearly impossible to promote alternative perspectives directly regarding civic and political issues (such as government intervention in social affairs). Using science education as a vehicle to pave the way for civic discourse may be a goal worth pursuing for educators who want to introduce alternative civic perspectives. I decided to choose Kunming, a small city located in southwestern China as my target location because Uber was preparing to enter the taxi market in Kunming (as it has in many other cities in China). Another reason to choose this particular site and population was because the college at the site was preparing to build a new student club for volunteer work. This scenario presented a perfect opportunity for the donation-to-club case study mentioned previously.

Other elements also led to the choice of sample and venue. First, the site was convenient for the recruitment of a large sample of students. Second, I believed that a self-development learning belief is more likely to be found in Chinese culture than elsewhere. Third, a Chinese education, in comparison to its strong emphasis on science and engineering, allocates relatively minor priority to the humanities, and ideological guidance is restricted in its civic education. Fourth, every student went through the same entrance examination, thus providing comparable baseline scores in science and humanities. Fifth, all students had learned conservation of energy in high school, and almost none of them had studied thermodynamic theories (such as entropy or self-organization theory), at least not in high school or freshmen classes. Sixth, college students were easier to randomize fully in comparison with high school students, who were mobilized and clustered by classes.

To summarize, taking into consideration the above concerns, I decided to conduct one correlational study (Study-1), two experiments (Study-2 and Study-3), and one follow up interview (Study-4) for a group of college freshmen in China. Part 2 of this chapter will provide the technical details of method, procedure, and measurement.

Part 2:

Method

Participants

Participants were recruited from two universities from Yunnan, China, respectively Yunnan Vocational College of Mechanical Engineering (School A) for Study-1, and Yunnan Agricultural University (School B) for Study-2, 3 and 4. Each school had more than 4,000 freshmen, and the sample size was roughly 250 from School A and 350 from School B.

In School A, participants came from weekly ideology education lectures, which typically cover a wide range of topics, including mental health, ideology education, discussion about current national and international political news, or any other lectures given by short-term visiting scholars. The school grouped students into multiple classes by majors, roughly 120 in each class. Each class received the lectures at different times during the week. Two of the classes participated in Study-1.

In School B, participants were recruited through a Science Festival. A Science Festival organized by the school was held for freshmen. In the announcement of the Science Festival, it was said that four lectures would be given in four different lecture halls (4 to 5 pm, a time that no class is arranged for freshmen). The lectures covered a wide range of science topics, but the specific topic could not be decided until the very last day depending on the availability of specific lecturers. The event was open to students without charge, and participants could redeem time spent for course credit by attending the lecture. The students were told that this was a pop-science lecture given in a story-telling style and that the course would teach them some interesting science theories. Students would be asked to give feedback to the lectures to help the curriculum designers evaluate and improve the course.

The participants were also told that they would be asked to answer many unrelated questions to help the curriculum designers prepare for lectures in other topics.

There were certain eligibility requirements for students who wished to enroll. These were:

1. They could only attend one lecture due to the large demand.
2. They needed to accept random assignment to lectures.
3. Since they would be randomly assigned to any one of the four slots, they needed to be sure before signing up that they were available for all four slots before being told of their specific time slot assignment.
4. Upon signing up, they would provide their student ID and contact information to receive reminders.
5. They would need to check in with student ID and course credit would be added to the record associated with their IDs.
6. They would complete a questionnaire and complete a short homework assignment if this was required.
7. They had to agree that they would not share the lecture material with other students who had not taken the class, because other students may have to help evaluate the lectures at another time and they should not be subject to a situation that could bias them.

The questionnaire asked for the students' IDs, but not their names. As their answers would be used for research purposes, the research team could not link their IDs to their names, and the school administration did not have access to their responses (except for the donation they are willing to make). All response and personal information was kept anonymous and confidential.

Allocation and Schedule (for Study-2 and 3)

The 350 participants recruited in School B were assigned randomly to four groups. These groups were allocated to the following interventions: two groups for Study-2 (respectively conservation of energy group and Nash equilibrium group, 25 participants each, with smaller sample size due to school restrictions) and two groups for Study-3 (respectively entropy group and self organization group, of 200 each). The specific allocation, schedule, and teacher assignment were as follows:

1. Group 1, the conservation group in Study-2, 22 participants, attended the conservation of energy lecture taught by teacher A.
2. Group 2, the Nash group in Study-2, 23 participants, attended the Nash Equilibrium lecture taught by teacher B (different from teacher A).
3. Group 3, the entropy group, 150 participants, attended the entropy given by teacher C.
4. Group 4, the self-organization group, 150 participants, attended the self-organization lecture on the seventh day given by teacher D.

Procedure (for Study-2 and 3)

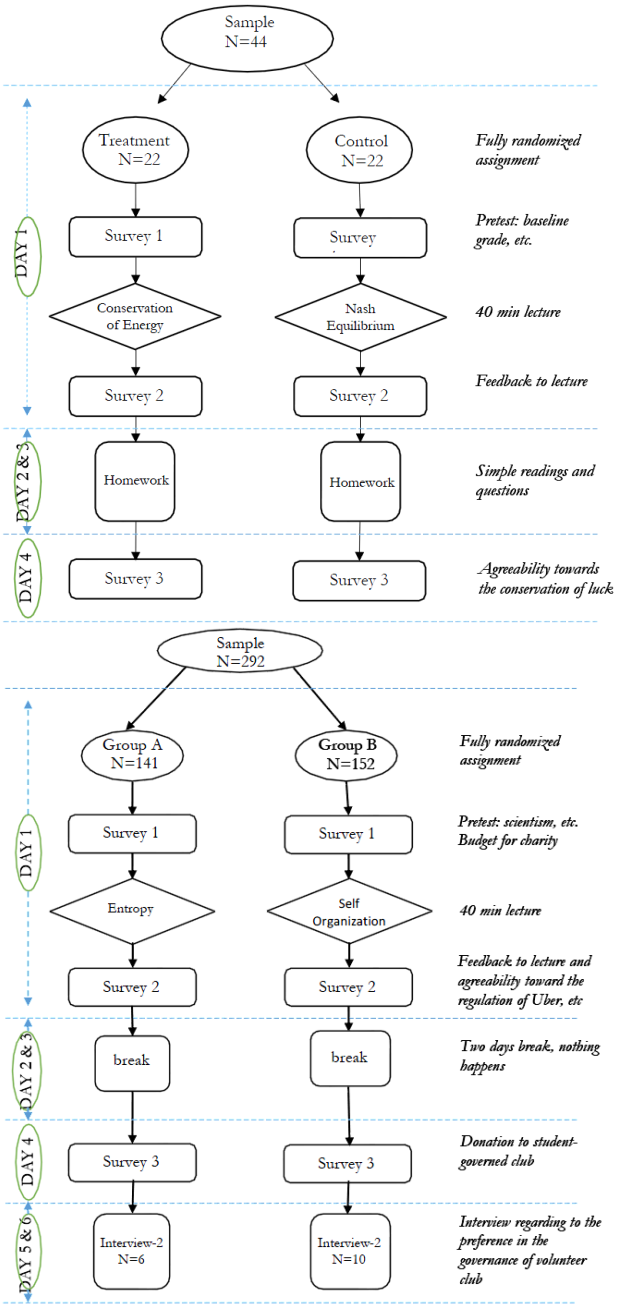


Figure 2.1. The procedure for Study-2 (left) and Study-3 (right). The sample size is the actual number of participants, not the same with the target sample size.

The procedures for the two experiments are shown in Figure 2.1. In brief, students from Study-2 took pretest survey, attended one lecture, and took course experience feedback survey; they then completed homework in the following two days. On the third day, they took the posttest.

Student from Study-3 took pretest, attended one lecture, and took the first posttest. Two days later, they took the second posttest. Twelve students in Study-3 (six from each group) who were willing to participate in a follow-up interview did not need to take the survey; rather, they participated in the interview three days later after the lecture. More details of the experimental procedure are provided below (and also in Appendix E):

1. All students checked in with a student ID, took 10 minutes to fill the pre-survey (survey 1). All students attended the lecture, which took 40 minutes, and completed the feedback survey (survey 2).
2. Students who took conservation of energy or Nash Equilibrium (Study-2) finished two homework assignments for each group. These assignments reviewed the very basic concepts over the next two days, each taking 5 to 10 minutes to complete. When they handed in the homework to the organizer at the office of the student union on the following Monday, they were given a questionnaire (survey 3) to complete and drop into a locked box.
3. Students who took entropy and self-organization (Study-3) did not need to do any homework. Immediately after the lecture, they were given an extended version of survey 2 that, in addition to the feedback questions, had questions regarding a case study of social issues including government intervention to online market, the regulation of Uber, power relationship between citizen and government, and the organization of knowledge structure and learning pace in MOOC. Two days later, they were given a questionnaire (survey 4), regarding to the Volunteer Club, by the headmaster of the class.
4. The Volunteer Club Planning Committee gave a list of IDs of those selected for the sample to headmasters, and the headmasters delivered and collected questionnaires

pursuant to each of the IDs. In this school, as in many colleges in China, each cohort of a department has one student as the headmaster, who assists fellow students with affairs of daily student life (like a residence assistant in a dormitory) and in academics (involving the connection between students and school administration or teachers, like teaching staff).

5. Twelve students (6 from each group, balanced by gender and major) who were willing to participate in a follow-up interview did not need to take the survey.
6. The four lectures were offered by four teachers who were graduate students majoring in science education at Yunnan Normal University. All of them had experience teaching in high school in Yunnan, China. They were asked to make their lectures interesting, with a minimum of jargon, but with more storytelling (TED talk style), to deliver the concepts accurately. I provided the stories. They avoided any attempt to, or to hint at, transfer to any other domain. They rehearsed with the researcher (myself).

Intervention

Conservation of Energy

The key concept delivered in this lecture is that energy in an isolated system is conserved; it cannot be created and neither can it be destroyed; it can only convert from one form of energy to another. In the process of conversion, the total amount of energy in the system remains constant. The lecture consisted of two parts. In the first part, the lecturer presented a list of the classical proposals for perpetual motion machines (including some Leonardo da Vinci) that violate the law of conservation of energy. The students discussed with their neighboring classmates why they thought the proposed machine would fail (focusing on the source of the energy, the conversion of energy, the flow, and exhaust of

energy), and the lecturer revealed the answers to the students after the discussion. In the second part, the lecturer told the story of Niels Bohr, who twice attempted to overturn the law of conservation of energy. His first attempt convinced a large group of renowned scientists of early twentieth century, but this approach was eventually disapproved in the course of new theories and empirical testing. One fruitful outcome of this debate led to the proposal and later discovery of the neutrino. This story was told in an anecdotal style that highlighted the excitement of the debates in theoretical physics in the early twentieth century. The conclusion of the lecture was that although scientists had tried for centuries to overcome the law of conservation of energy, none were successful, although the study of this law and attempts to disprove it had led to the discovery of many new theories and particles.

Nash Equilibrium

Expressed simply, the key concept delivered in the Nash equilibrium lecture is that a system will reach Nash equilibrium if every player is making his/her best decision based on other parties' decisions while other parties' decisions remain unchanged. The first half of the lecture introduced the life of John Nash in an anecdotal style, including his early signs of genius in math, his arrogant and odd personality, his brilliant achievement, his struggle with schizophrenia, the support from his wife Alicia Nash, and his death (with his wife) in car accident. The lecturer narrated the story of John Nash and played short clips from the film *Beautiful Mind* in the interlude. In the second half of the lecture, the lecturer provided an example of Nash equilibrium, known as the hawk-dove game, which in principle posits that the best action in a conflict depends on what the opponent is doing, specifically, yield if the opponent attacks to the end (dove versus hawk), attack if the opponent yields (hawk versus dove). However, if one does not know if the opponent is dove or hawk, then there exists a

evolutionarily stable strategy, which is witnessed when two animals scream or bluff against each other but do not engage in fighting. This lecture was designed to be an entry level introduction to Nash equilibrium through the use of story-telling. It did not cover the mathematics behind the theory.

Entropy

Entropy is the measure of disorder. The key concept in entropy (second law of thermodynamics) theory is that an isolated system can only spontaneously become more disordered through time, but cannot spontaneously become more ordered. To increase order, a system needs an infusion of higher ordered energy. This lecture used a demonstration of the change of entropy in different physics examples. The lecturer showed clips that demonstrate the dispersion of gas, ink, and sand. In the middle of each clip, the lecturer asked students to discuss the spontaneous change of the system over time, and compare the entropy of the system in different state. They students will discover that in every example, the entropy can only increase spontaneously. In each of the examples, the lecturer also asked students to think of as many kinds of approaches as possible to reduce the entropy in the system. For example, one can compress the sand, cool the air with air conditioning, and filter the ink. In each of the solutions, students were asked to identify the source, flow, and exhaust of energy. The student would realize that reducing entropy would always involve force from additional or external energy.

Self-organization theory

The key concept delivered in this lecture was that structures in open system can spontaneously reach a higher order without external control based on local interaction, random fluctuation, and positive feedback loops. Such systems tend to be highly efficient, adaptive, and robust, yet wholly decentralized. The lecture use snowflakes as the primary

example, presented different beautiful structures of snowflakes, and played a 5-minute clip of how molecules of water gradually organize into delicate snowflakes based only on local interactions. The lecturer also presented other examples such as the flocking of birds (and schooling of fish) and explained the local interaction in the crowd of animals, emphasizing the fact that the head bird emerges from the crowd and that other birds only follow and respond to its adjacent birds. By the end of the lecture, the lecturer showed video clips of how engineers develop self-organizing material based on self-organization theory.

Common Pedagogies

In each of the lectures, the lecturer always introduced the key concept at the very beginning of the lecture, and reiterated the key concept in every example. The two lectures in experiment 1 used an anecdotal style, and the two lectures in experiment 2 contained many examples. In each of the lectures, the lecturer mentioned that the target concept can be widely observed in the domain of physics, chemistry, and biology, but did not mention the application in human society.

Measurement

Pretest survey for all

For all participants, regardless of experiment, the pretest survey asked for demographic information, subjects of interest, entrance exam scores, physics tests, mindfulness, attitude towards scientism beliefs, transferential thinking style, and inward learning motivation (important covariates to investigate potential interaction effects and to contact the researcher if they would like to participate in an interview.

Study-1 also used this survey, but with some variation. In Study-1, this survey added one case study that asked participants' understanding of a fable from an old Chinese Taoism text

to measure if they took it literally or metaphorically as a proxy for metaphor awareness. This fable case study was not included in pretests for Study-2 and 3.

Fable case study

The full text of the fable is provided below (and in Appendix N):

> In Tao Te Chin, Laozi once said: "the ultimate goodness is like water." Water has ever since become a very important symbol in Taoism's ideology. In recent years, Taoism is gradually regaining its popularity in modern society, many people start to read Tao Te Chin to perceive the wisdom from old Chinese philosophy and religion. Different people may treat the symbols from Taoism differently.
>
> Take water for example, because of the text "the ultimate goodness is like water", many people take water very seriously. They insist on growing water-based plant at home, or for those who have a yard, they often place a pond in the yard. They believe this is not a simple decoration, but the wise message from old saints, that to use water properly at home can indeed bring goodness, such as luck, fortune, virtue, and morality, to a family. Some other people consider it as a metaphor, deem that water itself is not necessary, but that water reflects some characteristics that can teach people how "goodness" works around us. They think it is unnecessary and useless to expect for goodness simply by placing water-based symbols at home.
>
> Based on your own opinion, to what extent you agree with the insistence on having water to bring goodness (there is no right or wrong answer)?
>
> I support such an insistence. The wisdom from old saints must have its reasons, though we may not fully understand it. I believe water is not simply a symbol or metaphor, water itself can bring goodness to people.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐
>
> I do not support such an insistence. Laozi was only using water as a metaphor, it did not have to be water. To understand the wisdoms behind the metaphor is enough for people in modern society. We do not have to stick to the text or the ritual.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Scales development

Because Study-1 was the pilot study that aimed to select the final set of items for each of the scales in the pretest to be used in the following studies, it contained more items than did the final version of the scales. To select the items from the pilot test for the formal versions of the scales, I performed an item-fitting process based on the item response theory (IRT)

model following a common item selection procedure introduced by Mair and Lowry (2005), see Figure. 2.2.

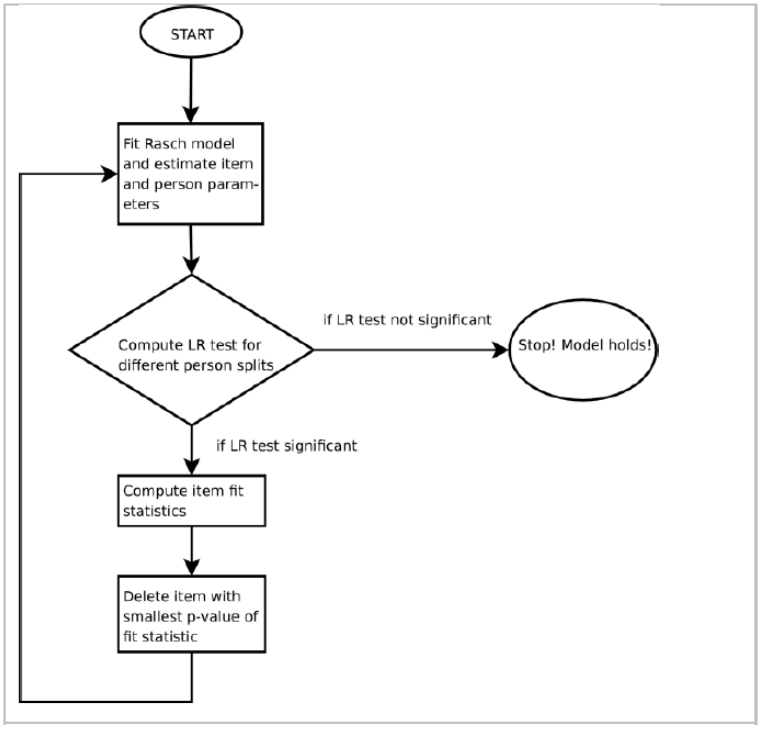


Figure 2.2. Item selection approach with IRT models (excerpted from Mair & Lowry, 2005)

The reliabilities of the scales are shown in Table 2.1 (Appendix G). The table contains two Cronbach's alpha values (columns 3 and 4) as measures of internal consistency, one from the pilot test (calculated only based on the final item sets), the other one from the experiment samples in Study-2 and Study-3. It shows that the scales have good internal consistency. Columns 5 and 6 report the first component (eigenvalue and variance explanation) from principle component analysis. It shows the scales have acceptable unidimensionality. In general, the higher the first eigenvalue (above 3 is usually considered very high) and the more variance explained by the first component, the better is the unidimensionality. Column 7In column 7, it reports the likelihood ratio (LR) test to the fit of the IRT model, which provides another angle to examine the reliability of each scale. A common practice is to split

the sample to two halves and compare if the IRT models of the two halves fit differently using the LR test. If there is significant difference, the model has poor fit, meaning if someone tests the scale on different populations, the coefficient for some of the items will be significantly different for different populations. In other words, considering that the IRT model is trying to find the most appropriate weights for each item to calculate the weighted average score for each individual, if the weight changes dramatically from person to person or from group to group, the weighted average score will become incomparable between persons or between groups. There are multiple split methods, the most relaxed method is random split; a stricter split method is to split by a binary variable (usually gender). In this table, I reported the LR test based on gender split. Column 7 shows that none of the scales have significant LR test result, meaning the items of each scale fit fine for IRT scaling.

Table 2.1
Reliability and Unidimensionality of the Scales

Scale	Number of items	α from pilot sample	α from experiment sample	First Eigenvalue	Variance Explained by First Eigenvalue	LR test of the IRT model: χ^2(df), p-value
Transference Thinking	9	0.73	0.82	3.24	30%	7.29(10), 0.69
Scientism Thinking	12	0.85	0.88	4.92	35%	17.87(13), 0.16
Inward Motivation	5	0.79	0.78	3.55	36%	3.43(6), 0.75
Executive Function	10	0.75	0.82	3.26	30%	6.95(11), 0.80
Physics Test	6	0.46	0.61	1.73	25%	3.89(5), 0.56

Tables 2.2 (Appendix H), Table 2.3 (Appendix I), Table 2.4 (Appendix J), and Table 2.5 (Appendix K) present the specific wording, item test correlation (higher the better), and fit of each of the items (preferably no significant p-values) in each of the scales.

Table 2.2
Scale for Scientism Thinking

Item #	Item wording	Number of observation	Item test correlation	IRT item fit p-value
SCI1	I admire scientists a lot.	228	0.55	0.26
SCI2	Science leads us to discover the ultimate truth.	228	0.53	0.52
SCI3	Science is the only criterial to decide between right and wrong	228	0.60	0.95
SCI4	To understand this world, we must rely on science.	228	0.59	0.92
SCI5	I only trust opinions that are supported by science.	227	0.63	0.98
SCI6	I will trust an opinion if more scientists support it than do not	228	0.61	0.82
SCI7	In modern society, science should be people's religion	228	0.66	0.99
SCI8	We should oppose anything that is inconsistent with science.	229	0.59	0.15
SCI10	Science is the only standard to examine truth.	223	0.62	0.45
SCI11	Human spirituality will eventually be explained by science.	228	0.63	0.98
SCI12	Hard science is more important than the study of humanities	228	0.56	0.62
SCI13	Anything that is inconsistent with science is wrong.	228	0.61	0.08

Table 2.3

Scale for Transference Thinking

Item #	Item wording	Number of observation	Item test correlation	IRT item fit p-value
TRAN1	I think many things that appear to be unrelated are related.	228	0.62	0.97
TRAN2	I am good at expanding my imagination, jumping out of my contextual constraints.	230	0.60	0.99
TRAN3	I often see significant wisdom in insignificant cases.	228	0.54	0.23
TRAN4	I think different matters and actions often share the same unified explanation.	227	0.52	0.99
TRAN5	Subject learning often inspires me to think about life wisdom.	226	0.52	0.15
TRAN6	I think imagination is more important than knowledge.	229	0.59	0.70
TRAN7	I think human society is very like the animal world.	228	0.54	0.25
TRAN8	I think we can consider human beings as molecules or cells.	229	0.56	0.48
TRAN9	I enjoy discussion about metaphysics and life wisdoms.	229	0.57	0.83

Table 2.4

Scale for Inward Motivation of Learning

Item #	Item wording	Number of observation	Item test correlation	IRT item fit p-value
INWD1	Perseverance in learning trains one's character	230	0.75	0.99
INWD2	I believe studying hard can make one stronger	230	0.74	0.80
INWD3	I think the study of one technique cannot be considered the mastery of knowledge.	228	0.74	0.99
INWD4	I believe that all-around (liberal-art) education is more important than technical education.	230	0.71	0.70
INWD5	I hope that teachers can bring me closer to life wisdom.	230	0.76	0.93

Table 2.5
Scale for Mindfulness

Item #	Item wording	Number of observation	Item test correlation	IRT item fit p-value
MF1	In leisure time, I can't think of anything to do.	230	0.48	0.80
MF2	It's difficult for me to sit still.	230	0.50	0.36
MF3	I have unrealistic plans.	226	0.59	0.99
MF4	I often lose stuff (such as keys, wallet, homework, etc.).	230	0.57	0.54
MF5	It's difficult for me to wait in a line.	230	0.67	0.87
MF6	It's difficult for me to make transitions from one task to another.	230	0.47	0.98
MF7	I make careless mistakes when I complete tasks.	230	0.61	1.00
MF8	I often forgot what I am doing in the middle of a task.	230	0.51	0.66
MF9	I do not check the mistakes I make in my work.	230	0.63	0.94
MF10	I often flick my fingers or shiver my legs.	229	0.48	0.01

Class experience survey for Study-2

For Study-2, survey 2 asked for feedback concerning the lecture (e.g., too easy or too difficult).

Posttest for Study-2

For Study-2, the survey asked students' opinions towards items (as shown in Table. 2.6, Appendix L) that suggest the conservation of luck, to examine romantic transfer from conservation of energy to lay conception of karma. Participants need to answer to a 4 category Likert scale (from strongly disagree to strongly agree).

Table. 2.6. The posttest survey for Study-2

Items that suggest the conservation of luck
To what extent do you agree with the following statement?
1. When my belongings are lost or stolen, I comfort myself that I am trading possession for luck.
2. If one fails in one thing, it means he/she can be successful in something else.
3. Before a game, the coach should humbly admit his/her team's weaknesses.
4. Before a game, the fans should not boast about their team, but should compliment the opposing team.
5. I believe that luck is conserved.
6. One can accumulate luck by purposefully suffering losses.
7. I think the conservation of luck has its scientific basis, although we do not fully understand its deeper mechanisms.
8. Although the conservation of luck sounds superstitious, I will still try my best to abide by it.
9. Luck is like a bank; one needs to save often in order to withdraw some at a time of need.
10. Conservation of luck may not be a strict science theory, but it is consistent with science theories in its essence.
11. Even though the conservation of luck is not a science theory, but it is consistent with science
12. I think everything is conserved, including luck.
13. Performing a huge good deed with great effort will save more luck than performing a small good deed with little effort.
14. Conservation of luck is complete superstition, I don't believe it at all

First posttest for Study-3

For Study-3, in addition to the feedback items, the survey also asked opinions about four case studies to examine romantic transfer from thermodynamics to order and control in social domains.

The four case studies are described below (and also in Appendix O):

1. MOOC.

MOOC is the abbreviation for Massive Open Online Courses, a new popular trend in education technology and innovation. It also draws a lot of attention and discussion in the field of education. MOOC compiles a huge amount of course material, such as lecture video, reading material, homework, and even online discussion in an online platform, and offers this to all students for free or for a low fee.

Some people are very optimistic about MOOC, considering it the future of inclusive education. They believe MOOC can provide an open and accepting learning environment where students can be self-motivated and self-paced, without pressure. They also believe with the enormous amount of learning material provided, students can have easy access to knowledge whenever they need it and can efficiently build up their own knowledge system. However, others have been more hesitant. They are concerned that students cannot efficiently organize the scattered knowledge into an organic system; they are also concerned as to whether students can find their own learning pace, or will procrastinate or even fall by the wayside. They have been suggesting MOOC should assign head teachers to students, just like the teachers for each classroom or tutors for each small group. They believe head teachers can help students organize their knowledge system and keep them on a regular learning pace. Not everyone agreed; people who are optimistic that students can do this on their own believe it is unnecessary and works against the proposal to have MOOC in the first place.

> Based on your own opinion, to what extent do you agree with the following statements (there is no right or wrong answer):
>
> I think students need a head teacher to guide their learning paces; otherwise, they will procrastinate and even fall by the wayside.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐
>
> I think it is difficult for students to build their own knowledge structure; it is necessary to assign head teachers to help students organize knowledge.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

2. Uber.

Uber is a fast-growing new taxi company that is planning to enter Kunming (home to the participants). Different from traditional taxi business, Uber allow private drivers to become a

taxi driver with their own cars without a permit from government. Customers schedule a ride on their cell phones and the nearest private driver will come to pick them up. Many welcome Uber, thinking it meets the high demand of the customer and gives private drivers a chance to earn by carpooling. However, many are concerned that Uber will harm traditional taxi drivers' businesses, and there may be other safety risks. The local government of Guangzhou has recently forbidden Uber to operate. Instead, the government is planning to release a government version of "Uber," owned by the government, with the intention to strengthen monitoring, balancing between demand and supply, and reconciling between private drivers and taxi drivers. Many people welcome this action from the government; many others do not.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer)?

I think Uber fits into the demands in taxi market, it is unnecessary for the government to intervene.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

I am in favor of banning Uber entirely and replacing it with a government version of Uber.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

3. Political Parties.

In a remote hypothetical nation, there are two political parties that have been having a heated debate for decades. Party A believes the nation should have "strong citizens and small government," meaning encouraging citizens to take the initiative, be innovative, to encourage local towns and villages to be more autonomous from the central government. This party believes that to have people pursue their interests is the key to social harmony. Party B believes the nation needs "stronger government and weaker citizenry," meaning to strengthen government's ability to monitor social order, maintain social stability, and adjust the economy on a timely basis. They believe that the appropriate assignment of resources and maintenance of social justice is the true path to a harmonious society.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer):

I prefer strong nations over strong citizens.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

I prefer strong citizens over strong nations.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

4. Taobao (Ebay).

In the past decade, commercial selling witnessed the transition from physical store to online store. Increasingly sellers shut down their physical stores on the street and became online sellers through such online facilities as Taobao and WeChat. More phenomenally, anyone, even people who are not in the sales business professionally, can easily open their own online store and make money. However, the online economy is not without problems; it has been frequently reported by media that some online sellers sell fake products and that online sellers viciously compete by dumping product on the market in a manner damaging to other sellers. Considering the online market is a new business venue, some people hope the government will intervene and regulate this new market; some others think the problem is temporary and that the bad stores will die out in a free market without government intervention.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer)?

Macro-economic-control by the government is an invisible hand that designs strategic plans and assign resources. I think prosperity of online economy depends on macro-economic control.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

The government should come forward to maintain the order of markets and monitor online sellers.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Under free market competition, online sellers will self-discipline themselves spontaneously and become increasingly trustworthy.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Second posttest for Study-3.

For Study-3, the survey asked two questions, shown in Table 2.7 (Appendix M), specifically,

1. volunteer experience (have you participated in any volunteering work before?)

2. the amount of money the participants are willing to donate to a volunteer club that is completed self-governed by students, to examine MT from thermodynamics to social structure and management.

Table 2.7. The second posttest survey for Study-3.

Category	Example items
Demographics	*Please provide the following basic information* ID:___
Volunteering experience	*Please give your answer to the following questions* Have you participated in any volunteering work before? Yes □ No □
Donation	*Currently the Planning Committee is considering to handed over the Volunteer Club to students to organize autonomously, run by the students and monitored by students as much as possible, with minimum involvement from school administrations. For such a reason the Club needs to fund raise on its own, instead of being subsidized by the school.* *The Committee is discussing how the Club should raise and manage funding and budget. Our current preference it the funding should partly come from company sponsorship and partly from donation from members. Each member can donate any amount between 0~50RMB (0~8 dollar) as membership fee each year, it's completely voluntarily and should not exceed 50 RMB, please exact your number to 1RMB, rather than give a coarsen estimation in 5s or 10s.* *Please estimate how much you would like to donate to the student self-governed Volunteer Club* I would like to donate _____

Interview

In the semi-structured interview, I read the cases aloud, such as regulation of Uber or governance of a volunteer club, to the interviewee. Afterwards, I guided the conversation with a sequence of overarching questions (see Table 2.8, Appendix P).

Table 2.8. Overarching interview questions and their rationale

	Question	Rationale
1.	As between the government version of Uber and the original private Uber, which do you prefer, and why? Or: as between student-autonomously-governed clubs and school-administration-governed clubs, which do	In each of the cases presented, there are two options. One suggests a more centralized, hierarchical regulation that is consistent with the entropy framework; the other suggests a self-autonomous regulation that is

you prefer, and why?	consistent with self-organization theory. These questions ask participants to state their preference and their justifications.
2. According to this passage, some people believe that the private Uber (or student-governed-clubs) will necessarily become disordered. What is your view? 3. In your opinion, what is the source of disorder and what is the key to increasing order in Uber markets (or student organizations)?	These questions focus on order and disorder using Uber or club as an anchor to encourage the participants to reveal their mental models about order versus disorder. Specifically, these questions challenge participants to think about the advantages or necessity of central hierarchical control. The questions require students to explain and justify their preferences.
4. According to this passage, some people believe that the government should exercise control over Uber. What do you think about this belief? Or: some people hope that the school administration should play a leadership role in managing the club. What is your opinion about this?	These questions focus on key players and leadership.
5. Who do you think have more responsibility to the healthy organization of the Uber market (or student-governed club)? Do you think there should have leader(s)? Who should be the leader? Why should this person (or agency, group) be the leader? How is leadership formed?	
6. In this passage, some people believe the government should leave Uber alone and not to intervene. What do you think about this issue? Or: some people may prefer that the club be governed by students autonomously. What would you prefer, and why?	These questions ask participants to reflect on the advantages of free markets or autonomous organizations. They require participants to justify their preferences.
7. What will in the beginning and what will happen in the long term, if there is very little government intervention to Uber?	These questions ask participants to predict the trajectory of an unsupervised system.

	Or: What will in the beginning and what will happen in the long term, if school administrations are not involved in the club?	
8.	So you suggest … (quote the participant's summary of statement). Under what condition would you consider the opposite stance?	This question asks participants about exceptions. It tries to probe the boundary and conditions.

CHAPTER III:

STUDY-1—TRANSFER, SCIENTISM AND LITERALISM

I think the hinge of the matter is to be found in a very short syllable, namely, in the word 'is', the meaning of which is not always given by 'is' but sometimes by 'signifies'.

–Huldrych Zwingli (1525)

Research question

Study-1 had two purposes, the first of which was to establish the reliability of the measurement tools that I would use in pretests for Studies 2 and 3. The reliabilities of the scales have been summarized in Chapter II. The second purpose was to explore the relationship among these measurements through correlational studies and eventually through a path analysis. The specific research questions were:

1. (a) What is the relationship between scientism beliefs, transferential thinking style and intrinsic learning motivation (personal growth oriented)?

   (b) What additional variables (e.g. gender, major, baseline physics test score) predict scientism beliefs, transferential thinking style, and inward learning motivation?

2. (a) What variables predict the sensitivity to the presence of metaphors?

   (b) Do people who score higher in scientism beliefs, or transferential thinking style, or inward learning motivation tend to have stronger sensitivity to metaphors (for example, give metaphorical interpretation to old Taoism religious text) or weaker sensitivity to metaphors (for example, give fundamentalist/literal interpretation to old Taoism religious text)?

Procedure

In my experiment school, all freshmen year students needed to attend to general lectures about ideological education weekly. The school grouped the total number of more than 2000 freshmen into multiple classes (roughly 120 students in each class) based on their major similarities, and each class received the lectures in the lecture hall in different times of the week. This provided an ideal occasion to recruit many participants to answer the survey. I had access to two of the classes (one class with students majored in engineering, and the other class with humanity majors), and assigned consent sheets and questionnaires to all students in the two classes. Only those who agreed to participate need to answer to the survey.

Material

Full details of the survey are provided in Chapter-II. Here only briefly review the measurements. This survey included demographic information such as age, gender, ethnicity. It also asked participants entrance examination grades in math and Chinese. It contains a 10 items junior high school level physics tests to measure their basic knowledge about physics. It contained four scales: scientism, transference, inward learning motivation and mindfulness.

By the end of the survey, there was a case study. The case study was introduced in Chapter-II, and briefly reviewed here: The case introduced a fable from ancient Chinese Taoism text, which stated that "the ultimate goodness is like water". The case followed that many people take this text seriously believing water itself was goodness or could bring about goodness, therefore they would place water pond in their backyard, or fish tank in their home, or water based plants in their balcony; where as other people took it metaphorically believing water

was not goodness itself but it revealed certain principles that could teach us about goodness. There were two items following to the case, one stated a literal understanding of the fable, the other one states a metaphorical understanding. The participants needed to answer to what extent they agree to each of the statements.

Sample

This study draws on data I collected while piloting a pretest questionnaire from a sample of 230 freshmen-year college students in China. The participants in this sample did not participate in Study-2 and Study-3.

Table 3.1 (Appendix Q) summarizes the means and standard deviations for each variable. Please note that scientism, transferential thinking, inward learning motivation, and mindfulness are scored as the average of the Likert-scaled items (1=strongly disagree, 2=moderately disagree, 3=moderately agree, 4=strongly agree), although these variables were converted to IRT scores, a more accurate composite score for further analysis. IRT scores, for which the mean is anchored to be 0, are less easily interpretable than are scores on a Likert scale, where a mean above 2.5 means there are more people who agree to the items on the scale.

Table 3.1

Descriptive of variables in Study-1

Attribute	Mean	Standard deviation	Range
Male	53%	NA	NA
Age	19.68	0.80	18-21
STEM major	35%	NA	NA
Scientism	2.88	0.55	1-4
Transferential	2.92	0.48	1-4
Inward Motivation	2.93	0.51	1-4
Physics Test	3.44	1.78	0-7
Math	72.38	18.17	0-150
Chinese	103.85	12.75	0-150

Variables:

Metaphor: an ordinal categorical item that indicate that the extent that the participant agree that "the ultimate goodness is like water" was only a metaphor, that people do not literally need to place water in their homes.

Literal: an ordinal categorical item that indicate that the extent that the participants agree that "the ultimate goodness is like water" was not just a metaphor, but that water related objects can literal bring about goodness.

Metaphor awareness proxy: Metaphor minus Literal, this variable approximated the participants sensitivity to metaphors.

Scientism: IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that natural science will give the ultimate explanation to social phenomenon in the pretest.

Inward (inward learning motivation): IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that to learn is to "make oneself a better and moral person rather than just to acquire the skill" in the pretest

Transference (transferential thinking style): IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that phenomenon in separate domains share common root, and learning in one domain inspired the understanding of other domains.

Mindfulness: IRT score of ordinal categorical items. It indicated the extent that the participants are mindful to their own thoughts and actions.

Physics test: sum score of the physics tests, ranging from 0 to 10.

Math: a continuous variable reporting the math score in entrance examination.

Lang: a continuous variable reporting the Chinese language score in entrance examination.

Gender: A dichotomous variable indicating if the participant is a female

Major: A dichotomous variable indicating if the participant is a STEM major

Age: A continuous variable indicating the age (counted by year) of the participant

Analysis

Mindful that the ultimate goal of Study-1 was to build a path analysis to explore a chained relationship between variables, I have made the assumption that the chain of effects should point from lower tiers to higher tiers, but not the reverse direction. The most fundamental tiers are the demographic information (age, gender, major), the basic test scores (language, math, physics), and mindfulness. The second tier is learning motivation, the third is the transferential style of thinking and the scientism style of thinking, and the final tier is whether the subject takes a stated metaphor literally or metaphorically. By the end of the model building process, I considered alternative models to check whether any other scenario, such as placing variables in different tiers, would result in an appropriate or even improved model fit.

Result

The pair wise correlation are shown in Table 3.2 (Appendix R).

Table 3.2
Pairwise Correlation Between Variables

	trans	scism	Inwd	literal	metp	EF	phys	math	lang	age	major	gendr
Trans	1											
Scism	0.15*	1										
Inwd	0.70***	0.10	1									
Literal	0.34***	0.31***	0.38***	1								
Metap	-0.02	-0.08	-0.01	-0.36***	1							
EF	0.02	-0.04	0.19**	0.19**	0.03	1						
Phys	0.13~	0.02	-0.03	-0.05	0.09	-0.02	1					
Math	0.06	-0.08	-0.04	-0.08	-0.06	-0.19*	0.03	1				
Lang	-0.25***	-0.03	-0.03	0.15	0.04	0.28**	0.13	-0.20*	1			
Age	-0.09	-0.04	-0.16*	-0.01	0.11	0.06	0.06	-0.11	0.07	1		
major	-0.06	-0.02	-0.06	-0.04	-0.01	-0.07	0.09	0.03	0.11	0.21**	1	
gendr	-0.08	-0.03	-0.09	-0.08	-0.01	0.08	0.02	0.03	-0.03	0.32***	0.16*	1

Note: ~ 0.1 > p > 0.05; * p < 0.05; ** p < 0.01; *** p < 0.001

What predicts an inward motivation of learning?

Among all variables from the bottom tier (for which all bottom tier variables have been controlled), only mindfulness predicts the inward motivation of learning ($\beta = 0.24$, se = 0.09, $p = 0.01$). This means that those who have a higher score in mindfulness are more likely to agree that the purpose of learning is to introspect and cultivate personal self-growth.

What predicts scientism thinking?

None of the variables from the lower tier can predict scientism thinking, except for transferential thinking (from the same tier as scientism), which can predict scientism thinking with marginal significance ($\beta = 0.28$, se = 0.15, $p = 0.06$).

What predicts transferential thinking?

Inward motivation of learning has a positive effect on transferential thinking ($\beta = 0.75$, se = 0.07, $p < 0.001$), the effect of scientism thinking is positive but marginal ($\beta = 0.12$, se = 0.06, $p = 0.058$), the effect of mindfulness is negative yet marginal ($\beta = -0.13$, se = 0.07, $p = 0.07$), and the effect of the Chinese test is negative as well ($\beta = -0.02$, se = 0.007, $p = 0.005$). This means that students who are motivated to learn for personal self-growth or those who believe that science is the gold standard to explain all things are more likely to believe that principles from different contexts are interconnected and transferable. Those who rank higher in mindfulness or language skills are less likely to exhibit a transferential style of thinking.

What predicts metaphoric versus literal understanding of a fable?

Following to the fable in the case study, there were two items that stated either a literal or a metaphorical understanding of the fable, and the participants answered as to the extent to which they agreed with each of the statements. In my analysis, I first treated the two items separately as outcome variables. Second, I created a proxy of metaphor sensitivity (the metaphor item minus the literal item) and treated this proxy as the outcome variable.

Water is not just a symbol; it literally IS goodness.

With all variables controlled for, transferential thinking ($\beta = 1.11$, se = 0.38, $p = 0.004$), scientism thinking ($\beta = 0.58$, se = 0.21, $p = 0.006$), and language test score ($\beta = 0.059$, se = 0.003, $p = 0.03$) are positive predictors of literal understanding of the fable. The physics test score is a marginal negative predictor ($\beta = -0.25$, se = 0.13, $p = 0.059$).

It is only a metaphor.

Scientism is a negative predictor of agreement with the metaphoric understanding (β = -0.50, se = 0.20, p = 0.01). It is the only predictor for this item after controlling for all other variables.

Proxy for metaphor sensitivity

Scientism is a negative predictor for the proxy of metaphor sensitivity (β = -0.58, se = 0.19, p = 0.003). Transferential thinking is also a negative predictor yet marginally significant (β = -0.46, se = 0.26, p = 0.08). In the meanwhile, the physics test score is a marginal positive predictor (β = 0.21, se = 0.12, p = 0.06) and a STEM major is marginally more sensitive to metaphor than a non-STEM major ((β = 0.71, se = 0.37, p = 0.06). Figure 3.1 (Appendix S) illustrates how participants with high metaphor sensitivity (blue) and low metaphor sensitivity (red) are clustered in a two-dimensional coordinate of transferential and scientism styles of thinking.

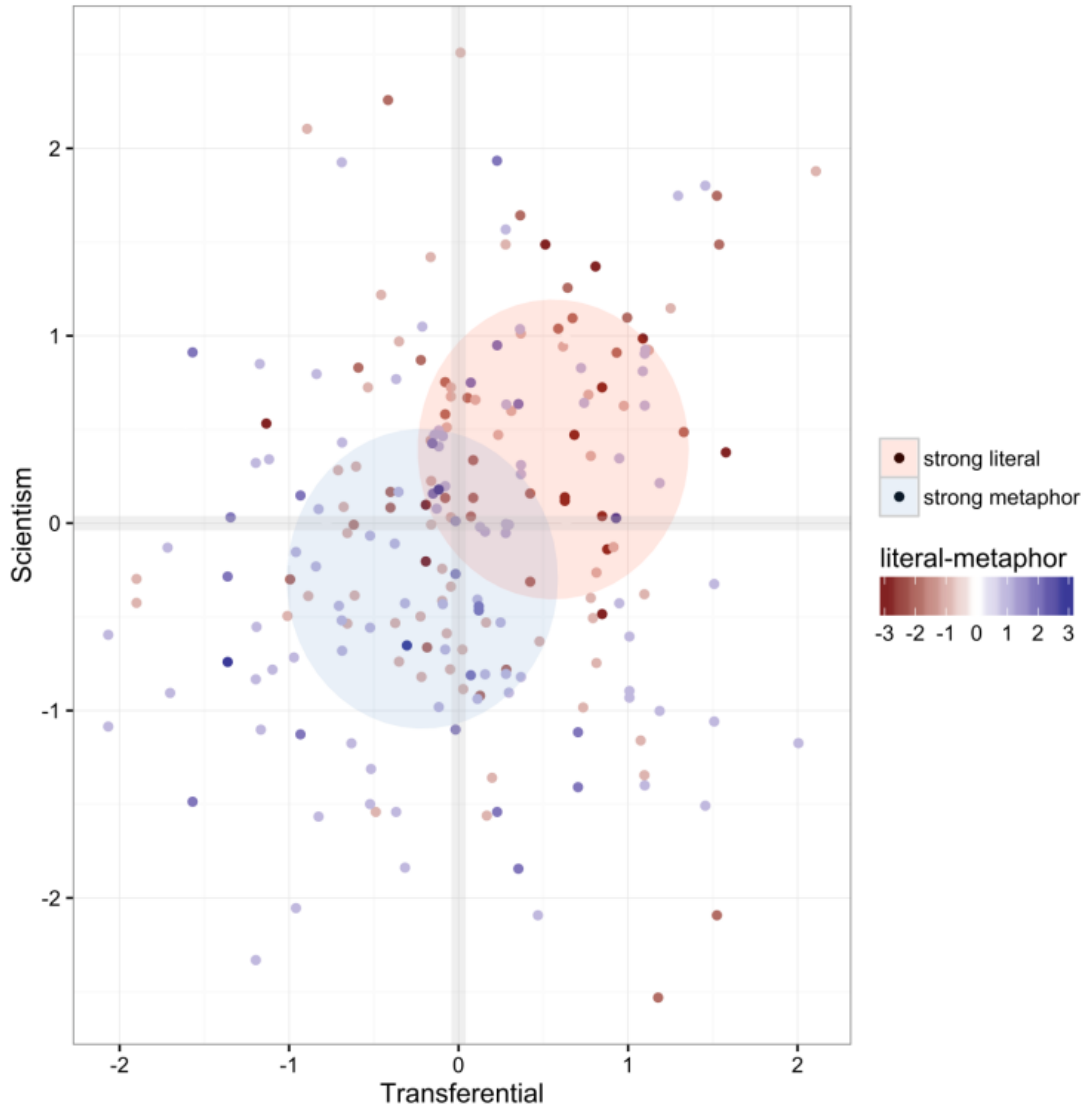


Figure 3.1. Scatterplot of the interpretation to the fable (proxy of metaphor sensitivity), from strongly literal to strongly metaphorical, on a two dimensional coordinate consists of transferential and scientism style of thinking. The small dots are the position of each individual's proxy. The shaded circles are the confidence intervals of the center of strong holders of each of the two opinions.

Considering all of the relationships simultaneously:

The path analysis and diagram (Figure 3.2, Appendix T) best summarize all the relationships described above when considered simultaneously. The green paths indicate positive effects, and the red paths indicate negative effects. Thinner and more transparent paths indicate smaller and less significant effects. The two most significant predictors for metaphor

sensitivity are transferential and scientism styles of thinking, with both being negative predictors. Transferential and scientism styles of thinking positively covary with each other. Transferential style of thinking is positively predicted by inward learning motivation and physics test scores, but negatively predicted by language test scores. The scientism style of thinking does not have any strong predictors. Lastly, inward learning motivation can be positively predicted by mindfulness. This model had an appropriate model fit $\chi^2(228, 3) =$

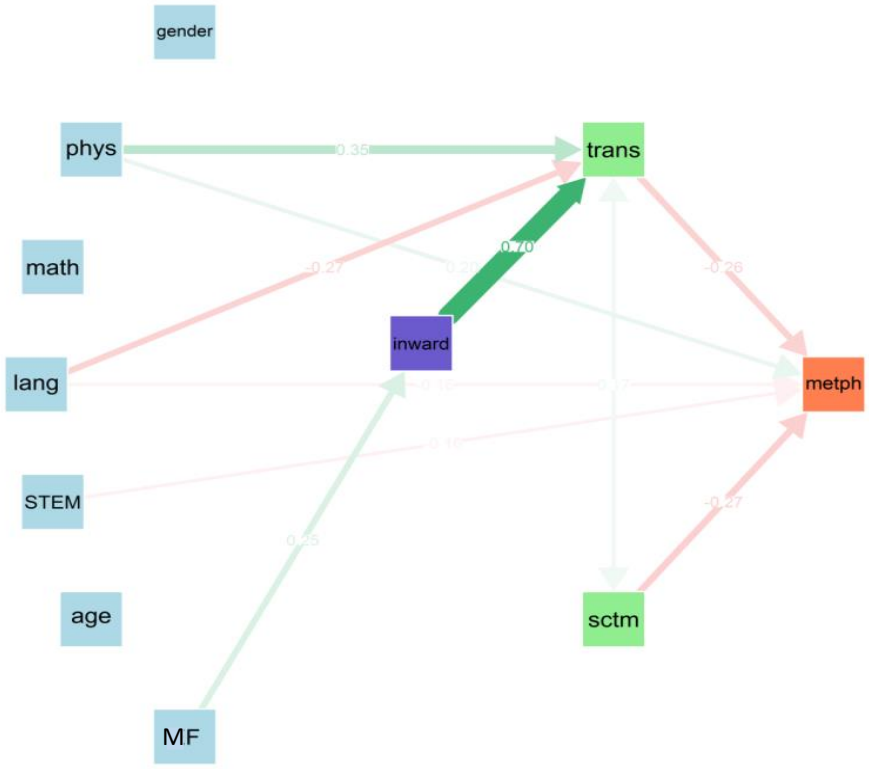


Figure 3.2. Path diagram of the chained effects considered simultaneously. The thickness and solidity of the paths indicate the sizes of the effects. The green paths indicate positive effect and the red paths indicate negative effects.

0.96.

Discussion

Study-1 revealed several intriguing results. For the first research question as to the predictors of inward learning motivation, transferential thinking style, and scientism, the study confirmed the following existing intuitions:

1. People who are more mindful of their current thoughts (mindfulness) are more interested in examining how learning has shaped their own personal growth (inward learning motivation). Indirectly, through inward learning motivation, they are more likely to prefer transference.
2. People who are eager to gain personal transformation through learning (inward learning motivation) are more eager to transfer what they have learned to different contexts for inspiration.
3. People who have relatively poor language skills (if we assume that Chinese language test in entrance examination, reported in pretest, is a measurement of general language skill) tend to transfer more, probably because they lacks the ability to use language with precision or fail to comprehend the boundary of terminologies.
4. People who have higher physics test score are more likely to prefer transference. One of the possible explanation is that people who find physics science relatable to real life events are more interested in physics and perform better in physics.
5. People who tend to transfer are also more likely to believe in scientism, probably because they consider many seemly unrelated phenomenon to be reducible to simple science theories and are therefore more likely to hold the belief that science provides the ultimate explanation of all things.

For the second research question (i.e., are people who hold strong scientism beliefs and transferential thinking styles more sensitive in detecting metaphors or more likely to take

metaphors literally), this study found that people who scored higher in scientism and transferential thinking style tended to give a literal interpretation of a Taoism biblical text. (Before interpreting this result, we are reminded that the fable case study was not a measurement of participants' belief in Taoism. Unfortunately, I did not measure participants' religion preferences, but it is almost certain that very few of the participants believed in Taoism, based upon the national poll (Tong & Liu, 2007) that 70% of the population claim themselves to be atheist and 14% of the population believe in Taoism, Buddhism, and folk religions (e.g. Dragon King). Operationally, this fable provided participants with an old Chinese Taoism text and measured how likely it was that they would give a literal interpretation. Thus, a more careful reading of the result would be that people who tend to hold strong scientism beliefs are the same people who interpret biblical text literally, probably because they tend to interpret all text literally, be it scientific or religious. When they read science, they hold a fundamentalist view of science, considering that nature and human society should follow the teaching of science and seek inspirations mapped from scientific text. When they read religion, they also hold a fundamentalist view of religion and seek revelation from biblical text. They stick to the words in the source domain (e.g., in the text "goodness is like water," water is from the source domain), but meanwhile, they extend the boundary of these words to believe that "goodness is indeed water" rather than "goodness is similar to water." In another hypothetical example, they probably are the same people who believe that "the fittest will survive" is literally a law in human society, rather than an evolutionary theory that can occasionally teach us about human society under certain conditions.

Additionally, those who interpret text literally are also those who share a transferential thinking style. A possible explanation is that when people are unaware of a resemblance as a

metaphor, they neglect the boundary constraints of different domains and tend to take instances in one domain as the direct supportive evidence to the other domain, thereby easing the criterial of analogy and increasing the chances of transferring and the tendency to transfer. On the converse, this result suggests that people who transfer the most are the least likely to take their transference as a metaphor, but are most likely to hold it as literal truth. This is particularly interesting considering that my definition of romantic transference (from Chapter I) was that romantic transfer is metaphorical and informal (not taken as a serious theory), but participants who romantically transferred in this study are most likely to take the metaphors literally, not metaphorically (at least as a personal wisdom, if not a "personal scientific theory"). This contradiction reveals the different perspectives the neutral observer (me) and the active transfer makers (the participants). The active transfer makers hold a metaphor as true by directly making literal interpretations of the metaphor. However, it remains a metaphor from a neutral observer's perspective because the participants' personal theories neither went through grueling hypothesis testing nor had been accepted by the scientist community.

This result also gives a glimpse (though a speculative hypothesis) of the perceived revelation between science and religion, especially by people who romantically transfer. It is not necessarily that science is giving a direct hint of the possibility of a higher intelligence, nor is it that the teaching of religion actively seeks scientific proof, but that there is a trait in personality or habit of mind that "romanticizes" a lot of texts. By romanticize, I mean blurring the boundaries of words, mapping the laws from specific disciplines to other areas, but being unaware of the metaphorical nature of such a mapping procedure. If we can do a mental experiment, we can hypothesize that those who live in an atheist industrial society worshiping science and believing all things can be reduced to a simple science formula would

very much be likely to worship in some form of religion and believe all things can be retraced back to a few lines of fundamental biblical text should they have lived in or been exposed to a religious environment. The reason behind it is that they share the same trait of literalistic style of interpretation combined with the a transferential style of theory making. If this hypothesis is true, we should observe those who strongly believed in scientism and immigrated from atheist society to a religious society would be more likely to become religious compared to the same cohort of immigrants who do not previously hold scientism beliefs. This mental experiment assumes two strong causal links—not tested in the correlational study—that (1) there is a certain personality trait that is interested in seeking transfers and take it literally—people with such trait tending be more susceptible to the kind of ideologies that simplify and assimilate multiplicities—and that (2) teaching science as a faith, or as oversimplified yet ultimate truth, is itself an exercise of literal interpretation of transfer, which may pave the way for religious revelation.

CHAPTER IV:

STUDY-2—FROM CONSERVATION OF ENERGY TO CONSERVATION OF LUCK

> *The paradox of the [scientific] fact-builders is that they have simultaneously to* increase *the number of people taking part in the action—so that the claim spreads, and to* decrease *the number of people taking part in the action—so that the claim spreads as it is.*
>
> *—Bruno Latour (1987)*

Research question

Study-1 has shown the positive correlations between transferential thinking, scientism beliefs and literal interpretations to religion text. Building upon this finding, this study adopts an experimental (randomized controlled trial) approach to examine if students who learn science concepts (conservation of energy in this case) can spontaneously and romantically transfer to naïve religious ideas (the conservation of luck). Specifically, the research question was:

> Were students who were randomly assigned to learn conservation of energy more likely to agree that luck is conserved, compared to the students from the control group?

Procedure

Figure 4.1 (Appendix U) summarizes the procedure in experiment-1. In this study, 42 freshmen-year college students participated. I randomly assigned 20 to the treatment group and 22 to the control group. Both groups undertook a pretest survey identical to the survey piloted in Study-1. The treatment group attended a lecture that introduced the first law of thermodynamics—the conservation of energy. After they took the lecture, they had three days with which to complete reading three short passages that talked about the discovery of

this law and to answer some simple reading comprehension questions pertaining to the subject matter. On the fourth day, they answered to a post survey. In contrast, the control group received a lecture that introduced Game Theory. After the lecture, they had three days (including day 1) to finish reading three short passages about John Nash and his contribution to the Game Theory. On the fourth day, they answered to the same post survey as did the treatment group. The posttest listed questions that dealt with luck and asked the participants the extent to which they agreed with each of the statements.

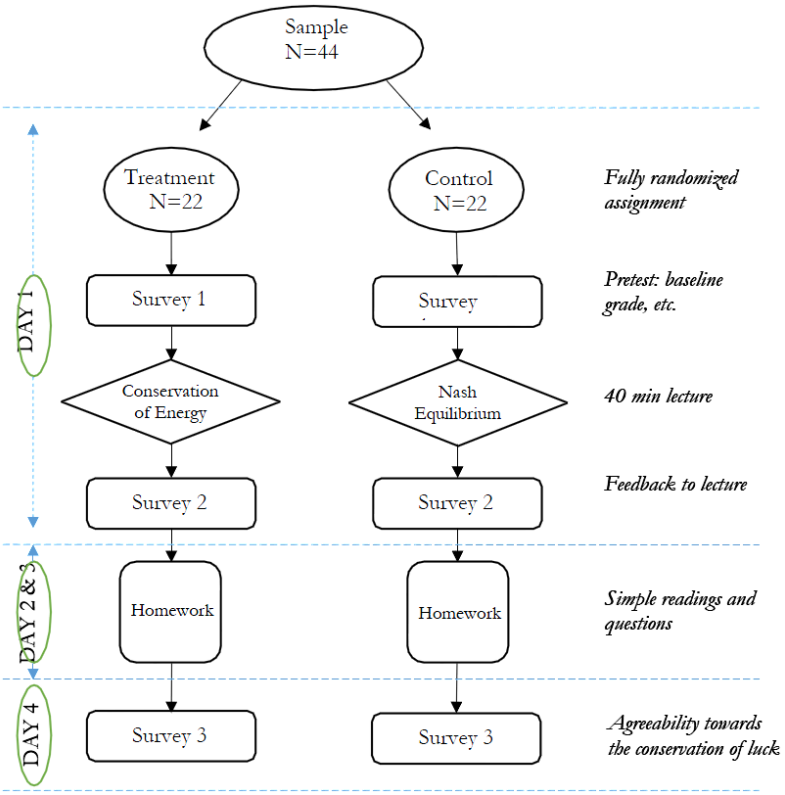


Figure 4.1. Procedure for Study-2.

Sample

Table 4.1 (Appendix V) provides the descriptive statistics of the pretest measures between the entropy and self-organization groups. All variables were well balanced between groups.

Table 4.1

Descriptive of Pretest Information

	Control Group		Treatment Group	
	Mean	Std	Mean	Std
Male	77%	NA	73%	NA
Age	19.91	0.12	19.80	0.11
STEM	45%	NA	55%	NA
Scientism	2.78	0.68	2.86	0.54
Transfererience	2.97	0.49	2.83	0.60
Inward Motivation	2.91	0.47	2.91	0.50

Material

Full details of the survey 1 to 3 are provided in the Chapter-II. Here only briefly reviews the measurements.

Survey-1:

Survey-1 was similar to the survey used in Study-1, with minor modifications. This survey contained all of the pretest items. It asked participants demographic information. It also included the scaled for scientism, transference and inward motivation, same as the scale in Study-1. However, it did not include participants' entrance examine test scores, because participants reported that they were reluctant to reveal their scores (even anonymously) in study-1. It did not include a high school physics test, due to time constrains.

Survey-2:

This survey only asked participants' general experience about the lecture. The results of these items were not yet analyzed in the following analysis.

Survey-3:

This survey contained 14 items that asked participants' agreeability to the conservation of luck. 4 items concerned the scientific (vs. superstitious) basis of conservation of luck; 6 items concerned the zero-sum mechanism in the conservation of luck; 2 items concerns pre-game

comments before sport competition; and 2 items directly asked participants general agreeability to the conservation of luck. The items are listed in Chapter-II, as well as in Figure CON in the following.

Intervention:

The treatment group received a lecture about conservation of energy. This lecture was given in a story-telling manner. It told the true stories of scientists in history who tried to create theories or machines (e.g. perpetual motion machines) to challenge the conservation of energy (the first law of thermodynamics) and ended unfruitful. One example included in the lecture was the story about Niels Bohr, an influential physicist and Nobel Prize Laureate, who, for twice, came up with new theories to disapprove the conservation of energy. His theories raised heated discussions in the scientific community and they were eventually disapproved through decades of experimentations and new theory development. One of the fruitful breakthroughs thanks to this decades long debating was the discovery of neutrino, which was also the last piece of evidence that fully disapproved Bohr's theories.

The control group received a lecture about Nash equilibrium. This lecture was also given in story-telling style. It told the stories of John Nash, his theory development, and his other life stories, such as his mental illness and his death, which had just happened two weeks before the lecture. The example cases of Nash equilibrium were chosen from the field of evolutionary biology, without any mentioning to human society.

Homework:

For treatment group, the homework contains a three A4 page reading material, that reviewed the Bohr's story, and 10 high school easy level physics test items that were all related to the conservation of energy. For example, "battery converts chemical energy to ____ energy".

For the control group, the homework contains a three A4 page reading material, and 5 follow up reading comprehension questions, at the easiest level.

Variables

Outcomes:

CL (conservation of luck): A set of ordinal categorical (4 category Likert scale) outcome

Question predictor:

Treatment: A dichotomous predictor indicating if a participant is assigned to the treatment or control group (in Experiment-1, 1 = "COE," 0 = "NAE)

Key covariates: following covariates are added to the model to examine potential interaction effects.

Scientism: IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that natural science will give the ultimate explanation to social phenomenon in the pretest.

Inward (inward learning motivation): IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that to learn is to make myself a better and moral person rather than just to acquire the skill" in the pretest

Transference (transferential thinking style): IRT score of ordinal categorical items. It indicate the extent that the participant agreed to the claim that phenomenon in separate domains share common root, and learning in one domain inspired the understanding of other domains.

Other covariates: following covariates are added to the model to control for potential confounding effects.

Gender: A dichotomous predictor indicating if the participant is a female

Major: A dichotomous predictor indicating if the participant is a STEM major

Age: A continuous predictor indicating the age (counted by year) of the participant

Analysis

The analysis contained two steps. The first was simply ordered logistic regression, treating answers to each of the items as ordered categorical outcome variables and examining the main effect of treatment while controlling for other variables including age, gender, belief in scientism, transferential thinking style, and learning motivation.

An ordered logit model assumes there is an unobserved latent variable Y^* that gives rise to observed outcome Y such that when Y^* falls between two thresholds (e.g., between φ_0 and φ_1) the observed Y will attain a certain number.

The ordered logit model can be written as:

$$Pr(Y_i \leq j \mid X_i) = \frac{\exp(\varphi_j - X_i^T \beta)}{1+\exp(\varphi_j - X_i^T \beta)} \quad , \varepsilon_i \sim \textit{logistic}$$

whereas *i* means for each individual; $j \in \{1, 2, 3, 4\}$ because the outcome is measured on a 4-point Likert scale; X_i is a column vector of independent variables such as T_i (treatment), W_i (covariates including age, gender, learning belief, scientism belief, scores in entrance exam, etc.) and the interaction terms; X_i^T is the transpose of X_i into row vector; β is a column vector of parameters for each item in X_i; the product of $X_i^T \beta$ can be expanded as $T_i \times \beta_1$

$+Age_i \times \beta_2 + Gender_i \times \beta_3 + Belief_i \times \beta_4 + T_i \times Belief \times \beta_5$ … whereas β_1 is the parameter for the main effect of treatment, and β_5 is the interaction effect of treatment and learning belief.

The predicted probability to choose a certain value of Y is:

$$\pi_{ij}(X_i) = Pr(Y_i = j \mid X_i) = Pr(Y_i \leq j \mid X_i) - Pr(Y_i \leq j\text{-}1 \mid X_i) = \frac{\exp(\varphi_j - X_i^T \beta)}{1+\exp(\varphi_j - X_i^T \beta)} - \frac{\exp(\varphi_{j-1} - X_i^T \beta)}{1+\exp(\varphi_{j-1} - X_i^T \beta)}$$

The average treatment effect (ATE) of the intervention is: $\tau_j = \mathbb{E}[\pi_j(T_i = 1, W_i) - \pi_j(T_i = 0, W_i)]$

Meaning the predicted average treatment effect of intervention on choosing j on the Likert scale is the estimated probability of choosing j when T = 1 (treatment group) minus the estimated probability of choosing j when T = 0 (control group), keeping covariates constant. In other words, it is the marginal difference between groups for each choice

The second step was to create a composite score of answers to all items using IRT scaling and to use the composite score as a continuous outcome variable in a simple multiple regression, including the main effect of treatment while controlling for other variables.

Result

Item level

Among the 14 items in the scale, 10 items showed treatment effects, the other four did not reach statistical significance (with p-value at 0.05). Figure CON shows the mean log odd ratio between treatment and control group (log transformation of the treatment divided by control) on each of the items. When the log odd ratio is greater than 0 (the line in the

middle), this means the treatment group scored higher than the control group on average. When the lower bound of the confidence interval is greater than 0, this means that more than 95% of the log odd ratios between two groups are greater than 0 and that, therefore, the main effect of treatment is statistically significant. The reason to employ the log odd ratio is because it downscales the odd ratio so that it can fit the illustration frame. I can choose to plot the marginal differences in different scales such as the odd ratios or the raw differences. The conclusions regarding the main effect, however, are the same. The odd ratio, and the log odd ratio are listed in two columns embedded in Figure 4.2 (Appendix W).

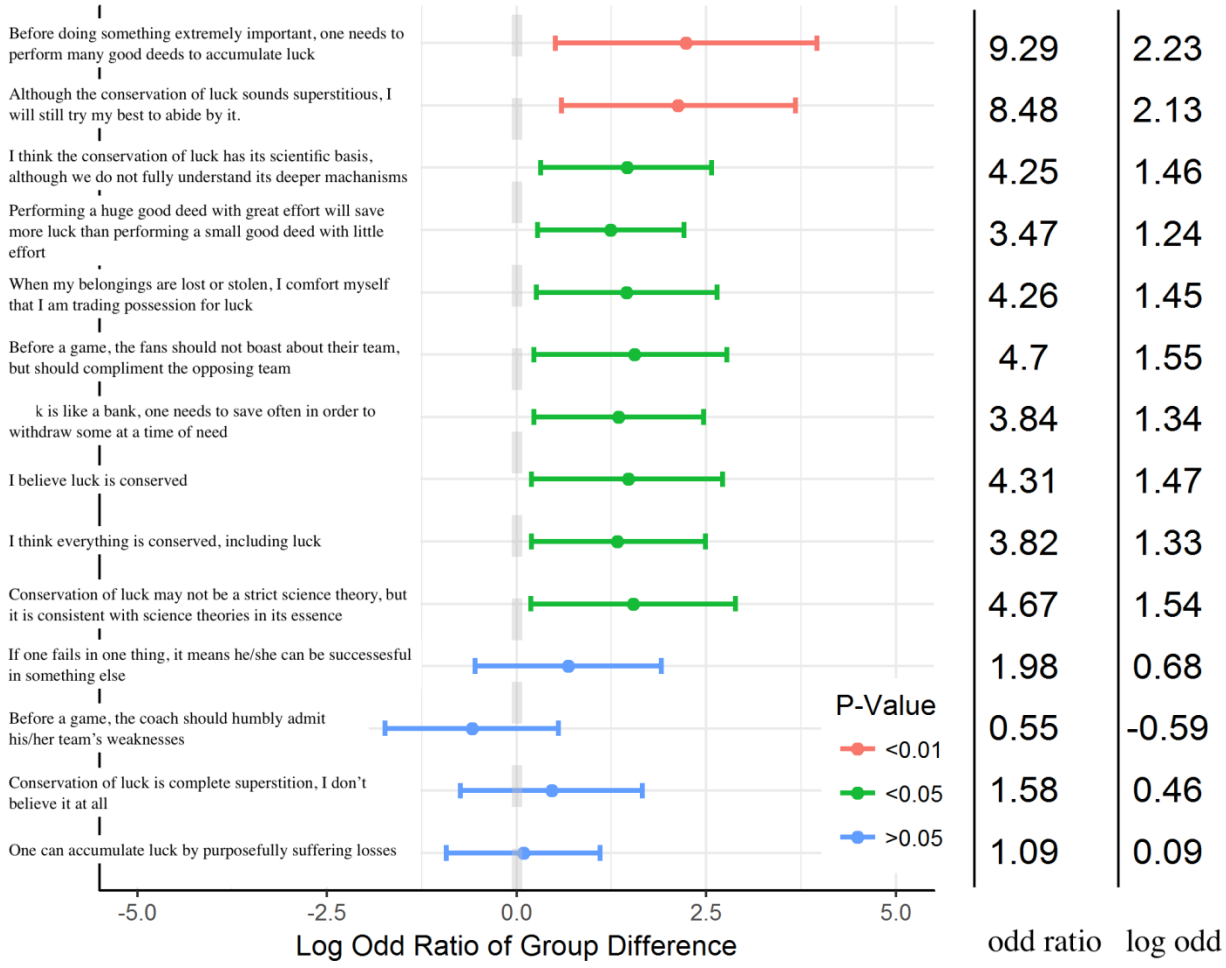


Figure 4.2. The mean log odd ratio between treatment group and control group on each of the post-test items. When the bar of an item overlays with the dash line (blue color), it

means the treatment group did not differ from the control group on this item. When the bar locates on the right side of the dash line (red or green colors), it means the treatment group scored higher than control group on this item. Different colors denote different size of p-values, as noted in the legend.

Composite level

I adopted three different approaches to create composite scores for the belief in the conservation of luck. The first approach summed the Likert scale scores. The second approach reflected the first principal component based on principal component analysis. The third approach was IRT weighted score based on IRT models of the test. There was a statistically significant treatment effect (controlling for other variables), regardless which composite score is used as the outcome variable, as shown in Table 4.2 (Appendix X). The coefficients appeared different for different composite scores because the scales are different, but once standardized, they were nearly the same.

Table 4.2
Treatment Effect Depending on Different Approaches to Create a Composite Score.

Composite score	Coefficient	Standard error	p-value	Standard coefficient
Sum of Likert	3.29	1.55	0.04	0.24
Principal Component	1.75	0.57	0.005	0.39
IRT weighted	0.71	0.21	0.002	0.37

Discussion

Of the 13 items that suggested the conservation of luck, 10 items showed a significant treatment effect. The result from this study is a strong indicator that students who learned the conservation of energy are more likely to consider that many other entities in their lives (e.g., luck, particularly in this study) are also zero-sum conserved.

A careful reading of the items reveals a richer understanding of the mental model of luck held by participants from the treatment group. The participants agreed to the generic notion

that conservation applies for all things, including luck. Moreover, they did not merely carry over the vocabulary of conservation generically, but they demonstrated a more sophisticated mapping between the conservation of energy and conservation of luck. Participants from the treatment group were more likely to agree that luck is like a bank and that there is a balance between savings and withdrawals; they were also more likely to agree that applying greater effort for a greater good deed will save more luck than applying smaller efforts for a smaller good deed. A treatment effect on such items revealed the participants' quantitative understanding of luck as a careful transaction and calculation between the two sides (savings versus withdrawal/payment) of the equation. Such a calculated balance between the amount of luck and amount of efforts is strikingly analogous to the quantitative conversion between different forms of energy (e.g., battery conversion of chemical energy to electric energy) introduced by the law of the conservation of energy.

Compared to the control group, participants from the treatment group were more likely to agree that purposefully making an effort to practice virtuous deeds will accumulate luck. However, they were not more likely (they were equivalent to the control group) to agree that failure or purposefully suffering would convert to luck. In other words, participants from the treatment group believed people needs to channel their efforts to achieve a virtue aptitude (a better word for it??) to accumulate luck, but simply exhaust wasteful efforts was useless. This idea is similar to the notion covered in the conservation of energy, namely, that one needs to convert energy efficiently to the energy potentials (potential is a physics terminology meaning energy restored and yet to be released) in order to apply a force; there would always be energy exhausted in the form of heat, which is wasted and cannot be used. Thus, the most effective batteries are those that convert more useful electric potentials and exhaust less heat, as a battery that completely exhausts into heat is useless for producing electricity.

Likewise, inducing self-suffering, failure, and self-criticism (like the coach who humbly admits his/her own team's weakness) would not effectively channel the "energy" to useful "potentials," but to do something moral actively should be effective (like the fans not boasting of themselves, but complimenting the other team). Interestingly, however, losses not directly inflicted by the self may be considered a good opportunity to gain luck. This is shown by the significant treatment effect on items such as "when my belongings are lost or stolen, I comfort myself that I am trading possession to luck." I cannot find a proper corresponding relationship between this idea and the conservation of energy without overworking the words.

When speaking of the science basis of the conservation of luck, participants from the treatment group were (1) more likely to believe that conservation of luck had a scientific basis, although this might not be fully understood, and (2), even if it was not a strict science, it was consistent with science in essence. They were less likely to claim (3) the conservation of luck was pure superstition, compared to the control group; and interestingly, participants from the treatment group were more likely (4) to abide by the conservation of luck even if this might have sounded superstitious to them. These four points properly illustrated the core definition of romantic transfer: People take the transfer as if it has scientific basis, though they may not take it as a serious science, and may not be interested in further investigation, nevertheless, that does not prevent them from being content with the transferred conclusion and taking it seriously as a personal wisdom.

It has been the paramount interest of moral psychology to understand the normative moral standard in the population and the motivation behind moral behavior, such as altruism and justice. The classical and dominant theory of moral psychology is that people are motivated

to be moral either because of their emotional perception of harm or care via empathy or because of their cognitive development in the understanding of justice and fairness. Such theories assume the object of morality is others as opposed to self. The reason that self-interest plays a less important role in moral psychology is not because it is disapproved for being selfish or deemed ignoble. Rather, through study over four decades, it has become known that people tend to associate moral behavior with intrinsic motivation, and more importantly, that to compensate moral behavior with external reward would in effect reduce people's interest in such activities, best known as the overjustification effect (Deci, Koestner, & Ryan, 1999; Kunda & Schwartz, 1983). In other words, although reward and compensation motivate people in their quest for happiness and benefits, people actively avoid being motivated by direct compensation in moral reasoning. Such a conflict between reward and morality can be resolved by converting the moral behavior to abstract forms of credit that can be used in other situation not directly related to the context of the current moral behavior. A common examples of such a conversion can be found in religions. Almost every religion teaches its followers to practice kindness, partially, if not solely for the motivation of redeeming "credit" in the future. Huebner and Garrod (1991) showed that Tibetan Buddhist monks' response to Kohlberg's dilemma cases were so strikingly different from people in the western world that their answers could not fit into any of the existing stages of Kohlbergian moral development. In their responses, the Buddhist monks reasoned about moral behavior in terms of karma, the principle of cause and effect that a good deed brings about good karma that can be redeemed for future happiness. The result of this study is the demonstration, in its discussion about the conservation of energy, that a conversion does not only exist in religious narratives, but also in (and is enabled by) scientific narratives. Therefore, in future studies of moral psychology, it is worthwhile to reflect retrospectively

on the simple intrinsic/extrinsic dichotomy of the motivation in moral reasoning or the notion that extrinsic reward is less important, but consider the possibility of an abstract transformation of reward for future causes, even for a non-religious population.

CHAPTER V:

STUDY-3—FROM THERMODYNAMICS TO SOCIAL CONTROL

There's an awareness that there are general concepts, like chaos, that can be quantified and applied to a lot of unrelated contexts. This awareness is having a very good effect: it brings together people who might otherwise have languished in separate disciplines

–Martin Rees (1995)

Research question

Building upon the result from Study-2 that showed students were able to transfer from science concepts to naïve religious ideas by reviewing previous known science knowledge, in the second experiment, my primary question was whether students were able to transfer from newly learned science knowledge to social ideas that were politically charged. Specifically, the research questions were:

1. Were students who learned entropy more likely to prefer tightened social, political and economic control from bureaucratic administrations, compared to students who learned self-organization theory? Conversely, were students who learned self-organization theory more likely to prefer relaxed social control and more individual freedom, compared to students who learned entropy?
2. Were students who learned self-organization theory willing to donate more to student self-governed clubs, compared to students who learned entropy?
3. Was there consistent treatment effect between RQ1 and RQ2? Specifically, were students who were affected by the treatment in RQ1 the same students who were affected by the treatment in RQ2?

Procedure

Figure PROC2 summarizes the procedure in Experiment-2. This study's subject population consisted of 292 freshmen-year college students and it employed a procedure similar to that of Experiment-2. I randomly assigned 140 subjects to a group that listened to lecture about entropy, and the other 152 listened to lecture about self-organization. After they all received their respective lectures, they responded to four case studies with a total number of 9 questions that reflected the participants' preference to hierarchical social control and the need for external intervention. One week later, all of the participants responded to a questionnaire which asked about the amount of money they were willing to donate to a student club that would be completely governed by students, without school administrative supervision. It is noteworthy that the pretest had asked about the amount that the participants were willing to donate for charity in general, to control for the baseline budget each participant had for charitable donation.

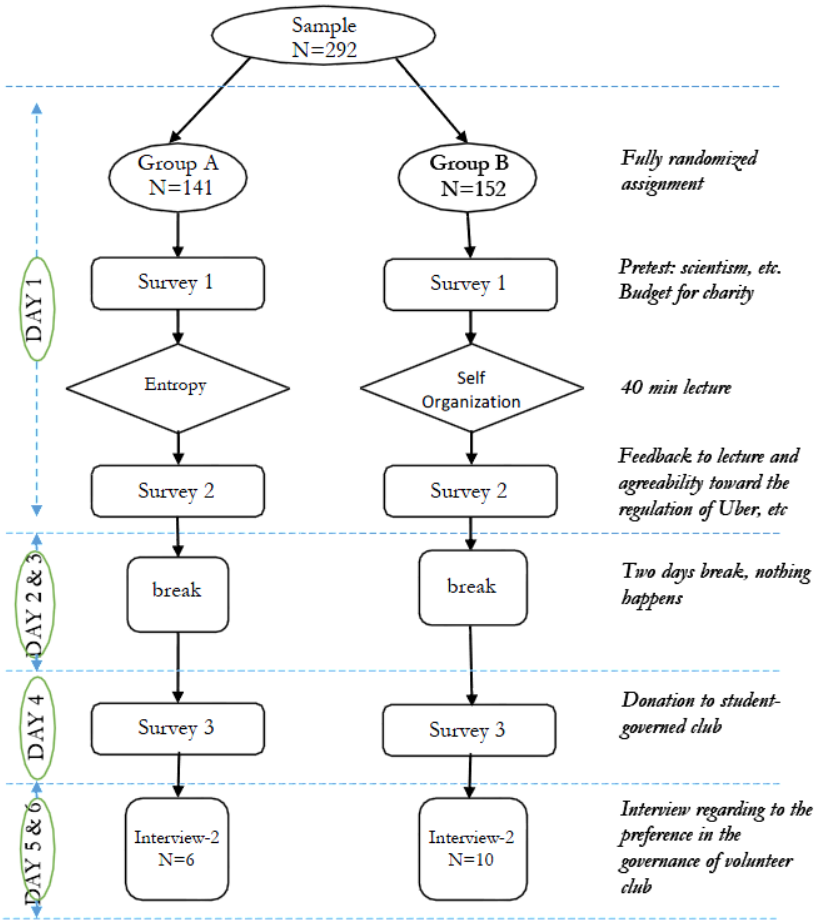


Figure 5.1. Procedure for Study-3

Sample

Table 5.1 (Appendix Z) displays the basic information of the two groups in the pretest. The two groups were well balanced.

Table 5.1

Descriptive of Pretest Information

	Entropy Group		Self-Organization Group	
	Mean	Std	Mean	Std
Male	33%	NA	37%	NA
Age	19.24	0.12	19.33	0.11
Scientism	3.27	0.04	3.21	0.04
Transfererience	2.86	0.04	2.85	0.04
Inward Motivation	2.95	0.04	2.96	0.05
Budget for Charity	21.34	0.91	22.93	1.24

Material

Full details of the survey 1 to 3 are provided in the Chapter-II. Here only briefly reviews the measurements.

Survey-1 (pretest):

Survey-1 contains the pretest items, which are the same as the pretest used in Study-2. One addition item added to this survey was the

Survey-2 (first posttest):

The first part of the survey asked participants' general experience about the lecture. The second part of the survey contains 4 case studies, with a total number of 9 questions, explained in Chapter II. The four cases are 1) whether MOOC should assign head teachers to help students organize the knowledge structure; 2) whether the government should intervene the Uber market; 3) between two political parties, one promotes strong citizen and small government, the other one promotes strong government over citizen, which one the people should support; and 4) should government intervene the online small business (e.g. ebay sellers). The 9 questions are listed in Figure 5.2.

Survey-3 (second posttest):

This survey only contained two questions. The two questions were embedded in a larger questionnaire sent out by the school administration. The school administration was preparing to launch a volunteer club, and preparing to have students organize the club as much as possible. The original survey contains more items that ask students attitude and interests to participate in volunteer work. However, I only had access to two items. The first item asked participants previous experience in volunteer work; the second question asked

participants the amount (no more than 50 RMB) they were willing to donate to a student-governed volunteer club.

Intervention:

The entropy group received a lecture about entropy in thermodynamics theory. The key take-home message was that in an enclosed system, entropy, the measure of disorder, will only increase, unless external higher ordered energy is channeled into the system. The examples included videos or animations of the disperse of sands, liquid, gas particles, restore battery power from external electric power, and cooling down a room using air conditioner that uses higher ordered electric power.

The self-organization group received a lecture about self-organization theory in thermodynamics. The key take-home message was that sometime in an open system, a system can self-organize into regular and even intricate patterns through a bottom-up procedure, without external design and hardly achieved by external design. The examples include videos or animations of the formulation of snow flakes, the migration of huge flocks of birds or fish, and the activities in complicate systems such as biochemical reactions and how enzymes speed up, but not change, such process.

Variables

Outcomes:

RU (regulate Uber): A set of ordinal categorical outcome variables indicating the extent that the participant agrees that "the government should regulate Uber"

RM(regulate market): A set of ordinal categorical outcome variables indicating the extent that the participant agrees that "the government should regulate online sellers"

GOV(government vs citizen): A set of ordinal categorical outcome variables indicating the extent that the participant preference between two parties that have different stance on the power position between government and individual citizen.

MK(head teacher for MOOC): A set of ordinal categorical outcome variables indicating the extent that the participant agrees that MOOC should assign teacher to help student organize their knowledge system.

Donation: A continuous variable, ranged from 0 to 50, for the amount of donation a student is willing to give as membership fee to a club that is to be governed by students without school intervention, as reported by each participant in Experiment-2

Question predictor:

Treatment: A dichotomous predictor indicating which of two groups a participant is assigned to (1 = "ENT," 0 = "SEO")

Key covariates: same as Study-2, the following covariates are added to the model to examine potential interaction effects.

Scientism: IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that natural science will give the ultimate explanation to social phenomenon in the pretest.

Inward (inward learning motivation): IRT score of ordinal categorical items. It indicated the extent that the participant agreed to the claim that to learn is to make myself a better and moral person rather than just to acquire the skill" in the pretest

Transference (transferential thinking style): IRT score of ordinal categorical items. It indicate the extent that the participant agreed to the claim that phenomenon in separate domains share common root, and learning in one domain inspired the understanding of other domains.

Other covariates: same as Study-2, the following covariates are added to the model to control for potential confounding effects.

Gender: A dichotomous predictor indicating if the participant is a female

Major: A dichotomous predictor indicating if the participant is a natural science major

Age: A continuous predictor indicating the age (counted by year) of the participant

Analysis

The first analysis was similar to the analysis in Experiment-2. I adopted ordered logistic regression, treating item responses in the first post-test as outcome variables, examining the main effect of treatment while controlling for age, gender, belief in scientism, transferential thinking style, and learning motivation. The second analysis considered the amount of donation to the student governed club in the second post-test as the outcome variable. Because this variable was a continuous variable, I used ordinary least squares regression to examine the main effect of treatment while controlling for the baseline budget for charity. The third analysis examined the consistency between the treatment effect in the first post-test and the second post-test. The consistency can be shown in an interaction effect between treatment and the first post-test items on the amount of willing donation in the second post-test. For a hypothetic example, if (a) the result showed participants in the self-organization

group (compared to the entropy group) are more likely to agree to one of the items in the first post-test, "Uber can regulate itself in a free market; the government does not need to license Uber"; (b) the result showed that participants in the self-organization group (compared to the entropy group) were willing to donate more to the student-governed club in the second post-test; and (c) participants who are affected by the treatment in the first post-test are the same group of students who are affected by the treatment in the second post-test, then we should see participants who score high in the pro-Uber item from the self-organization group willing to donate more to the club than those who also scored high in the pro-Uber item but from the entropy group.

Result

Ordered categorical items from the first post-test

Among the nine items in the first post-test, five showed as statistically significant treatment effects; the other four did not reach significant (p-value set at 0.05). Figure 5.2 (Appendix AA) shows the mean log odd ratio between treatment and control group, the interpretation of the figure is the same with the Figure 4.2 in Study-2.

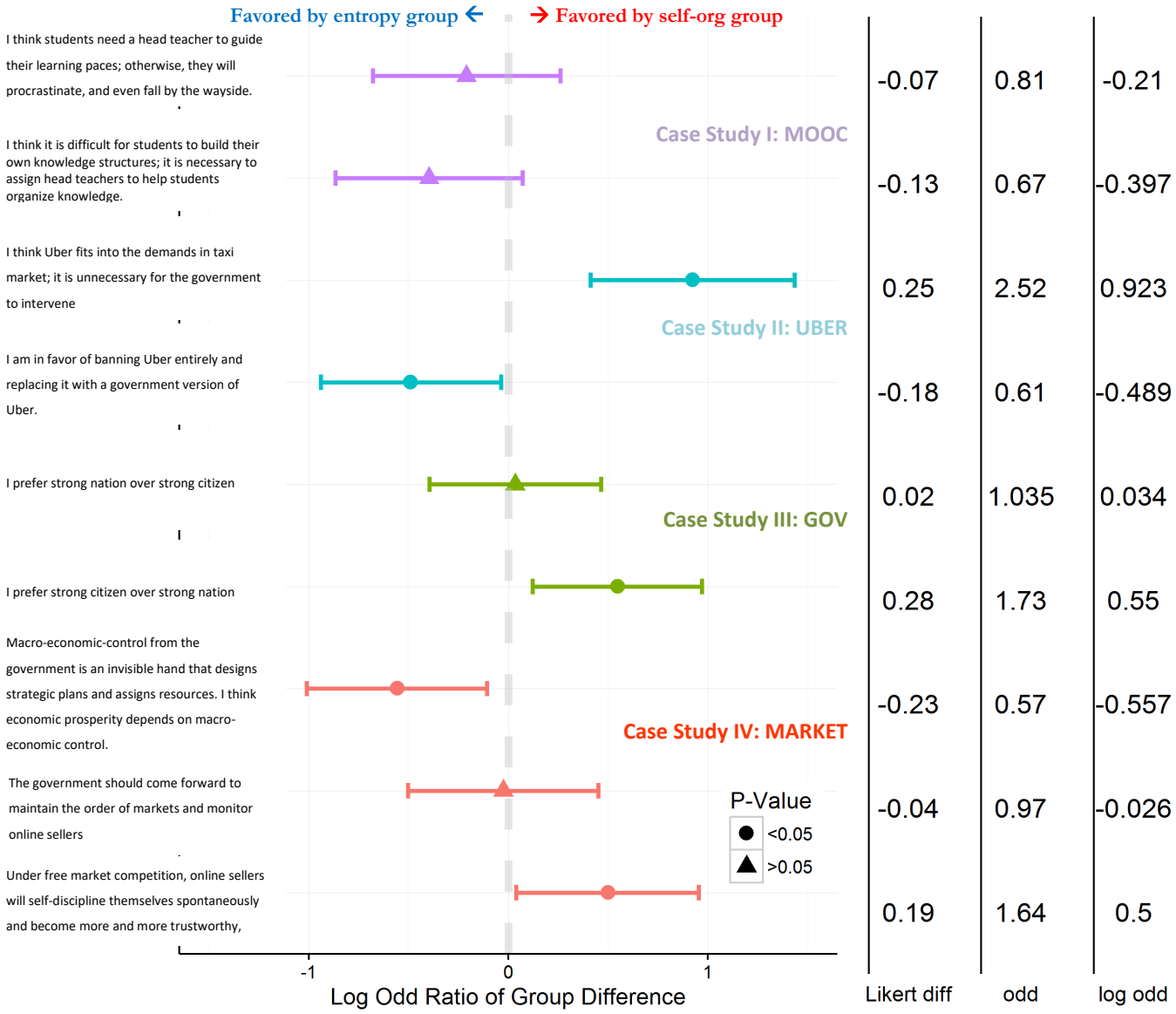


Figure 5.2. The mean log odd ratio between self-organization group and entropy group on each of the post-test items. When the bar of an item locates on the left side of the dash line, it means the entropy group score higher than self-regulation group on this item. When the bar locates on the right side of the dash line, it means the self-organization group scored higher than entropy group on this item. The color of the bars denotes the topic of the case studies, as marked in the graph. The shape in the center of the bars denotes the p-value.

Donation

I have detected a treatment effect on the amount the participants were willing to donate to student-self-managed club. Specifically, the self-organization group was willing to donate 3.5 RMB (se=1.35, p=0.01) more than the average willingness to donate from the entropy

group. This is equivalent to two cans of Coca-Cola or a half size of fries in McDonald's in China. Of all controlled variables, the baseline budget for charity was a significant predictor (β=0.45, se=0.04, p<0.001). Interestingly, there existed an interaction effect between treatment and baseline budget for charity (β=-0.18, se=0.09, p=0.04). This means that participants who had a low budget for charity were more sensitive to the treatment; indeed at the lower end of budget, participants from the self-organization group were willing to donate 7 RMB (roughly 1 USD) more on average than the entropy group, while at the upper end of budget, one cannot distinguish the two groups. Figure 5.3 (Appendix AB) shows the interaction effect.

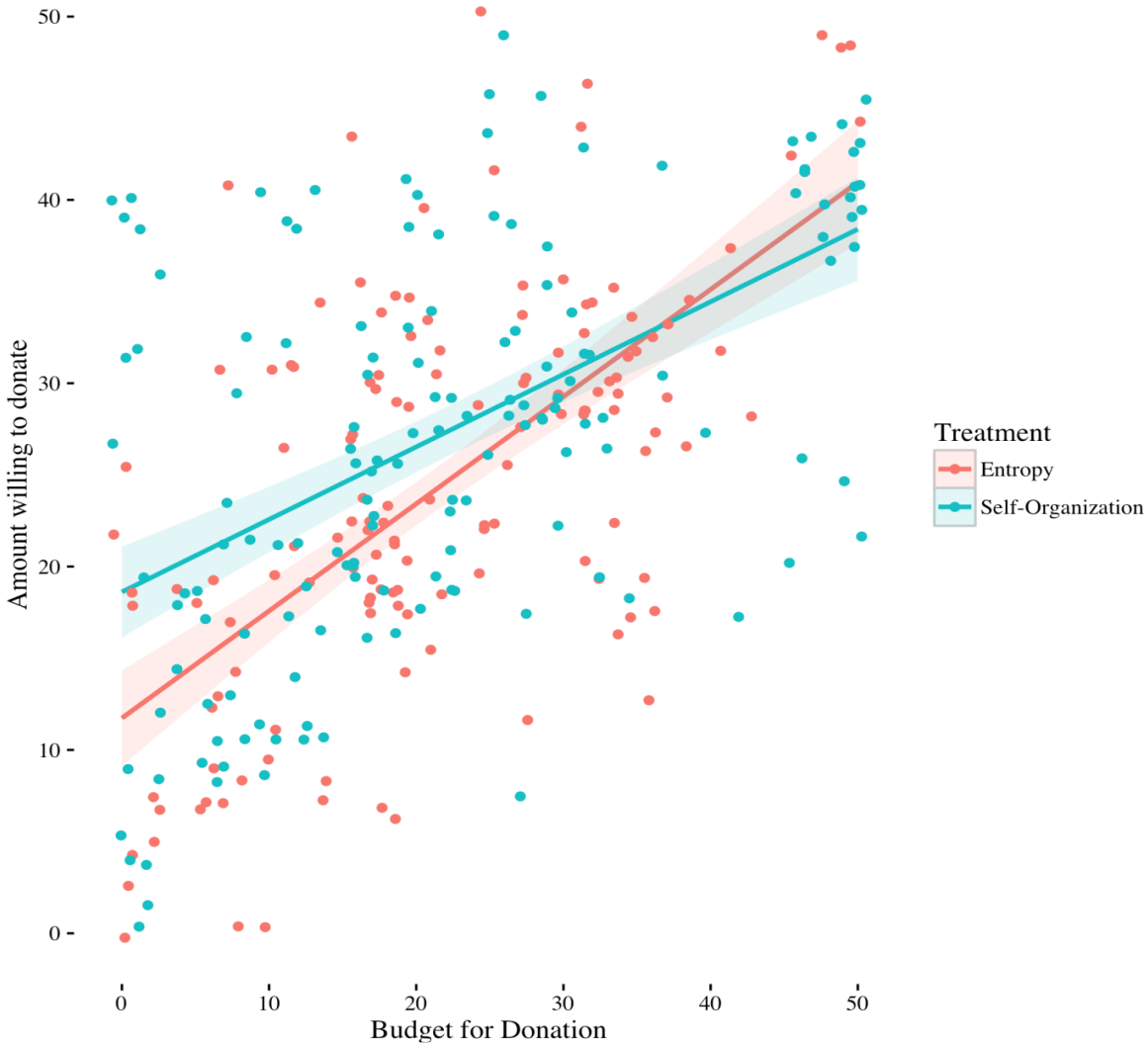


Figure 5.3. An interaction effect between treatment and baseline budget for charity. This means that participants who had a low budget for charity were more sensitive to the treatment, while at the upper end of budget, one cannot distinguish the two groups.

Consistency between the first and second post-tests concerns whether those who appeared to be affected by the treatment in the first post-test were the same participants who appeared to be affected by the treatment in the second post-test. For example, are those who favor free market in the first post-test also donating more to the student-governed club in the second post-test, and further, whether this association differed between the two groups? When there is a strong association, it suggests that participants considered the two questions in the same mental model. When there is weak association, it suggests that participants

considered the two questions as unrelated. I hypothesized that the self-organization treatment should channel the participant into a certain mental model, namely, that participants in this group should show a stronger association between the two questions than the participants from the entropy group. In statistical terms, the consistency measure was simply an interaction effect between treatment and each of the first post-test items in predicting the donation in the second post-test (donation ~ treatment × post-test$_i$, with i denoting each of the first post-test items). The only interaction effect that I detected was between the treatment and the item "I prefer strong citizen than strong nation."

As shown in Figure 5.4 (Appendix AC), there were more participants from the self-organization group located in the first quadrant and more participants from the entropy groups located in the fourth quadrant. This means, for those who favored a strong citizen over a strong nation after the self-organization intervention, they would donate more to the student-governed club. However, for those in the entropy group, even if some favored a strong citizen over strong nation after the treatment, they would donate only at the average level. This suggested that participants from the self-organization group considered the "strong citizen over strong nation" and "more support to student-governed club" in the same framework and that those agreed to the first statement after the treatment would also agree to donate more. To the contrary, participants in the entropy group did not consider the two statements as related. Even if there were participants who preferred a strong citizen after the treatment, they would not necessarily agree to give more support to the student-governed club.

Other items (e.g., support free market) that were significant in Figure 5.2 did not have a significant interaction effect with treatment. This suggested that even if more participants

supported a free market as a result of the self-organization treatment (compared to entropy), these participants did not consider that a free market was related to supporting student self-governance; thus, they would not donate more than the average amount. In other words, self-organization treatment (compared to entropy) activated different directions of transference, one direction was the (political) power relationship between individual and government and another direction was the marketing strategies in macro-economy. Those who transferred in the direction of economy did not transfer to support of student self-governance; those who transferred in the direction of political power also transferred in the direction of supporting student self-governance. Such a domain specific consistency was not surprising, as it confirmed that participants had freely transferred to different and multiple domains and further extrapolated based on their first-step inferences.

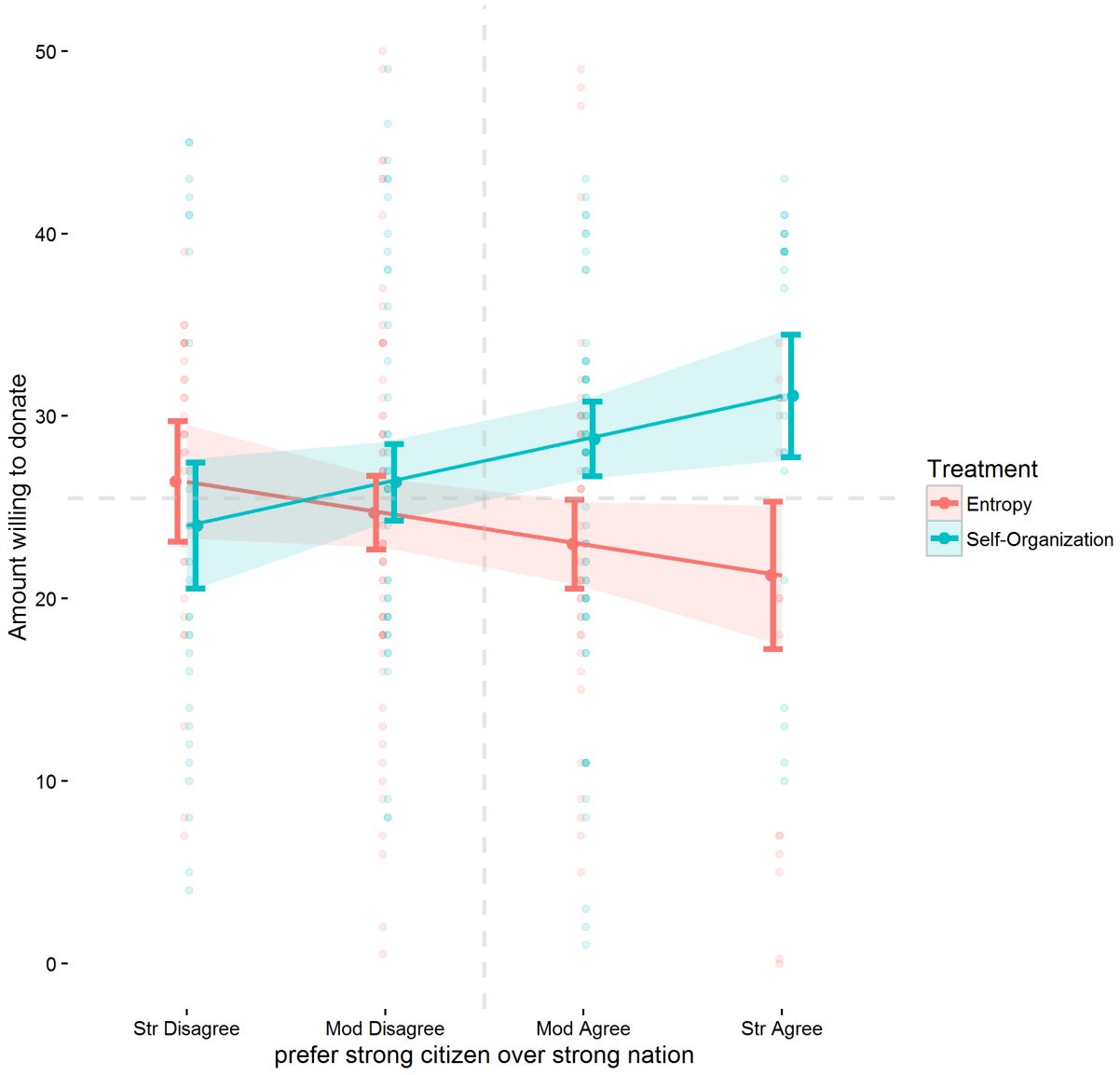


Figure 5.4. An interaction effect between treatment and an item from first post-test items ("I prefer strong citizen over strong nation) in predicting the donation in the second post-test (donation ~ treatment × strong-citizen). There were more participants from the self-organization group located in the first quadrant and more participants from the entropy groups located in the fourth quadrant. This means, for those who favored a strong citizen over a strong nation after the self-organization intervention, they would donate more to the student-governed club. However, for those in the entropy group, even if some favored a strong citizen over strong nation after the treatment, they would donate only at the average level.

Discussion

This study has shown that students are able to transfer to civic political ideologies from newly learned science concepts. Moreover, learning different science concepts can lead to different implications about the same topic. Consider Uber, for example, where participants who learned self-organization (about snowflakes) preferred to have Uber regulate itself and deemed government intervention unnecessary, whereas participants who learned entropy preferred a government version of Uber to replace the current Uber. All of their preferences are in reference to the other group, and if we assume that the randomization successfully balanced observed and unobserved variables (such as their previous preference), we cannot attribute the effect to other variables than the different topics introduced in science lectures. It is a noteworthy reminder that the science lectures purposefully avoided any hint of associating the science concept to social phenomenon and, therefore, that the transfer processes were largely spontaneous and unsupervised.

The interaction effect between treatment and budget (from pretest) on the amount of donation is an interesting finding that this study does not directly explain. Two speculative explanations might be considered, however. First, it is possible that participants who have stringent budgets tend to think more carefully about the terms of a donation and that they more actively seek a good reason to donate. They participants, therefore, are the most sensitive to the implications from the science lectures that provide possible mental models to justify donations. In comparison, students who have abundant budgets for charity in general will donate absent additional reasons to do so. As a result, they are less sensitive to external treatment. A second speculative explanation is simply the ceiling effect. The question in the survey had set the maximum to 50RMB. Thus, even if participants in the budget's higher end wanted to donate even more to the club, they were not allowed to do so. In this case,

there could also have been a treatment effect for participants with an abundant budget (two parallel lines instead of the convergent lines) had there not been any donation cap. Although the second explanation is possible, the data did not fully support it because there were very few participants who actually claimed to be willing to donate the full amount to the club, meaning that the ceiling was rarely reached. However, I cannot exclude the possibility that if there was no cap, participants would consider donating more because they were not confined to a specific range.

The treatment effects on the attitudes (e.g., Uber, MOOC, party) and on the amount of donation together present a fuller picture of the transfer process. First, participants transferred to different domains, such as marketing and politics, and did not transfer to the domain of MOOC (regulation of online classrooms or the organization of knowledge). Second, those who transferred to marketing were not necessarily the same participants who transferred to politics, as participants were free to transfer to any domain. The study did not find any variable that predicted which direction people would transfer (i.e., there was no interaction effect). Third, participants made further transfers based on their previous transfers, and the two steps were confined to the same domains. Participants who transferred to marketing did not further transfer to school politics and governance, but participants who transferred to national politics and governance did transfer to school politics and governance, as if they were extrapolating based on their first transfer. This result shows that the mental models delivered by science concepts stayed with the participant over the long term and that participants reused their transferred personal knowledge at different times, provided that the different occasions concerned the same concept domain.

Observers can only observe the transfer if the questions they probe are in the same domain to which the participants transfer. Such is the difficulty in the study of transfer. Student do not always transfer to the "useful" domains to which we hope they will transfer, such as transfer from computer programming to a more logical worldview. Students often transfer in unpredictable directions to unpredictable domains. However, because researchers have prior assumptions that these domains are "useless," they do not measure such domains and cannot detect signals of transfer. Researchers can substantially address such a loophole if they start to consider the fuzzy occurrences of romantic transfer as a problem or as an opportunity, as I will discuss in the final chapter.

CHAPTER VI:

STUDY-4 INTERVIEW STUDY

The truth being that the excessive increase of anything often causes a reaction in the opposite direction; and this is the case not only in the seasons and in vegetable and animal life, but above all in forms of government. The excess of liberty, whether in states or individuals, seems only to pass into excess of slavery. Yes, [this is] the natural order.
—Plato (360 BC)

Research question

The previous two experiments have shown that participants could spontaneously transfer from different science concepts to different social political or moral implications. This study aimed to have a better understanding of the participants' own narratives through interview methods and qualitative data analysis. The driving research questions were:

1. What mental models do the participants invoke when reasoning about social control?
2. What do they believe to be the source of social order and disorder?
3. To whom (which agency) do they attribute the responsibility for social order?
4. What expectations, if any, do they have for change over time in a social system?
5. How do participants from different groups vary in how they discuss, and position themselves, in relation to topics addressed in question 1-4 ?
6. To what extent the participants from the entropy group differ from the participants from the self-organization group in their narratives about social control?
7. To want extend the participant *disagree* that the science concepts (entropy or self-organization) are transferable to social ideas. If they do disagree, what are their justifications?

Sample

There were 12 participants in Study-4. 6 of them came from entropy group and the other 6 came from self-organization group. Their detailed information is shown in Table 6.1 (Appendix AD).

Table 6.1
Basic information for participants in Study-4

ID	Name	Group	Gender	Age	Major
E1	Tong	ENT	Female	19	Agriculture
E2	Lu	ENT	Female	18	Marketing and sales
E3	Bing	ENT	Female	19	Electric engineering
E4	Kun	ENT	Male	18	Finance
E5	Tsai	ENT	Male	18	English literature
E6	Kai	ENT	Male	19	Electric engineering
S1	Zeng	SEO	Male	19	English literature
S2	Lin	SEO	Male	18	Agriculture
S3	Wei	SEO	Female	19	Marketing and sales
S4	Jie	SEO	Female	19	Finance
S4	Wen	SEO	Male	18	Marketing and sales
S6	Hui	SEO	Female	18	Electric engineering

Analysis

For thematic analysis, following Boyatziz (1998), I first familiarized myself with the discourses and then developed codes for labeling each utterance. The form of the code depended on the actual data, but, in general, it was motivated to capture participants' reactions (e.g., trust/distrust), their understanding of the dynamics within an organization (e.g., scatter/cluster), their understanding of the source of order and disorder in an organization (e.g. external agency/internal agency), their anticipation of the organization with and without hierarchical intervention (e.g. evolve/collapse), and their justification of

their preferences. In the initial round of the coding process, I used the participants own words or phrases in order to be truthful to the data (Saldaña, 2013). I then modified the codes in the following rounds of recoding to shorten, summarize and highlight key terms to generate the most salient thematic topics. Within each topic, I categorized participants' response into multiple positions. For example, in the theme of leadership, there existed two position: one posited leadership come from external agencies, and the other posited that leadership emerges from within the system. The code book for themes contained (a) label names; (b) definition and description of each code in order to identify them; and (c) example utterances for each code (Boyatziz, 1998). The mental models (systematic metaphors) emerged "upward" from the elementary codes. Following Cameron, Low, and Masien (2010), I treated the codes as vehicles and group the vehicles into mental models.

To determine consistency, I compared the mental models that emerged from the data with the two existing metaphor frameworks. For each individual, I examined the positions that he/she took in each theme belongs to the same mental model. And between groups, I examined if the positions between the two groups are distinguishable. This analytical procedure revealed to what extent the participants' mental models were congruent or incongruent with the metaphor framework, specifically to specify how the participants useed the frameworks to reason about social organization, and how and when participants shifted frameworks or critically unpack their frameworks.

Results

The results section consists of two parts. The first reports on the themes that emerged from the interview. The second part reports on the thematic consistency within individuals and

differences between the entropy and self-organization groups, a summary of which is shown in Figure 6.1 (Appendix AE).

Themes

Five major themes emerged from thematic analysis of the participants' reasoning about the two cases (Uber and student club). Each of the themes contained two positions. The following describes each theme, its description, positions within theme. and examples in detail.

Individual agency and attributes. Participants frequently talked about the individual members from within the system. They talked about the individual qualities, including intentions, motivations, awareness, capability, and maturity as determining factors in deciding whether the members should be trusted to manage a system. Within this theme, there were two positions that participants frequently took. One posited that an individual had good qualities, such as good intentions (wanting to succeed, contributing, and attaining the greater good) and capabilities (skills and experience). The other posited that individuals (at least occasionally) could be rule breakers, and not everyone had sufficient capability to be accountable.

For example, Tong from the entropy group (a 19-year-old female majoring in agriculture) said, "This is fundamental in human nature. Some people are simply evil. They probably will use the Uber platform to con others for their own selfish interests. Because there will always be such bad people in our society, Uber will never work." Bing (a 19-year-old female majoring in electric engineering), another participant from entropy group, said, Let's not forget that we are only students. We are not mature enough or experienced enough to handle many obstacles if there weren't a teacher helping us." Zeng (a 20-year- old male majoring in English literature), from self-organization group, said, "There are good apples

and bad apples. If there are more good ones than bad, then there is hope [that Uber may work]." Hui (an 18-year-old female majoring in electric engineering), from self-organization group, said, "I think most students nowadays are pro-social people, especially students who would like to participate in the volunteer club. I believe if everyone contributed some kindness, it (the organization of the club) won't be too bad."

Unity, chaos, and spontaneity. Participants frequently talked about how a group of people could unite or fragment into chaos. Their discussions about unity and chaos were tied to their expectations of how a group of people spontaneously behave in the natural course of events. Some of the participants commented that people will naturally cluster in a cohesive manner; others commented that people will break away from unity and create a mess spontaneously.

For example, Hui said, "People with the same motivations and with the same interests will attract each other and join together on a mission." Tong said, "Too much freedom is too spontaneous and will lead to total collapse."

Leadership, its origin, eligibility, and function. Every participant talked about leadership. In this theme, participants discussed who should be leaders, why a group needs leader, and what a leader should do. There were two positions taken regarding leadership. One posited that leaders would emerge from within the group, from among members. These are leaders because of their charisma, capability, and because they lead by setting an example as pathfinders that others will follow. The other position held that leaders should come from outside of the group. These are officials coming from a higher hierarchy. They are eligible because they have official titles, bear responsibility, and have the power, recourse, and capability to lead people from within the lower hierarchy. They are responsible to arbitrate between conflicts and set rules. In brief, as a metaphor, the leader from within the group is

like a bellwether among a flock of sheep, and the leader from outside of the group is like a herding dog.

For example, Wei, a 19-year-old female majoring in marketing and sales from the self-organization group, said, "First of all, we need a leader to stand in the front line. It's like a flock of ducks; without the head duck, others won't walk. Only if there is a head will others walk. Therefore, we need someone to stand out." Kun, an 18-year-old male majoring in finance from the entropy group, said, "I don't trust the Uber as a private company because they do not have the perfect system. If there is someone from the government who can design an appropriate regulatory system, I can give it some trust."

Natural change over time. Within this theme, participants talked about the expected changes in a system over time if there is no intervention from the outside (thus, the natural change). An utterance needs to explicitly mention the long-term timeframe, such as "gradually" or "as time goes by" to be categorized in this theme. There are two positions in this theme. One posited that a system will deteriorate in the long term, even if it was well organized in the beginning. The other position held that a system would adapt, evolve, and improve gradually, admittedly facing obstacles along the way.

For example, Jie, a 19-year-old female majoring in finance from the self-organization group, speaking about the potential of a volunteer club if it is completely run by students, said, "Probably the first two years will be a total mess. No one knows what to do, and everyone is trying to feel things out. But I think it is totally possible that some of the members will find a way to work things out in four years, because they will learn as they as they go along." Lu said, "If students manage the club themselves, it will be perfectly fine in the beginning, no problem. But as time goes by, you know, when there are people, there is a power struggle, and thus there will be conflicts."

Responsibility and function of institutional structures (e.g., law and policy). The remaining major theme to emerge from the transcript was the role of institutional structures, such as law and policy. The participants talked about the responsibilities borne by those who administer institutional structures and how they should fulfill their duty. In general, there were two positions. One posited that institutional structures should actively monitor and enforce social order by giving direction and constantly checking for rule breakers. The other posited that institutional structures should establish platforms (e.g., set up a fair system, but then keep hands off) to facilitate (e.g., help when required) and as catalysts (e.g., expedite progress) individual performances. In short, there was a hands-on approach and a hands-off approach.

For example, Kai, a 19-year-old male majoring in electrical engineering from the entropy group, said, "It is useless to just make the rules if you do not enforce them. The law enforcement officers should monitor the drivers, and then the market will be regulated." Wei said, "The government should publish a reasonable policy. If the policy is fair and transparent, everyone can compete freely under the same policy. That's enough."

It is noteworthy that the themes are not mutually exclusive; they overlap and connect in a coherent way in which one theme presupposes another. Such interconnectedness reveals two general mindsets—the hands-off and the hands-on. The hands-off mindset assumes that individuals are spontaneously bound to each other. This is a precondition to the assumption that members will increasingly follow a capable leader from among themselves, which itself is a precondition for the optimistic belief that social members will gradually improve a society by themselves. Such assumptions are the prerequisites to a more relaxed social control. The hands-on mindset assumes that conflict of interests spontaneously drives individuals apart. This presupposes that external agencies deliver leadership and arbitration,

without which one can foresee a total collapse from within the system in the long term. Because of these assumptions, active social control is preferable.

Thematic Consistency Within Individuals and Differences Between Groups

The questions remaining are (a) whether everyone spoke consistently within one mindset, and (2) whether there a difference in the themes, as well as mindsets, between the entropy and self-organization groups.

Figure 6.1 illustrates the consistency of mindset within individuals and the difference in mindset between groups. There are 14 positions placed on a circle. The first two rows belong to theme-I (individual agency), the third row belongs to theme-II (spontaneity), the fourth and fifth rows belong to theme-III (leadership), the sixth row belongs to theme-IV (change over time), and the seventh row belongs to theme-V (institutional structure). The two numbers beside each position are the numbers of participants who took the position from the entropy group versus those from the self-organization group. The positions of the hands-on mindset are placed on the left side of the circle (red) and the positions of the hand-off mindset are placed on the right side of the circle (blue). The 12 participants are placed in a row in the center of the circle. An out-going arrow connects each participant to the

position that he/she took.

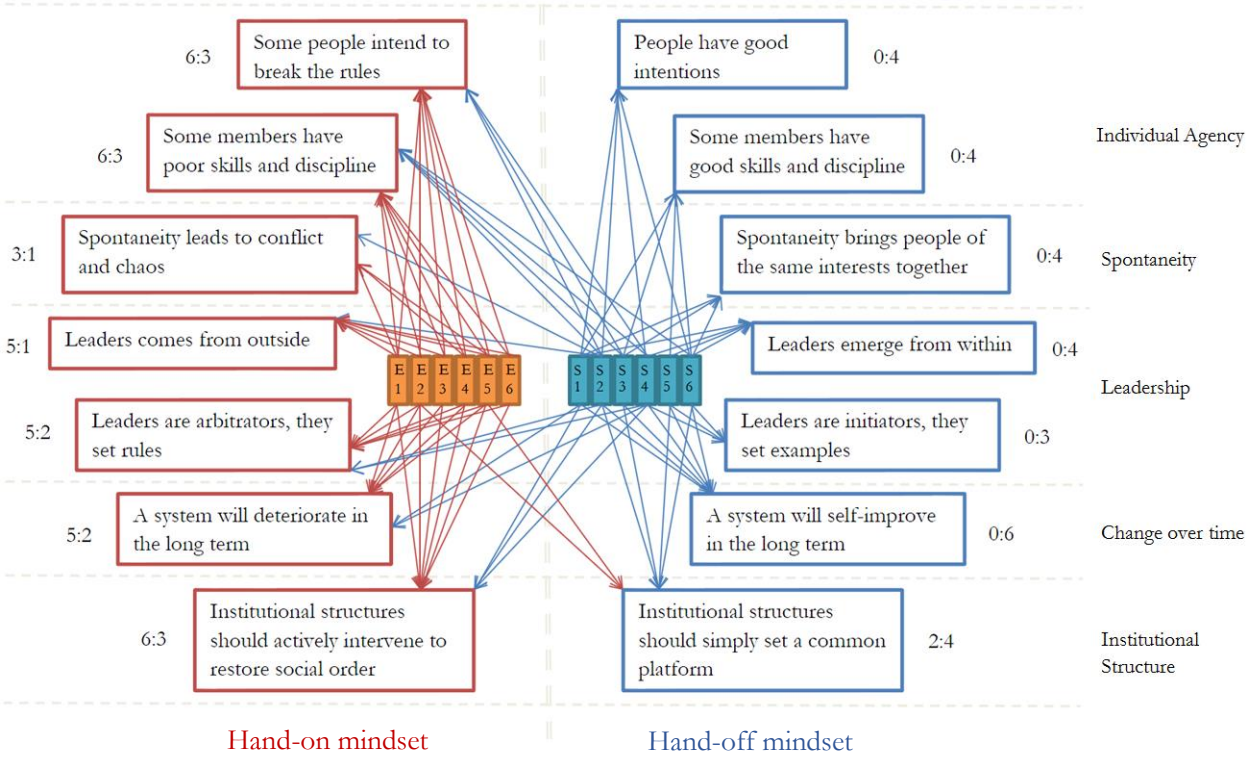


Figure 6.1. Connecting each participant to each position.

As shown in Figure 6.1 that I created (I'd like to call it a turtle plot), participants from the entropy group were almost exclusively framed within the hands-on mindset, only E2 and E5 also considered a position from the hands-off mindset. The participants from the self-organization group were predominantly framed within the hand-off mindset, although four of them (S1, S2, S3 and S4) also considered some positions in the hand-on mindset. To have a better understanding of the mindset of participants, we must look more closely at the individual transcripts.

Narratives

Lin (S2) exhibited a balanced perspective. He explained his positions regarding the management of the volunteer club, saying,

It depends. If the student members sincerely want to serve others, we should let them manage the club. They will have good ideas on how to run the club….But I also somewhat agree that the existence of a teacher in the club can be helpful. Because when you have many members, there will be many ideas. Occasionally, there might be some students who want to show off by demonstrating how unique they are. In such a situation, one teacher, who has more authority, can help resolve the conflicts and unify ideas….

The most important factor is that the students be responsible. If everyone has the same interest and the same goal, they will unite….I think the school only needs to check at the registration level (meaning officially register the club as part of the school). The school should give most of the power to students.

Lin explained his position on the regulation of Uber, saying,

It's safer to have the government involved in regulating Ubers. Some drivers will charge the customers unfairly. People have their own self-interests; everyone wants more money….If the customers give increasingly positive comments to the good drivers, and the bad drivers are eliminated through competition, the Uber system will eventually improve….The government can monitor the drivers' ratings, identify their plates and licenses, and sanction the untrustworthy drivers. Then, the better drivers will remain in business, providing a better service for the public….On a second thought, though, the drivers might bribe customers for better ratings. It's better to have the government more involved.

Lin was relatively sympathetic to student self-management. He believed students who share the same interests will united and recommended that the school only become involved at registration, as a gatekeeper. He also considered the possibility that some students were outliers who could be assimilated. In case of strong outliers, she also welcomed the involvement of a single teacher as an arbitrator and unifier. For similar reason, Lin

recommended the government to regulate Ubers regarding drivers who deceive and fraud. In her reasoning about expected change over time, she suggested a feedback loop that gradually improves the Uber market through a fair competition, charging the government with facilitating the competition platform. Lin was a prototypical example for a balanced view, one sympathetic to a hands-off approach, but welcoming of external control over possible "bad apples" within the system. As shown in Figure 6.1, other participants from the self-organization group who considered external intervention were also those who mentioned that some members might not be accountable.

Hui (S6) was a strong advocator for the hands-off approach and she explained her position on the management of volunteer club with several ideas, saying,

I prefer that the club is completely handed over to students and that the school not be involved at all….I think most students nowadays are pro-social people, especially students who would like to participate in the volunteer club. I believe that if everyone contributes some kindness, student control should work….I don't think there will be too much of a problem. College students are mostly adults. I believe they have the ability and the intention to organize this club well. This is a good opportunity for them to develop themselves and become more mature. They cannot adapt to society if elders always protect them…. If everyone starts the effort with good will, they will make efforts to work together in the club. There will always emerge someone who can lead, and other students will respect that person. He/she will be a good leader, and everyone will work together to make the club great…. We need to take the time to practice and to handle the real work in society. Maybe we are only freshmen in college and we are not very experienced, but we should do it ourselves so that we can develop ourselves.

Hui spoke of her position on the regulation of Ubers, saying,

I know some are worried about "black cars" (illegal taxis that overcharge and are unsafe), but there are only a few of them after all. Uber will add convenience to people's lives. The traditional taxis can still run their business. I don't think there are any serious conflicts….In a healthy society, people can follow rules without government involvement and intervention….It requires citizens to have the awareness, a spontaneous idea that is shared by all….But this is difficult, and under the current situation in China, it's hard. People's qualities (character, virtue) need to improve….So, I think the government should be involved a little bit, to set the rules that can constrain the drivers. But its role should be limited and Uber should run as usual.

Hui was optimistic about student self-management. Her optimism was based upon the assumption that most members were pro-social, that they would be united by their same interests, and that capable leaders would emerge among the members. Her optimism was also applied to the regulation of Uber. She believed that ideally Ubers drivers could regulate themselves if they shared the same awareness, but considering it more realistically, she recommended minor government involvement.

Lu, who supported strong interventionist approaches, was a prototypical example from the entropy group. She explained her position on volunteer club:

This is a difficult question; it fundamentally depends on the teacher who joins the club. If this teacher wants to manage the club well, he will work hard at it. That's good for the club. If the teacher is only here for the title, does not do much work, but hands over all the duties to students, then the club is doomed to fail.... Anyway, I think it's better to have some teachers in the club; they are older, more capable, and more experienced than students are. If they are responsible and want to do it well, it's good for the club....If students manage the club themselves, it will be perfectly fine in the beginning, no problem. But, as time goes by,

you know, when there are people, there is power struggle, and then there will be conflicts. When some students have increasing power, they will have increasing conflicts. I believe everyone has two sides; some of the time, you are dominated by your kind side, but at other times, the evil side takes over. When self-interests lure one's evil side, he cannot resists it....Power struggle is so common in the management team of the club, there will be a number one and a number two. Everyone will think he/she is better than others and will want control over others. Everyone will want to take the credit and also the benefit. I don't think people placing their moral standard before lucrativeness. I think the best system should control the smartest people so that they cannot sneak through the loopholes. But of course, everyone should be involved in designing such a system; once it's well designed, you can let it spin….I trust the school administrators more because they are outside of the system and outside of conflicts of interest. They will see the problem from a neutral and fair perspective. They can monitor and manage without being entangled in the conflict of interests.

Lu explained his position on the regulation of Ubers, saying,

My first intuition would be to have a government-owned version of Uber. Because government has the authority, it is more official. It can identify every driver and every customer; so it's safer. When there is any problem or conflict, you know who to call….Conflict of interest is unavoidable, it's destined to happen, I think it's very difficult to prevent it….I am afraid that Uber cannot regulate itself. The odds are 70% against it.. I think we need the government or a third-party agency to regulate it. Of course, the customers should have a say. But after all, the government is dominating and controlling everything."

Lu believed that power struggles and conflicts of interest are prevalent and unavoidable. She preferred regulators from outside of the system to resolve the conflicts, restore, and maintain

order. She not only preferred the existence of an external regulator, she also expected the regulator to practice active leadership and provide arbitration for the system. She had the complete opposite expectation of change over time than did Lin and Hui. She assumed that a highly-ordered system would spontaneously collapse over time.

Tsai was another example from entropy group. He explained his position on the management of volunteer club, saying,

I think the students should have most of the power and take most of the responsibility. But there will always be times that they encounter problem they cannot solve. Therefore, it's good to always have some teachers involved to give instructions....Although college students are already adults, they do not have experience in society. An instructor would have more experience and more connection than students….Without an instructor, the students will probably be shy and timid in the beginning. They don't know which direction to go, are afraid of taking actions, and restrain themselves in a small space. But as they get relaxed and expand to a larger space, they will probably become too daring, unchained, and they forgot who they are and their own limits….[Question: "What do you mean *unchained?*]…They go about all directions, do too much, and make a mess.

Tsai further explained his position on the regulation of Uber, saying,

I think, although our government is not always reliable, I still tend to trust the government….I can understand that car owners want to make some money using their own car. If the government comes forward to promote such a kind of economy and publish a comprehensive system to regulate it, that's fine….Without government intervention, however, there will remain the possibility of illegal conduct. Granted there might be some drivers who are trustworthy, but there might also be some drivers who would kidnap you for ransom….We don't need the government to manage the company, but we need government

to create a complete regulation mechanism and to monitor the company and its drivers….I don't think it is practical to expect a healthy market without government control, at least not in our current society. Maybe it's possible when communism is achieved. But I don't know how many years it will take, not likely to happen before I graduate from college....[Question: "What would communism look like?] A perfect social economic system, a perfect legal system, and everyone has awareness of law. All citizens are united to cooperate with each other and with the government. Not now, not like this.

Tsai, unlike Lu, did not strongly believe that people are destined struggle with each other. He had hopes that the students should be the key players in the club and that Uber should be kept as a private company, but he did not make direct acknowledgement that students or Uber drivers are accountable. He believed that even if (hypothetically) some members exhibited good will, the potential problems and "bad apples" would disorganize the whole system. He preferred an external agency that not only created and maintained the platform, but also actively provided instruction or supervision to the members. He also shared the mental model that particles condense initially, but that they behave chaotically as they expand. He envisioned a perfect society that he labeled as "communism" in which all institutional structures are perfectly designed and all people will abide by laws as a united group. His vision for a top-down unity contrasted dramatically with the vision of Hui and Lin, which was built from the bottom up from the level of individual members.

Discussion

The interview study gives us a glimpse into the mental model that participants relied upon when they discussed social organizations. The most apparent finding is that none of the students directly cited the thermodynamic theories. None of the students made claims that they supported or were opposed to hierarchical regulation because of entropy or self-

organization theory. This suggested that the participants were not aware that the interview was related to the science lectures and they were not trying to give socially desirable answers. This result appears to disprove the hypothesis that students actively drew on science theories to support their social beliefs. However, given the systematic difference in participants' narratives between groups, I can reasonably argue that participants generated (or selected) and relied upon a personal wisdom that was consistent with the science treatment they received, even though they did not give direct credit to the science treatment but assumed the wisdom to be their own. It is possible that the science model affected the participants to shape their mental models for social organization, but for various reasons they avoided using the physics terminology directly. One of the possible explanation is that the participants were not sure if the interviewer had knowledge about the thermodynamic theories (the interviewer was not present in the science lectures), they did not want to take the trouble to introduce a physics theory with which the interviewer had no familiarity, but instead they explained it in a lay language in the social context without reference to physics theories. Another possible explanation is that they were not fully comfortable with using the new academic terminology, or perhaps they did not remember the exact (and low frequency) vocabularies, although they understood and had been affected by the essence behind the vocabularies. Moreover, it is also possible that the participants were aware that they were transgressing boundaries between different disciplines, that they worried about the validity of the transgression, and that they were too shy to claim or acknowledge directly having made the transgression, even though they were still trying to express the idea borrowed from the physics discipline.

The positions that participants took were largely consistent with the expected implication from the science concepts that they received. The theory of entropy emphasizes the

inevitable increase of chaos absent the necessary introduction of higher ordered energy from outside of the system. Consistently, participants from the entropy group were more in favor of hierarchical regulation. They were concerned the prevalence of rule-breakers, the inevitable deterioration of social order, and the necessity of leaders who make and enforce rules, maintain order, and arbitrate conflicts. Such a should come from outside of the system. None of the participants from the entropy group ever mentioned that there were rule abiding and self-disciplined members of good will in the system. (They did not claim there were not any good members, but they did not mention there were any; instead, they focused on the possibility of bad members). None of the participants considered it possible that the social system could gradually improve itself without external regulation. All were were certain that a social system was destined to collapse without external regulation. It seems surprising that there were no balanced views from the entropy group, but considering the dominating discourse of strong centralized control for social stability and harmony in the current Chinese political and cultural context, it is not surprising that the entropy model reassured and enhanced participants' existing ideologies, consensus, or social desirable responses.

The theory of self-organization emphasizes that the highly regular and intricate patterns in the physical world can gradually be shaped from local interactions that do not need, and cannot be achieved by, external design or control. Expectantly, participants from the self-organization group shifted their focus onto the good members within the social system. They attributed social order to the shared goals and shared interests of the individual members, they anticipated leaders to emerge from within based on interaction and attractions among members, they also expected a social system to gradually improve itself through feedback and adaptation, and they also considered the role of government or

administrators to be setting the common platform or facilitating members' performances. Interestingly, their positions were more balanced than the entropy group. Participants from the self-organization group also considered the possibility of the existence of rule breakers; some mentioned that it was more practical to have external agencies enforce rules or expedite the improvement of the social system. This balanced view showed that these participants still hesitated. It suggests that they were diverging from their baseline assumption (similar to the entropy group) that they had learned from their ideological education or from their daily experience. They recognized that there were rule breakers and that people should rely on officials to prevent or eradicate rule breakers. It also suggested that participants were making the transfer with a critical mind. They were affected by the science model. They made the transfer, but they were also examining the transferred implications in light of their a priori experience and the realities. As a resolution, they added additional constraining conditions to their transference, such as, "I think students can self-govern the club, if certain conditions are met, such as there are enough number of members who have good will and self-discipline. If there are many rule breakers, I would prefer some external intervention."

The interview data is a valuable addition to the experiment data presented in Study-3. It partially illustrates the mental models that explain why the two groups had different preferences in social organizations. It also partially explains why it was sometime difficult to observe transference. The answer to this question from the interview data is that (a) students do not always feel comfortable using a newly learned vocabulary even if they have already transferred and (b) students are aware of the special circumstances between domains that may make the direct transfer unreliable. Instead, they may set additional conditions on the

transfer. In other words, participants may have already transferred, but they do not fully believe in it because the additional conditions that they set to the transfer are not yet met.

Let us assume for now that the baseline ideology commonly shared by freshmen-year college students coming from an agriculture-based third-tier city in China is to trust the government and follow the government, which is not a very radical assumption considering the propaganda, ideological education and ideological examination that each of the students had to pass through to get into and graduate from college in China. The entropy concept fits in with, attracts them to, or enhances students' existing ideologies, whereas self-organization challenges or bifurcates students' existing ideologies and promote alternative ideologies through the students' self-generated transference. The transfer is not simply carrying over the science theory to reach an arbitrary conclusion; it creates a rich mapping between domains based on their shared features, and students can formulate a coherent mental model to substantiate their social beliefs.

CHAPTER VII. GENERAL DISCUSSION

Nature should say everything or nothing, that I might see which cause I ought to follow
–Blaise Pascal (1660)

In an early winter evening of 2016, I picked up a good friend of mine, Ran, heading for a Chinese restaurant on the outskirts of Framingham, Massachusetts. At that time, Ran was dropping out of an MIT PhD program, and a dozen friends were getting together at the restaurant to give him comfort. On our way to the restaurant, I chatted with Ran about my dissertation topic and my findings. My Study-3 quickly got Ran's attention because he was the teaching assistant for graduate-level course in thermodynamic theory in MIT's chemical engineering department. He reflected deeply for a moment and said, "You should know there is a big problem in your assumption." I got very nervous and thought, Ran is a *critical defender*. (Chapter I categorized consumers of romantic transfer as defenders, appreciators, followers, and pioneers).

Ran said further, "You are assuming entropy and self-organization theory to be two incompatible theories, but in fact they are compatible within exactly the same framework of *Gibbs free energy*." He continued, "A system tends to rest at its lowest Gibbs energy, so the available Gibbs energy quantifies the energy potential of a thermodynamic system. You do not need to understand this, but just remember the formula, $G = H - T \cdot S$, where G is Gibbs energy, H is energy restored in a system, T is the temperature, and S is the entropy. When T is constant, there are two ways to reduce G to reach the resting state quickly, to reduce H, or to increase S. When temperature T is very low, a system is very cold, and increasing S is useless because T times S makes $T \cdot S$ very small even if S is large; thus, a system would not necessarily rest at a large entropy state, but could reach a low G by reducing H instead. This is when you get a snowflake; your temperature is low, entropy is low, and restored energy is reduced to reach a resting state. Now consider when temperature is very high. Entropy is

weighted as very important, and increasing of entropy can quickly reduce G even if H is high. That way you can reach a resting state with high energy and high entropy."

I was barely able to follow Ran. He continued, "That being said, the analogy that your participants made is very interesting. Entropy is the social disorder, and energy is government control. When you have high social order, meaning low entropy, you can have low government control; when you have low social order, meaning high social entropy, you will need high government control to reach the stable state in a society. I got it. It's an interesting idea." Okay, so I am a bit relaxed and thought: Ran is probably somewhere between a tolerating *appreciator* and a joyful *follower*.

But Ran did not stop there, he thought aloud further and said, "Okay, then you must answer what is T in your equation? If you want to explain everything with Gibbs energy, what do you think is the temperature equivalent your social domain?"

"What do I think?" I have no idea.

Ran apparently did not expect an answer from me and gave the answer directly, "Ah! Let me tell you, temperature is the education level. Low temperature means high education level, high temperature means low education level. When education level is high, T is small, then people can stay harmoniously with low social entropy and low government control; when education level is low, T is high, then human groups will reach equilibrium in a chaotic state and can use some government control. So, you should see it now as a PhD-to-be in education, that education cools people down. Without education, people are restless fireballs, they crave for entropy, crave for indulgences, they would not stop until there are no more rules to break; with education, people are cooled down, they start to enjoy self-disciplined order and can regulate themselves without government controlling what they do." Ran turned out to be a *pioneer* in romantic transfer.

I was left stunned, with waves of revelation rushing in to my head, recalling how eagerly my participants in Study-4 called for taking individuals' education and "quality" into consideration.

Summary of Key Findings

The four studies presented in this dissertation concluded with the following findings, which, taken together, tell a fuller story than does each individually.

1. Participants who held strong scientism beliefs (believing in science as a faith) were more inclined to have a transferential learning style, and people who combined scientism with a transferential learning style were most likely to give literal interpretations to (religious) text.
2. Participants who learned different science concepts could transfer to different domains of social ideologies. Those who learned conservation of energy were more likely to believe that luck is conserved. This idea is slightly different from the karmic doctrine in that karmic doctrine teaches the gaining of virtue through suffering, humbling, and undoing, whereas the idea of conservation of luck held by participant suggests restoring luck through making use of extra effort up to but not including the point of exhaustion of effort. This idea is analogical to the transformation of energy to energy potentials taught by the conservation of energy. Those who learned entropy were more likely to prefer tightened external control, be it in the field of politics or marketing, whereas those who learned self-organization theory were more likely to prefer relaxed external control and more individual freedom.
3. There are multiple possible domains to which participants transfer. Once a participant transferred to a specific domain, he/she made further extrapolations within the domain, but not extrapolation to other domains.

4. Participants did not directly use the lexicon from the science domain to reason in social domains; instead, they organized their own language to rephrase the science theory and to explain their social beliefs; further, participants from different groups who received different science concepts took different positions in their social discourse but shared similar positions within groups, and the positions were largely consistent with the implications of the science concept that they received.
5. Participants did not make the transfer or accept the transfer mindlessly, instead they were either biased by their prior belief (e.g. preexisting ideology of social control) to reinforce the transfer, or set prerequisites (or conditions) to evaluate the plausibility of the transfer in the specific context.
6. I did not detect an interaction effect between treatment and preexisting scientism belief or transferential thinking style (e.g. treatment×scientism, or treatment×transferential). I had hypothesized that participant with scientism beliefs and transferential thinking style were more likely to transfer in Study-2 and Study-3. However, the data did not support such a hypothesis, possibly because the effect size was small and I did not have the power to detect a more subtle interaction effect. Nevertheless, it is also possible that explicit self-assessment of a transfer tendency does not always agree with the actual romantic transfer which is implicit such as the romantic transfer from entropy to a hand-on approach mindset, and in fact, everyone had equal chance to romantically transfer. Those who do not report themselves to be transferential actually did transfer in the experiment.

Reflection on Romantic Transfer

The most material question about romantic transfer may just be whether it is good or bad, right or wrong. However, I designed the studies in this dissertation to avoid the

question as to the scientific correctness of the potential romantic transfers. The questions in the post tests were controversial, yet none of them had absolute correct answers and none of the potential romantic transfers were dangerous ideas. Thus, this dissertation by its design cannot serve as the arbiter of the justness or correctness of romantic transfer as a learning product.

This research bears on Aristotle's assertion, "Metaphor is a sign of genius." Firstly, students do connect science knowledge to their lives by themselves; science is indeed relevant to them and they are able to find the relevance. Second, they are able to assimilate the scientific language into a personal vernacular for discussing social issues, without losing (or distorting too much) the essential meaning of the scientific theory in principle. The fact that students can paraphrase scientific tests is a sign of deep understanding. Third, they (sometimes) can evaluate the applicability of the transfer critically.

There are, however, a few worrying signs of concern: Students who make transfers are also prone to literal interpretations. This directly responds to many concerns introduced in Chapter I. As Dewey (1910) worried, science sometimes does pave the way for occultism and revelation; and as Goodman (1995) described, there are indeed people who place strong faith in science who are also secretly or potentially very religious. This is because people who are most interested in seeking corresponding patterns between domains are also most likely to take the analogy literally. Imagine a science education that trims the amount of content and reduce to a handful of core knowledges that can cut across between disciplines, as Cooper et al. (2015) suggested, and, in the meantime, fails to provide the training of scientific methodological mindset to discern misplaced generalization, we should anticipate increasingly tenacious misconceptions in the social domains or aspiration for intellectual design in religion, empowered by romantic transfer.

Science is very powerful, it is not only powerful in its understanding of nature and in building technologies, it also gives power to social discourses and social negotiations. When people learned (a) a widely applicable science understanding, (b) personally made a romantic transfer to other domains based on that understanding, and (c) took it literally as a personal wisdom but (d) not equipped with a mindset that has been trained with scientific method to evaluate the transference, they then (e) feel the power of science and the joyful ownership of such a power simply because they personally created a theory. This is what we have observed in the post-modern treatment of science: that (a) science is a story to tell, (b) a human activity confined by human subjectivity; (c) any person is free to transfer scientific principle according to personal discretion; (d)there is no single such transfer whose superiority over others is guaranteed, as Latour and Woolgar (1979, p237) famously said, "reality is the consequence rather than the cause".

Such a trend poses a threat to the authority of scientists, because the lay people do not consider their own mental exercises to be much different from the endeavors of scientists. Gross and Levitt (1994) criticized such a literal interpretation and the preaching of romantic personal wisdom backed by a scientific lexicon and named it "higher superstition." This probably explains why certain misconceptions are resistant to change even if a lay person has been warned by scientists, as for example (a) by believing antioxidant can prevent aging (even if the doctors tell the otherwise) in which a lay person transfers a superficial understanding of chemical oxidization to human bodies without being aware of the complicated genetic expression and microbiological reactions or (b) the fear of trans-genetic food (even though biologist do not find any harm in it) through the transfer that genetic mutation in vegetables will lead to genetic mutation in the human body without understanding the digestive process.

Alan Sokal, a professor in physics, wrote his masterpiece "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity," in which he speculated how quantum physics is interconnected with literature and philosophy. In 1996, *Social Text* published this article in its special issue to attack Gross and Levitt's anti-postmodernism arguments. A few weeks after its publication, Sokal revealed in another magazine that his article was a parody, later known as the *Sokal hoax*, to mock the postmodern transgressive interpretation of science. In reflection of his own hoax, Solal lamented,

> Yet entire Ph.D. programs are still running to make sure that good American kids are learning the hard way that facts are made up, that there is no such thing as natural, unmediated, unbiased access to truth, that we are always prisoners of language, that we always speak from a particular standpoint, and so on, while dangerous extremists are using the very same argument of social construction to destroy hard-won evidence that could save our lives. (p 136)

Bruno Latour (2004), Harry Collins and Robert Evans (2002), sociologists studying science, who have advocated that science is socially constructed, and that "the natural world has a small or non-existent role in the construction of scientific knowledge" (Collins, 1981, p3), have started to defend the objectivity of science from abuse of scientific concepts and terminologies, in the recent decades. After reading how politician argued that global warming is only a debatable opinion with insufficient and inconclusive evidence, Latour (2004, p226) reflected: "I myself have spent some time in the past trying to show 'the lack of scientific certainty' inherent in the construction of facts. I too made it a 'primary issue.' But I did not exactly aim at fooling the public by obscuring the certainty of a closed argument—or did I? ... I intended to emancipate the public from prematurely naturalized objectified facts. Was I foolishly mistaken? Have things changed so fast?"

My own observation is not as radical as Sokal's. romantic transfer is not destined to corrupt one's mind, as shown in the findings of this dissertation. It is a random walk in all

directions and is affected by its social ideological context. The spontaneity of the random walk gives a sense of innocence to romantic transfer (because it is inevitable and largely unintentional). What remains problematic and dangerous is the second step, or the lack of a second step. The second step after spontaneous transfer is to evaluate the transferred conclusion using scientific method, which aligns with Dewey's calling for a science education as is rooted in method but not in mere facts. Dewey did not intend scientific method to be laboratory training, but rather a mindset that understands what constitutes a scientific procedure of problem solving. The danger about which Sokal reflected is a lay public that learns a list of superficial and authoritarian scientific facts, romantically transfers, and combines with a mindset that believe scientific method in the postmodern era is no more than subjective opinion.

Another worrisome sign occurred to me is that it is apparent that science knowledge can be used abusively for social programing. A dictatorship, for example, can selectively emphasize the destined natural course of entropy in its propaganda aimed at tightening social control or international interventionism can selectively emphasize the natural occurrence of self-organization theory to encourage regional revolt and separatism. In his book, *Seeing Like a State*, anthropologist James Scott (1998) described how societies arrange themselves per the universal and context-free science that Scott termed *authoritarian high modernism.* His examples include the way Germany regulates its forests by "imposing on disorderly nature the neatly arranged constructs of science" to collectivization of agriculture in the USSR and compulsory villagization in Tanzania. In year 2016, the world witnessed the Chinese government developed a new social credit system, in which every datum on every citizen, such as, but not limited to payment history, travel history, medical history, and online history is collected in a citizen social credit system. This system then makes many decisions

automatically, such as whether a person is eligible to receive a passport to travel abroad. Such a governmental action did not encounter much objections, partially because it was disguised by the national excitement over a new age of "big data and machine learning."

Romantic Transfer as a Problem and an Opportunity

If romantic transfer, as suggested by the findings in this dissertation, is a spontaneous habit of mind, the solutions to the problems posed by romantic transfer should reside in the processes that occur before and after spontaneous transfer. Before transfer, students are tempted to map the features from the science domain to the social domain. At this stage, a richer understanding of the features in the science domain, such as the conditions, the boundaries, and the complexity of the scientific knowledge will provide students with more sophisticated criteria to evaluate the fitness of the mapping. Otherwise, when science teachers reduce complex science contents to a few core and crosscutting concepts, or further reduce scientific theories into a one-line Dobzhansky template, as suggested by Luna (2015), the features from the science domain will be significantly reduced and so will be the threshold for romantic transfer. This dissertation has already shown that students are mindful of the conditions or exceptions in determining the plausibility of romantic transfer. More facilitation in this mindfulness activity, such as reminding students of the implicit and metaphorical transfer, will probably be helpful in guarding against hasty transference. In other words, mental exercises in observing the dissimilarity is equally as important as synthesizing the similarities in science education. Under the zealous trend towards interdisciplinarity, science educators are practicing more of the synthesizing similarities than discerning dissimilarities.

After transfer, students often are content with the analogy but neglect the importance of examining the transfer with scientific method, because they do not

understand the mechanism in the black box; nor do they understand the methods to examine their transfer. For example, as all food, organic or trans-genetic, will be digested (dissolved and reshuffled) into amino acids before being absorbed by human bodies. The mutation in trans-genetic food only means the sequence of amino acid in their DNAs have changed, but the amino acid itself is the same. Therefore, theoretically, trans-genetic food cannot infect its mutation in human bodies. To provide a deeper understanding of the theories is not sufficient. Students should also understand that their own theories of "contagious mutation" are valid as hypotheses, that scientists also generated just like him or her, or any other science learners, moreover, scientists took it very seriously. In the following step, students should understand what scientists do in the field of public health, what kind of research has been done to examine this hypothesis, and more importantly, what are the methods one should adopt to scientifically test similar hypothesis. Such a training of scientific method does not rely on laboratory operations, but rely on deep understanding of theory, hypothesis formulation and the methods for hypothesis test. 100 years has passed since Dewey gave his speech on Science as Subject Matter and as Method, the education of science as a method is still not fully achieved (Rudolph, 2014; Smith & Girod, 2003), and people are still selling and buying anti-gravitational-wave-radiation clothes for pregnant women.

In addition to complexity and method training, another curricular feature (not merely confined to science education) is the awareness and tolerance of metaphor. Awareness of metaphor means sensitivity and acuity in detecting the metaphors in language and text. Tolerance of metaphor means to be content with the fact that some claims or doctrines are only metaphors, and to resist the urge to push for a literal interpretation. Poet Alexander Pope is famous for the line, "A little knowledge is a dangerous thing." In my perspective,

there are four steps involved in "a little knowledge" becoming "a dangerous thing": (1) A little knowledge plants the seed for romantic transfer, (2) romantic transfer is not examined with scientific method, but acquires scientific authority, (3) the romantic transfer, which is a metaphor, is taken literally, and (4) people carry their literal understanding of a metaphor into social actions that are possibly dangerous to themselves and to societies.

If educators understand the attributes, limits, and potential problems of the phenomenon, romantic transfer presents potential utility in social or civic education because science theory provides a reasonable continuous supply of new prototypes for transfer. In communities that are open to diverse perspectives, new science models can potentially bring about new perspective for intellectual discussion and enjoyment. For communities that are not open to the suggestions of different ideologies, new science models can introduce alternative perspectives through self-generated transfer. For students who live in an authoritarian community with strong censorship in ideological education, learning self-organization theory may empower individual agency and grass root organizations. For students living in deeply religious communities, learning evolution theory may encourage them to question the origin of human species. Such was exactly the strategy chosen by Darwin (1880, p1) who said: "it seems to me (rightly or wrongly) that direct arguments against Christianity and Theism hardly have any effect on the public; and that freedom of thought will best be promoted by that gradual enlightening of human understanding which follows the progress of science. I have therefore always avoided writing about religion and have confined myself to science." Nevertheless, I do not believe this is the most valuable opportunity afforded by romantic transfer, as such an introduction of new perspective is still unscaffolded and still eases the way to literalism and extremism. The greatest value that Romantic transfer presents to educators is the self-driven interest in nature and society, the

self-generated hypothesis of the human world, and a self-initiated window period for an alternative worldview. The moment a student makes a romantic transfer, we know that he/she has generated a hypothesis about human society. According to Dewey (1983) and other advocates for a discovery oriented learning (e.g. Brown & Campione, 1994), "learners learn best what they discover or can be led to discover for themselves" (Cobb, 1999, p15). Once a student invests his/her intelligence and imagination in romantic transfer, an exceptional opportunity is afforded to educator to bring in explicit debate and discussion and to introduce not only the scientific methods that examine nature, but more tools to examine social hypotheses.

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In Chapter I, I discussed the parallel between learner and scientists—that the learner goes through steps in science learning that are similar to scientists in history, and just like scientists, learner make hypothesis based on romantic transfers. Figure 7.1 (Appendix AF) illustrated the cycle of science inquiry by scientist (modified based on Munafo et al., 2017, and explained in detailed review by Pedaste et al., 2015). In most cases of romantic transfer,

and in most cases of informal science learning, students are only practicing the steps in the top left corner in the red triangle in Figure 7.1 (from interpretation, to dissemination, and to generating new hypothesis). Most of the apparent suggestions (the "easy cures") that I provided above, such as deeper understanding of science results, setting boundaries, avoiding misplaced generalization, discerning dissimilarities and being aware of the metaphor, are confined to this three-step triangle. I consider these suggestions as defensive approaches, as they are designed to prevent misconception and hasty generalizations. The reason that most students are confined to these three steps in informal science learning (such as learning science from pop culture or casual readings) is because this is the most economical (and entertaining) way of thinking like a scientist. It only requires making sense of science, hypothesis generation, and perhaps some thought experiments. Everything is carried out mentally, and it does not require any methods, equipment, or even further reading. The reason that most of the "easy cures" are also confined within this triangle is because (a) this is the most direct response to the problem, and (b) the solutions intend to eradicate the problem, rather than seeing it as one stage in the full cycle of science inquiry.

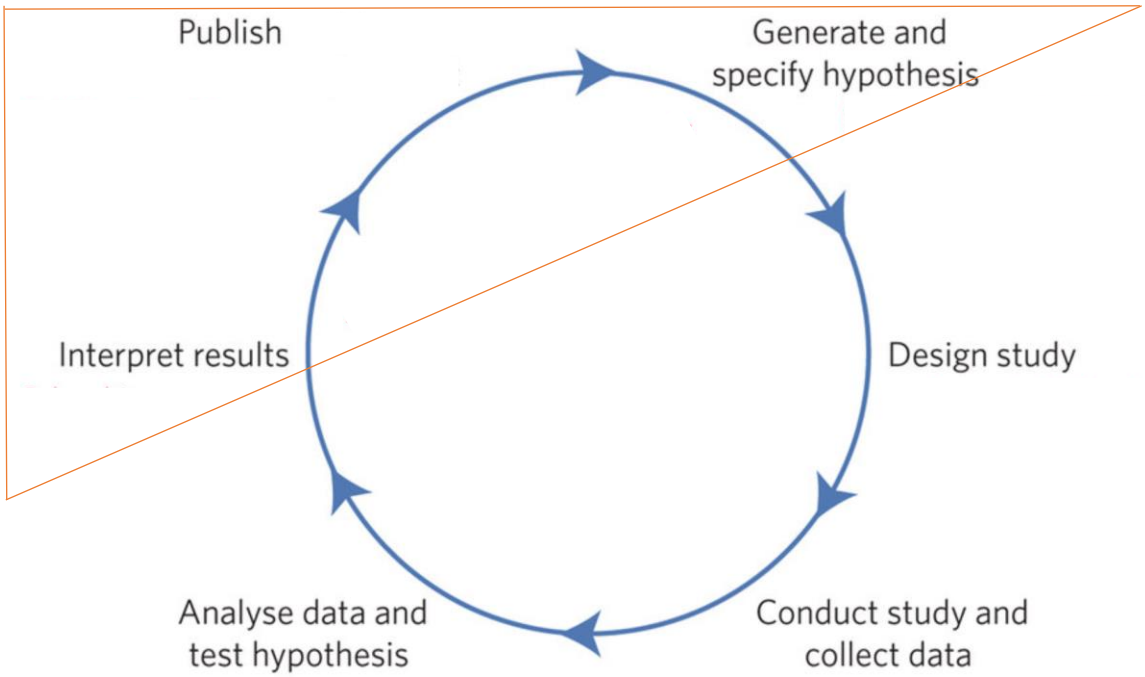

Figure 7.1. The cycle of scientific inquiry among scientists from generating hypothesis to publication and back to new hypothesis. The red triangle includes the three steps that students go through in romantic transfer or informal science learning (source: Munafo et al., 2017).

Once we changed the narrowed vision from the triangle to a fuller vision to see the cycle of science inquiry, we should be able to see the "scientists" way of responding to a romantic transfer—to treat it as a question, not a problem. To answer to the question, one should move forward to examine his/her hypothesis carefully. This is not a new approach, having been advocated by the American Association for the Advancement of Science (1993) and the National Research Council (1996) in the name of inquiry-based learning. It has also been practiced in the field of science education for decades (Chang & Mao, 1998; Nelson & Ketelhut, 2007; Zacharia, 2003). Research has shown that inquiry-based learning not only improves students' understanding of science as knowledge and as methods (Cuevas et al., 2005) but also raised students' interests in science as a career (Gibson & Chase, 2002). Dewey (1910) in *How We Think* provided a systematic operation of inquiry-based education,

including (1) defining the problem, (2) noting associated conditions, (3) formulating hypotheses, (4) elaborating various potential solutions/hypothesis, and (5) testing the ideas. Roger Bybee et al. (2006) reorganized the procedures to propose a 5E instructional model, which includes Engagement (inviting students to express their current understanding), Exploration (messing around with materials and ideas), Explanation (explaining in students' own words), Elaboration (making conceptual connections to new experiences, events, and ideas) and Evaluation (assessing students' progress and current ideas). The 5E instruction model has been thoroughly evaluated and shown to be effective in improving students' understanding of science concepts (Akar, 2005; Cardak, Dikmenli, & Saritas, 2008).

My argument is that physics teachers should apply inquiry-based learning procedures not only to physics hypotheses generated by their students, but also apply them to cross-domain and romantic hypotheses generated from their classrooms. Such a proposal is practical for two reasons: first, a huge number of contemporary science teachers are experienced, or have received training, in inquiry-based education techniques and this is not a novel pedagogy for them to acquire. Second, the inquiry-based pedagogy does not demand that teachers provide the correct answer; nor does it demand the teacher to lead the romantic transfer. Instead, inquiry-based pedagogy stays open and truthful to students' original imagination and hypotheses. This pedagogy provides teachers with tools to scaffold their self-exploration, elaboration, and evaluation, just like supporting self-motivated social scientists. I do not intend this pedagogy to be the only or best response to romantic transfer, partially because this may not be the most economical approach. Inquiry-based pedagogy requires a very personalized curriculum that helps students to complete the circle of (social) science inquiry. Nevertheless, I would argue that this is a rigorous scientific or social scientific approach.

Limitations

Sokal (2008) said in *Beyond the Hoax*, "We scientists tend to be more cautious when stepping out of our own field, and with good reason, for we know from personal experience how easy it is to make a fool of oneself." His assertion is especially true for someone like me studying the question of transference as I inevitably cut across multiple disciplines that are not my expertise. My dissertation project is limited in several salient ways, as the following paragraphs discuss.

First, this is not a behavioral study. I only measured participant's self-assessed report on different attitudes, but cannot assess the external validity of the conclusion, namely, if participants would have acted the way they reported they would in the survey. The primary effort I made to assess participants' behavioral reaction was to ask the amount of money they would like to donate to the student club—a real-life scenario. Even so, I did not call for an actual donation, but only a willingness to donate. As argued above in this chapter, the most interesting and probably the most dangerous step of romantic transfer occurs when people turn their transfers into action. Unfortunately, I do not have any measurement of participants' actions. Interpretation of the findings should be confined in the level of self-reported attitude or self-described perception, but not to generalize to social actions.

Second, I have spent much effort in avoiding explicit priming in order to measure spontaneous and implicit associations. However, it is always possible that the participants were still primed. If we generalize the definition of priming effect, any earlier event that brings about psychological change can be considered a priming. It is fair to describe the experiment as a simulation of a classroom scenario in which a teacher is not interested in making transfer, does not make any transfer, and is agnostic about students' potential transferences, but students can be primed to make transfer freely. The most critical question

is not whether students were primed, but rather noticed that the strange questions they were being asked were related to the lectures they had received and, thus, gave socially agreeable answers to cooperate with the lecturer or administrators. There are two indicators that this did not happen. First, it is fair to assume that at least in the donation test, the students were not aware that the questions were related to the lecture that they received because the donation test took place three days after the lecture and as art of a schoolwide survey administrated by the school. A treatment effect for the donation test showed that students could transfer in the long term and without being aware of the connection between the posttest and treatment. Second, in the interview study, none of the participants used any thermodynamic vocabulary in their responses. If participants were aware of the connection between the interview and the treatment, they might feel pressured to use more vocabulary from the lecture to demonstrate social agreeability. Nevertheless, because the studies did not provide explicit hints for transfer making, I cannot draw any conclusions as to what would have happened if there were any hint or encouragement. The suggestion I made earlier for more explicit debate and discussion to improve social understanding is largely based on speculation.

Third, the participants were sampled in a small scale rural city in China. The city is not representative of the general Chinese population. Still less possible is it to assume that the participants speak for students from other countries, such as those in the English-speaking world in which I currently live. It should be interesting for future studies to compare the occurrence of romantic transfer in different cultures. China has its distinctive cultural and ideological environment that encourage transfers. It is a nation that has been heavily influenced by teachings of Confucianism, Taoism, and Buddhism that emphasize on flow of energy and the interconnectedness of all beings; it is also a socialist society that place

authority and modernity of science above social dialects. Do students from the English-speaking worlds also romantically transfer? I do not have the answer. From the literature I have collected, however, a great deal of the discussion about transfer comes from English-speaking authors, and it is reasonable to anticipate that romantic transfer is also a common habit of mind in Western nations. I, although a Chinese, am not an expert in China studies. Because of my own limitations, this dissertation lacks a thorough review of Chinese philosophy and Chinese sociology of science. Instead, I treated the romantic transference as a psychological phenomenon and tried to disentangle the question using psychological methods.

Fourth, it is difficult to avoid the trap of overinterpretation when studying anything related to metaphor. I have attempted to differentiate statistically reliable treatment effects from my own speculations in trying to make sense of the learners' mind. For example, in Study-2, there were significant treatment effects on most of the items related to the conservation of luck, but there were no treatment effects for items that suggested purposeful suffering could bring good luck or that belittling oneself (or one's own sports team) could bring good luck. I explained this result by suggesting that students perhaps borrow from the conservation of energy the idea that one must convert energy to energy potential successfully to use the energy potential later to convert back to energy and that simply wasting energy does not work. I hope I had made it clear that this was only my speculation, but hopefully a reasonable one.

The fifth limitation is my personal subjectivity. Even though I have applied multiple techniques to strengthen the scientific objectivity of my project, my interest in this topic is subjective. Because I do not consider romantic transfer as a huge threat to humanity like Sokal did, or because of my trouble-avoidance personality, I did not draw any dangerous

implications from my findings. Therefore, both my design and my personality have limited the revelation of the dangers that may be implicit in romantic transfer, if there are any.

Final Remarks

This study has confirmed the hypothesis that students can spontaneously and romantically transfer from knowledge of science to social ideologies. Traditionally, science or social studies teachers may avoid discussion of romantic transfer because they perhaps do not have the required expertise, or do not want to teach outside of their own domains, or do not want to be held responsible for controversial transferences. However, knowing from this dissertation that romantic transfer is a common habit of mind of the students, I would argue that once a teacher introduces a science concept, he or she becomes to some extent responsible for potential romantic transfers, because we know romantic transfer is a prevalent and spontaneous extension of the knowledge of science. Future studies should carefully formulate and examine the best practices to take advantage of students' romantic transfers and by so doing convert such transfers into educational opportunity.

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APPENDIX

Appendix A. A high school physics test item.

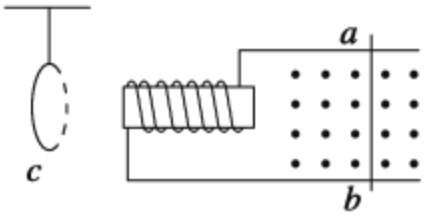


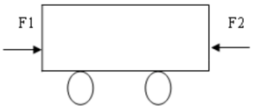
Fig 1.1 A high school physics test given by Mr. Xu.

Appendix B. A test item from Chinese Entrance Exam

The following graph reflected the development of national capitalism in contemporary Chinese history, F1 is friction, F2 is thrust force, the situation that F1>F2 occurred in ( )

E. *After the Sino-Japaness War of 1894*

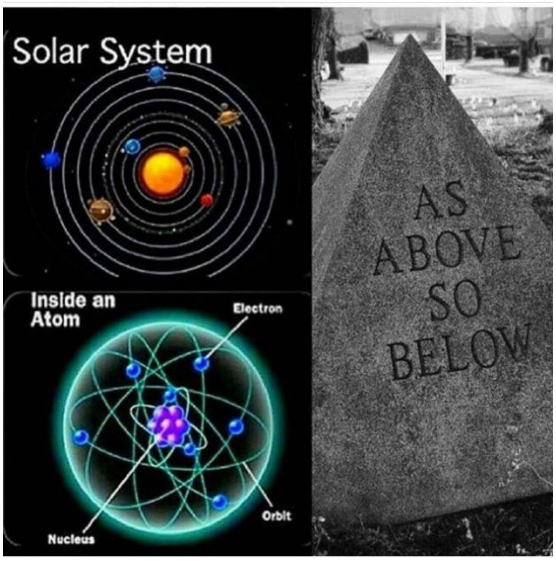
F. *During Liberation (civil) War*



G. *First 10 years under Nationalist government*

H. *During World War I*

Appendix C. An Instagram post



♥ 736 likes

kodiak_89 #truth #knowledge #wisdom #philosophy #science #astronomy #sacredgeometry #Zen #peace #love #universe #Gratitude #Namaste #meditation #meditate #happy #happiness #evolve #wakeup #unplug #freeyourmind #higherconsciousness #PinealGland #astrology #enlightment #fearless #WeAreOne #OneLove #revolution #nature.

Figure 1.2. An example of romantic transfer, screenshot from an Instagram account. The left side is the shared image; the right side is the hashtags given by the account users.

Appendix D. Graphic illustration of the procedure for Study-2 (left) and Study-3 (right)

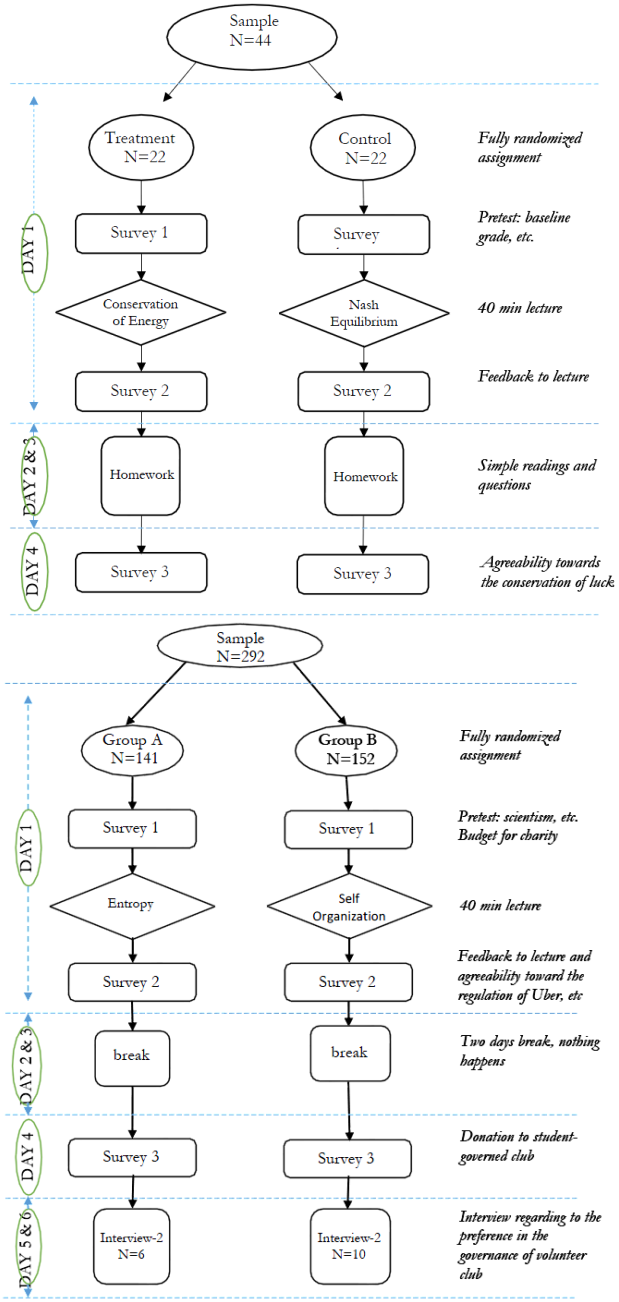


Figure 2.1. The procedure for Study-2 (left) and Study-3 (right). The sample size is the actual number of participants, not the same with the target sample size.

Appendix E. Details for experiment procedures for Study-2 and Study-3.

All students checked in with a student ID, took 10 minutes to fill the pre-survey (survey 1). All students attended the lecture, which took 40 minutes, and completed the feedback survey (survey 2).

Students who took conservation of energy or Nash Equilibrium (Study-2) finished two homework assignments for each group. These assignments reviewed the very basic concepts over the next two days, each taking 5 to 10 minutes to complete. When they handed in the homework to the organizer at the office of the student union on the following Monday, they were given a questionnaire (survey 3) to complete and drop into a locked box.

Students who took entropy and self-organization (Study-3) did not need to do any homework. Immediately after the lecture, they were given an extended version of survey 2 that, in addition to the feedback questions, had questions regarding a case study of social issues including government intervention to online market, the regulation of Uber, power relationship between citizen and government, and the organization of knowledge structure and learning pace in MOOC. Two days later, they were given a questionnaire (survey 4), regarding to the Volunteer Club, by the headmaster of the class.

The Volunteer Club Planning Committee gave a list of IDs of those selected for the sample to headmasters, and the headmasters delivered and collected questionnaires pursuant to each of the IDs. In this school, as in many colleges in China, each cohort of a department has one student as the headmaster, who assists fellow students with affairs of daily student life (like a residence assistant in a dormitory) and in academics (involving the connection between students and school administration or teachers, like teaching staff).

Twelve students (6 from each group, balanced by gender and major) who were willing to participate in a follow-up interview did not need to take the survey.

The four lectures were offered by four teachers who were graduate students majoring in science education at Yunnan Normal University. All of them had experience teaching in high school in

Yunnan, China. They were asked to make their lectures interesting, with a minimum of jargon, but with more storytelling (TED talk style), to deliver the concepts accurately. I provided the stories. They avoided any attempt to, or to hint at, transfer to any other domain. They rehearsed with the researcher (myself).

Appendix F. Item selection approach with IRT models, excerpted from Mair & Lowry (2005)

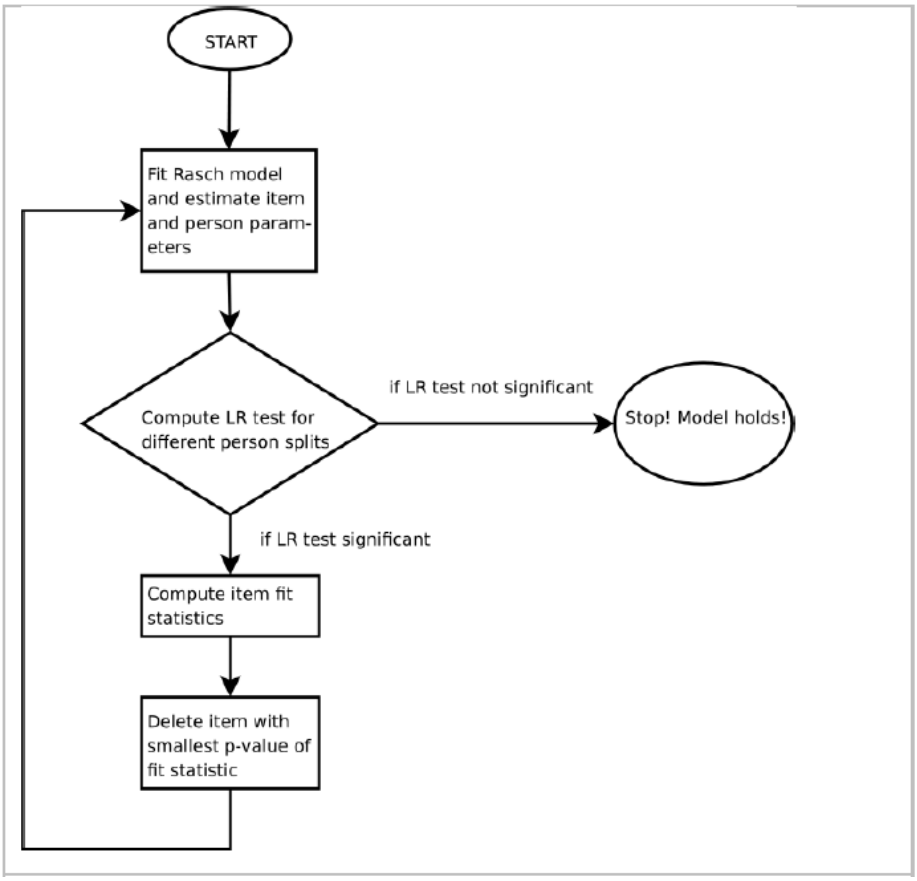


Figure 2.2. Item selection approach with IRT models (excerpted from Mair & Lowry, 2005)

Appendix G. Reliability and unidimentionality of the scales used in Study-1, 2 and 3

Table 2.1

Reliability and Unidimensionality of the Scales

Scale	Number of items	α from pilot sample	α from experiment sample	First Eigenvalue	Variance Explained by First Eigenvalue	LR test of the IRT model: χ^2(df), p-value
Transference Thinking	9	0.73	0.82	3.24	30%	7.29(10), 0.69
Scientism Thinking	12	0.85	0.88	4.92	35%	17.87(13), 0.16
Inward Motivation	5	0.79	0.78	3.55	36%	3.43(6), 0.75
Executive Function	10	0.75	0.82	3.26	30%	6.95(11), 0.80
Physics Test	6	0.46	0.61	1.73	25%	3.89(5), 0.56

Appendix H. Scale for scientism beliefs

Table 2.2

Scale for Scientism Beliefs

Item #	Item	Number of observation	Item test correlation	IRT item fit p-value
SCI1	I admire scientists a lot.	228	0.55	0.26
SCI2	Science leads us to discover the ultimate truth.	228	0.53	0.52
SCI3	Science is the only criterial to decide between right and wrong	228	0.60	0.95
SCI4	To understand this world, we must rely on science.	228	0.59	0.92
SCI5	I only trust opinions that are supported by science.	227	0.63	0.98
SCI6	I will trust an opinion if more scientists support it than do not	228	0.61	0.82
SCI7	In modern society, science should be people's religion	228	0.66	0.99
SCI8	We should oppose anything that is inconsistent with science.	229	0.59	0.15
SCI10	Science is the only standard to examine truth.	223	0.62	0.45
SCI11	Human spirituality will eventually be explained by science.	228	0.63	0.98
SCI12	Hard science is more important than the study of humanities	228	0.56	0.62
SCI13	Anything that is inconsistent with science is wrong.	228	0.61	0.08

Appendix I. Scale for transferential thinking

Table 2.3

Scale for Transference Thinking

Item #	Item		Number of observation	Item test correlation	IRT item fit p-value
TRAN1	18	I think many things that appear to be unrelated are related.	228	0.62	0.97
TRAN2	20	I am good at expanding my imagination, jumping out of my contextual constraints.	230	0.60	0.99
TRAN3	25	I often see significant wisdom in insignificant cases.	228	0.54	0.23
TRAN4	26	I think different matters and actions often share the same unified explanation.	227	0.52	0.99
TRAN5	28	Subject learning often inspires me to think about life wisdom.	226	0.52	0.15
TRAN6	29	I think imagination is more important than knowledge.	229	0.59	0.70
TRAN7	31	I think human society is very like the animal world.	228	0.54	0.25
TRAN8	32	I think we can consider human beings as molecules or cells.	229	0.56	0.48
TRAN9	34	I enjoy discussion about metaphysics and life wisdoms.	229	0.57	0.83

Appendix J. Scale for inward motivation of learning

Table 2.4

Scale for Inward Motivation of Learning

Item #	Item	Number of observation	Item test correlation	IRT item fit p-value
INWD1	Perseverance in learning trains one's character	230	0.75	0.99
INWD2	I believe studying hard can make one stronger	230	0.74	0.80
INWD3	I think the study of one technique cannot be considered the mastery of knowledge.	228	0.74	0.99
INWD4	I believe that all-around (liberal-art) education is more important than technical education.	230	0.71	0.70
INWD5	I hope that teachers can bring me closer to life wisdom.	230	0.76	0.93

Appendix K. Scale for mindfulness

Table 2.5
Scale for mindfulness

Item #	Item	Number of observation	Item test correlation	IRT item fit p-value
MF1	In leisure time, I can't think of anything to do.	230	0.48	0.80
MF2	It's difficult for me to sit still.	230	0.50	0.36
MF3	I have unrealistic plans.	226	0.59	0.99
MF4	I often lose stuff (such as keys, wallet, homework, etc.).	230	0.57	0.54
MF5	It's difficult for me to wait in a line.	230	0.67	0.87
MF6	It's difficult for me to make transitions from one task to another.	230	0.47	0.98
MF7	I make careless mistakes when I complete tasks.	230	0.61	1.00
MF8	I often forgot what I am doing in the middle of a task.	230	0.51	0.66
MF9	I do not check the mistakes I make in my work.	230	0.63	0.94
MF10	I often flick my fingers or shiver my legs.	229	0.48	0.01

Appendix L. The posttest survey for Study-2

Table 2.6 The posttest survey for Study-2

Items that suggest the conservation of luck
To what extent do you agree with the following statement?
1. When my belongings are lost or stolen, I comfort myself that I am trading possession for luck.
2. If one fails in one thing, it means he/she can be successful in something else.
3. Before a game, the coach should humbly admit his/her team's weaknesses.
4. Before a game, the fans should not boast about their team, but should compliment the opposing team.
5. I believe that luck is conserved.
6. One can accumulate luck by purposefully suffering losses.
7. I think the conservation of luck has its scientific basis, although we do not fully understand its deeper mechanisms.
8. Although the conservation of luck sounds superstitious, I will still try my best to abide by it.
9. Luck is like a bank; one needs to save often in order to withdraw some at a time of need.
10. Conservation of luck may not be a strict science theory, but it is consistent with science theories in its essence.
11. Even though the conservation of luck is not a science theory, but it is consistent with science
12. I think everything is conserved, including luck.
13. Performing a huge good deed with great effort will save more luck than performing a small good deed with little effort.
14. Conservation of luck is complete superstition, I don't believe it at all

Appendix M. The second posttest survey for Study-3

Table 2.7. The second posttest survey for Study-3

Category	Example items
Demographics	*Please provide the following basic information* ID:___
Volunteering experience	*Please give your answer to the following questions* Have you participated in any volunteering work before? Yes ☐ No ☐
Donation	*Currently the Planning Committee is considering to handed over the Volunteer Club to students to organize autonomously, run by the students and monitored by students as much as possible, with minimum involvement from school administrations. For such a reason the Club needs to fund raise on its own, instead of being subsidized by the school.* *The Committee is discussing how the Club should raise and manage funding and budget. Our current preference it the funding should partly come from company sponsorship and partly from donation from members. Each member can donate any amount between 0~50RMB (0~8 dollar) as membership fee each year, it's completely voluntarily and should not exceed 50 RMB, please exact your number to 1RMB, rather than give a coarsen estimation in 5s or 10s.* *Please estimate how much you would like to donate to the student self-governed Volunteer Club* I would like to donate _____

Appendix N. Fable case study

The full text of the fable is provided below:

> In Tao Te Chin, Laozi once said: "the ultimate goodness is like water." Water has ever since become a very important symbol in Taoism's ideology. In recent years, Taoism is gradually regaining its popularity in modern society, many people start to read Tao Te Chin to perceive the wisdom from old Chinese philosophy and religion. Different people may treat the symbols from Taoism differently.
>
> Take water for example, because of the text "the ultimate goodness is like water", many people take water very seriously. They insist on growing water-based plant at home, or for those who have a yard, they often place a pond in the yard. They believe this is not a simple decoration, but the wise message from old saints, that to use water properly at home can indeed bring goodness, such as luck, fortune, virtue, and morality, to a family. Some other people consider it as a metaphor, deem that water itself is not necessary, but that water reflects some characteristics that can teach people how "goodness" works around us. They think it is unnecessary and useless to expect for goodness simply by placing water-based symbols at home.
>
> Based on your own opinion, to what extent you agree with the insistence on having water to bring goodness (there is no right or wrong answer)?
>
> I support such an insistence. The wisdom from old saints must have its reasons, though we may not fully understand it. I believe water is not simply a symbol or metaphor, water itself can bring goodness to people.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐
>
> I do not support such an insistence. Laozi was only using water as a metaphor, it did not have to be water. To understand the wisdoms behind the metaphor is enough for people in modern society. We do not have to stick to the text or the ritual.
>
> Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Appendix O. Case studies in the first posttest of Study-3.

1. MOOC. MOOC is the abbreviation for Massive Open Online Courses, a new popular trend in education technology and innovation. It also draws a lot of attention and discussion in the field of education. MOOC compiles a huge amount of course material, such as lecture video, reading material, homework, and even online discussion in an online platform, and offers this to all students for free or for a low fee.

Some people are very optimistic about MOOC, considering it the future of inclusive education. They believe MOOC can provide an open and accepting learning environment where students can be self-motivated and self-paced, without pressure. They also believe with the enormous amount of learning material provided, students can have easy access to knowledge whenever they need it and can efficiently build up their own knowledge system. However, others have been more hesitant. They are concerned that students cannot efficiently organize the scattered knowledge into an organic system; they are also concerned as to whether students can find their own learning pace, or will procrastinate or even fall by the wayside. They have been suggesting MOOC should assign head teachers to students, just like the teachers for each classroom or tutors for each small group. They believe head teachers can help students organize their knowledge system and keep them on a regular learning pace. Not everyone agreed; people who are optimistic that students can do this on their own believe it is unnecessary and works against the proposal to have MOOC in the first place.

Based on your own opinion, to what extent do you agree with the following statements (there is no right or wrong answer):

I think students need a head teacher to guide their learning paces; otherwise, they will procrastinate and even fall by the wayside.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

I think it is difficult for students to build their own knowledge structure; it is necessary to assign head teachers to help students organize knowledge.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

2. Uber. Uber is a fast-growing new taxi company that is planning to enter Kunming (home to the participants). Different from traditional taxi business, Uber allow private drivers to become a taxi driver with their own cars without a permit from government. Customers schedule a ride on their cell phones and the nearest private driver will come to pick them up. Many welcome Uber, thinking it meets the high demand of the customer and gives private drivers a chance to earn by carpooling. However, many are concerned that Uber will harm traditional taxi drivers' businesses, and there may be other safety risks. The local government of Guangzhou has recently forbidden Uber to operate. Instead, the government is planning to release a government version of "Uber," owned by the government, with the intention to strengthen monitoring, balancing between demand and supply, and reconciling between private drivers and taxi drivers. Many people welcome this action from the government; many others do not.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer)?

I think Uber fits into the demands in taxi market, it is unnecessary for the government to intervene.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

I am in favor of banning Uber entirely and replacing it with a government version of Uber.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

3. Political Parties. In a remote hypothetical nation, there are two political parties that have been having a heated debate for decades. Party A believes the nation should have "strong citizens and small government," meaning encouraging citizens to take the initiative, be innovative, to encourage local towns and villages to be more autonomous from the central government. This party believes that to have people pursue their interests is the key to social harmony. Party B believes the nation needs "stronger government and weaker citizenry," meaning to strengthen government's ability to monitor social order, maintain social stability, and adjust the economy on a timely basis. They believe that the appropriate assignment of resources and maintenance of social justice is the true path to a harmonious society.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer):

I prefer strong nations over strong citizens.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

I prefer strong citizens over strong nations.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

4. Taobao (Ebay). In the past decade, commercial selling witnessed the transition from physical store to online store. Increasingly sellers shut down their physical stores on the street and became online sellers through such online facilities as Taobao and WeChat. More phenomenally, anyone, even people who are not in the sales business professionally, can easily open their own online store and make money. However, the online economy is not without problems; it has been frequently reported by media that some online sellers sell fake products and that online sellers viciously compete by dumping product on the market in a manner damaging to other sellers. Considering the online market is a new business venue, some people hope the government will intervene and regulate this new market; some others think the problem is temporary and that the bad stores will die out in a free market without government intervention.

Based on your own opinion, to what extent you agree with the following statements (there is no right or wrong answer)?

Macro-economic-control by the government is an invisible hand that designs strategic plans and assign resources. I think prosperity of online economy depends on macro-economic control.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

The government should come forward to maintain the order of markets and monitor online sellers.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Under free market competition, online sellers will self-discipline themselves spontaneously and become increasingly trustworthy.

Strongly Disagree ☐ Slightly Disagree ☐ Slightly Agree ☐ Strongly Agree ☐

Appendix P. Overarching questions for interview in Study-4

Table 2.8. Overarching interview questions and their rationale

Question	Rationale
9. As between the government version of Uber and the original private Uber, which do you prefer, and why? Or: as between student-autonomously-governed clubs and school- administration-governed clubs, which do you prefer, and why?	In each of the cases presented, there are two options. One suggests a more centralized, hierarchical regulation that is consistent with the entropy framework; the other suggests a self-autonomous regulation that is consistent with self-organization theory. These questions ask participants to state their preference and their justifications.
10. According to this passage, some people believe that the private Uber (or student-governed-clubs) will necessarily become disordered. What is your view? 11. In your opinion, what is the source of disorder and what is the key to increasing order in Uber markets (or student organizations)?	These questions focus on order and disorder using Uber or club as an anchor to encourage the participants to reveal their mental models about order versus disorder. Specifically, these questions challenge participants to think about the advantages or necessity of central hierarchical control. The questions require students to explain and justify their preferences.
12. According to this passage, some people believe that the government should exercise control over Uber. What do you think about this belief? Or: some people hope that the school administration should play a leadership role in managing the club. What is your opinion about this?	
13. Who do you think have more responsibility to the healthy organization of the Uber market (or student-governed club)? Do you think there should have leader(s)? Who should be the leader? Why should this person (or agency, group) be the leader? How is leadership formed?	These questions focus on key players and leadership.
14. In this passage, some people believe the government should leave Uber alone and not to intervene. What do you think about this issue? Or: some people may prefer that the club be governed by students autonomously. What would you prefer, and why?	These questions ask participants to reflect on the advantages of free markets or autonomous organizations. They require participants to justify their preferences.
15. What will in the beginning and what will happen	These questions ask participants

	in the long term, if there is very little government intervention to Uber? Or: What will in the beginning and what will happen in the long term, if school administrations are not involved in the club?	to predict the trajectory of an unsupervised system.
16.	So you suggest … (quote the participant's summary of statement). Under what condition would you consider the opposite stance?	This question asks participants about exceptions. It tries to probe the boundary and conditions of the assumptions that the participants have.

Appendix Q. Descriptive of variables in Study-1

Table 3.1
Descriptive of variables in Study-1

Attribute	Mean	SD	Range
Male	53%	NA	NA
Age	19.68	0.80	18-21
STEM major	35%	NA	NA
Scientism	2.88	0.55	1-4
Transferential	2.92	0.48	1-4
Inward Motivation	2.93	0.51	1-4
Physics Test	3.44	1.78	0-7
Math	72.38	18.17	0-150
Chinese	103.85	12.75	0-150

Appendix R. Pair wise correlation between variables in Study-1

Table 3.2
Pairwise Correlation Between Variables

	trans	scism	Inwd	literal	metp	EF	phys	math	lang	age	major	gendr
Trans	1											
Scism	0.15*	1										
Inwd	0.70***	0.10	1									
Literal	0.34***	0.31***	0.38***	1								
Metap	-0.02	-0.08	-0.01	-0.36***	1							
EF	0.02	-0.04	0.19**	0.19**	0.03	1						
Phys	0.13~	0.02	-0.03	-0.05	0.09	-0.02	1					
Math	0.06	-0.08	-0.04	-0.08	-0.06	-0.19*	0.03	1				
Lang	-0.25***	-0.03	-0.03	0.15	0.04	0.28**	0.13	-0.20*	1			
Age	-0.09	-0.04	-0.16*	-0.01	0.11	0.06	0.06	-0.11	0.07	1		
major	-0.06	-0.02	-0.06	-0.04	-0.01	-0.07	0.09	0.03	0.11	0.21**	1	
gendr	-0.08	-0.03	-0.09	-0.08	-0.01	0.08	0.02	0.03	-0.03	0.32***	0.16*	1

Note: ~ 0.1 > p > 0.05; * p < 0.05; ** p < 0.01; *** p < 0.001

Appendix S. Scatterplot of the interpretation to the fable on a two dimensional coordinate consists of transferential and scientism style of thinking

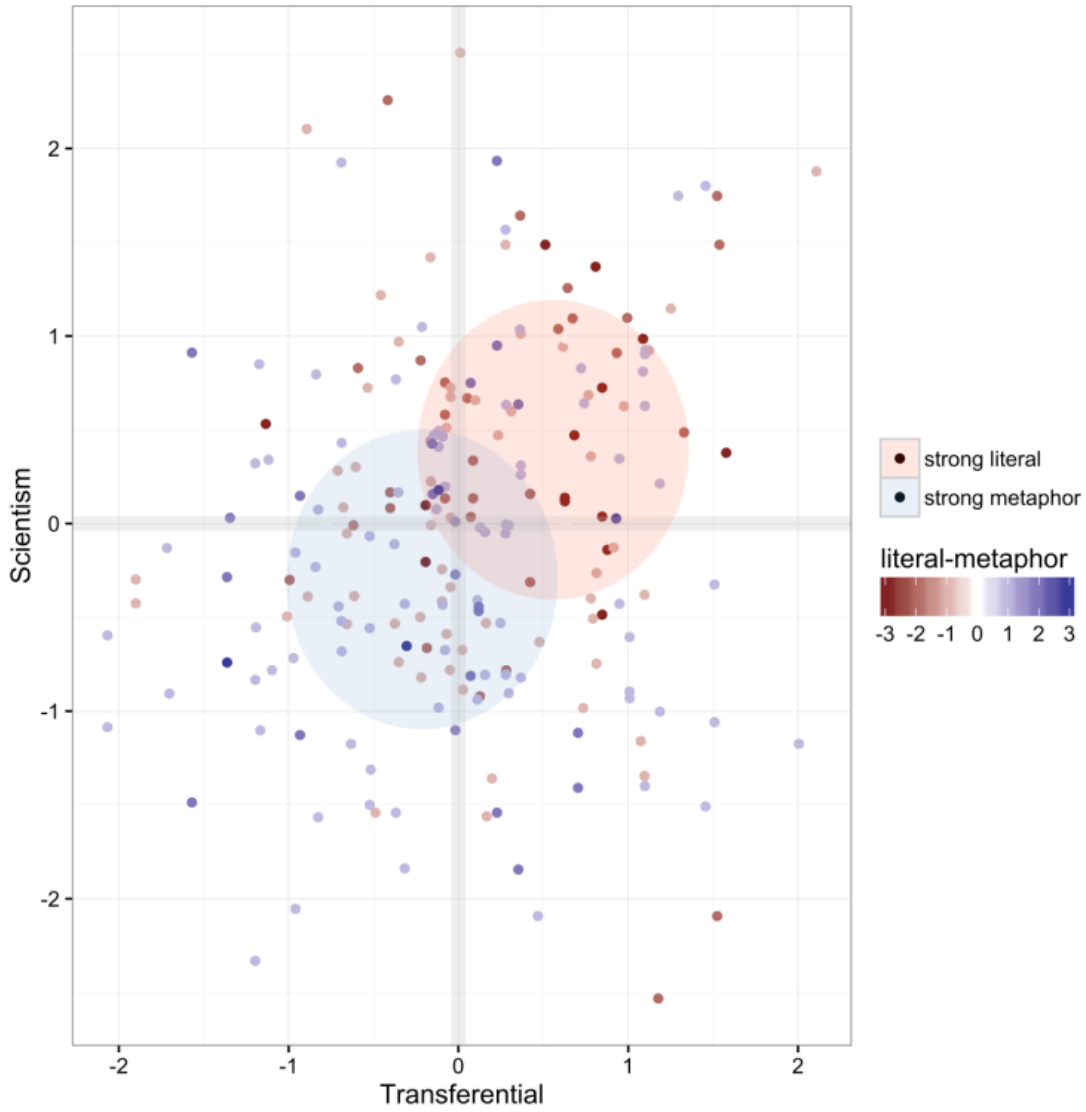


Figure 3.1. Scatterplot of the interpretation to the fable (proxy of metaphor sensitivity), from strongly literal to strongly metaphorical, on a two dimensional coordinate consists of transferential and scientism style of thinking. The small dots are the position of each individual's proxy. The shaded circles are the confidence intervals of the center of strong holders of each of the two opinions.

Appendix T. Path diagram of the chained effects between variables in Study-1

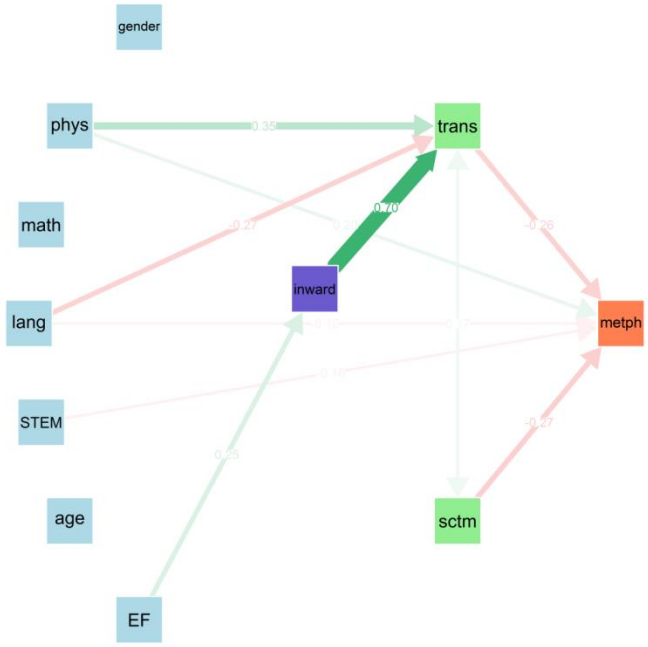


Figure 3.2. Path diagram of the chained effects considered simultaneously. The thickness and solidity of the paths indicate the sizes of the effects. The green paths indicate positive effect and the red paths indicate negative effects.

Appendix U. Graphic illustration for the procedure in Study-2

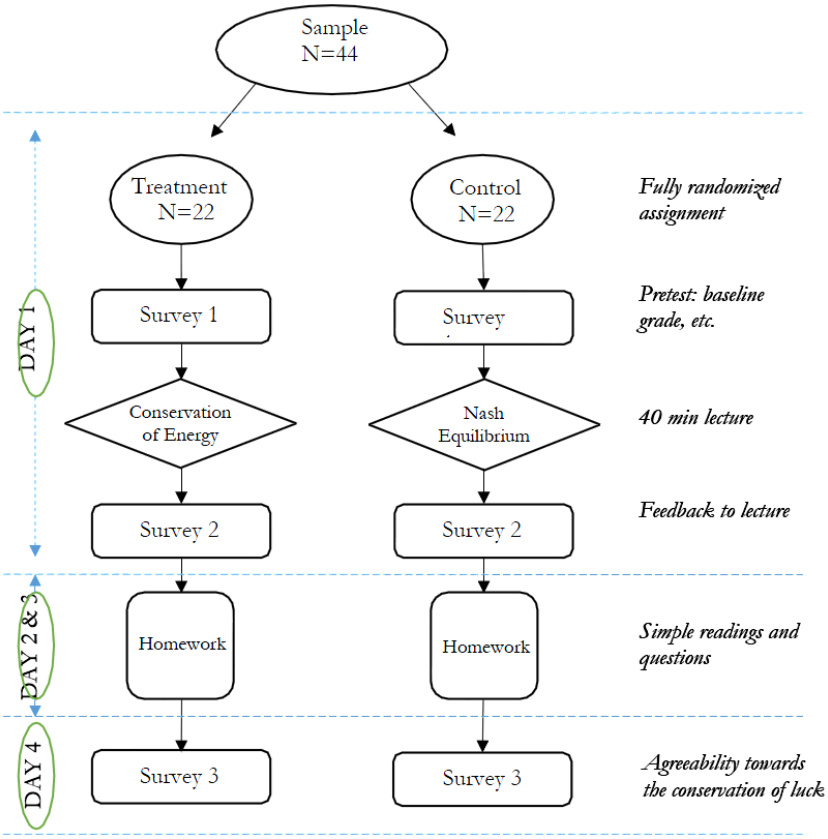


Figure 4.1. Procedure for Study-2.

Appendix V. Descriptive of pretest information in Study-2.

Table 4.1
Descriptive of Pretest Information

	Control Group		Treatment Group	
	Mean	Std	Mean	Std
Male	77%	NA	73%	NA
Age	19.91	0.12	19.80	0.11
STEM	45%	NA	55%	NA
Scientism	2.78	0.68	2.86	0.54
Transfererience	2.97	0.49	2.83	0.60
Inward Motivation	2.91	0.47	2.91	0.50

Appendix W. Treatment effect on each of the items in posttest in Study-2.

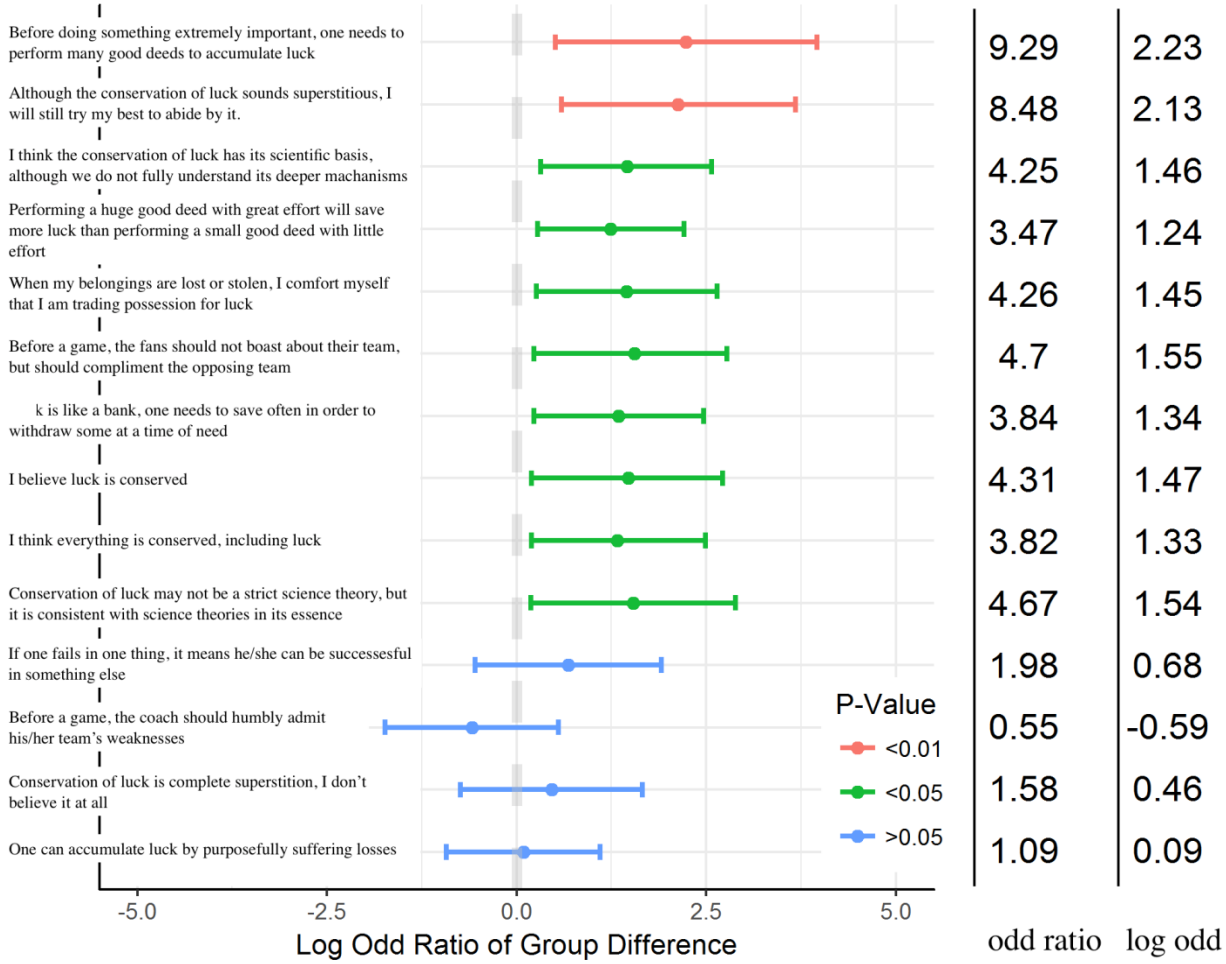


Figure 4.2. The mean log odd ratio between treatment group and control group on each of the post-test items. When the bar of an item overlays with the dash line (blue color), it means the treatment group did not differ from the control group on this item. When the bar locates on the right side of the dash line (red or green colors), it means the treatment group scored higher than control group on this item. Different colors denote different size of p-values, as noted in the legend.

Appendix X. Treatment effect depending on different approaches to create a composite score.

Table 4.2
Treatment Effect Depending on Different Approaches to Create a Composite Score.

Composite score	Coefficient	Standard error	p-value	Standard coefficient
Sum of Likert	3.29	1.55	0.04	0.24
Principal Component	1.75	0.57	0.005	0.39
IRT weighted	0.71	0.21	0.002	0.37

Appendix Y. Graphic illustration for the procedure in Study-3

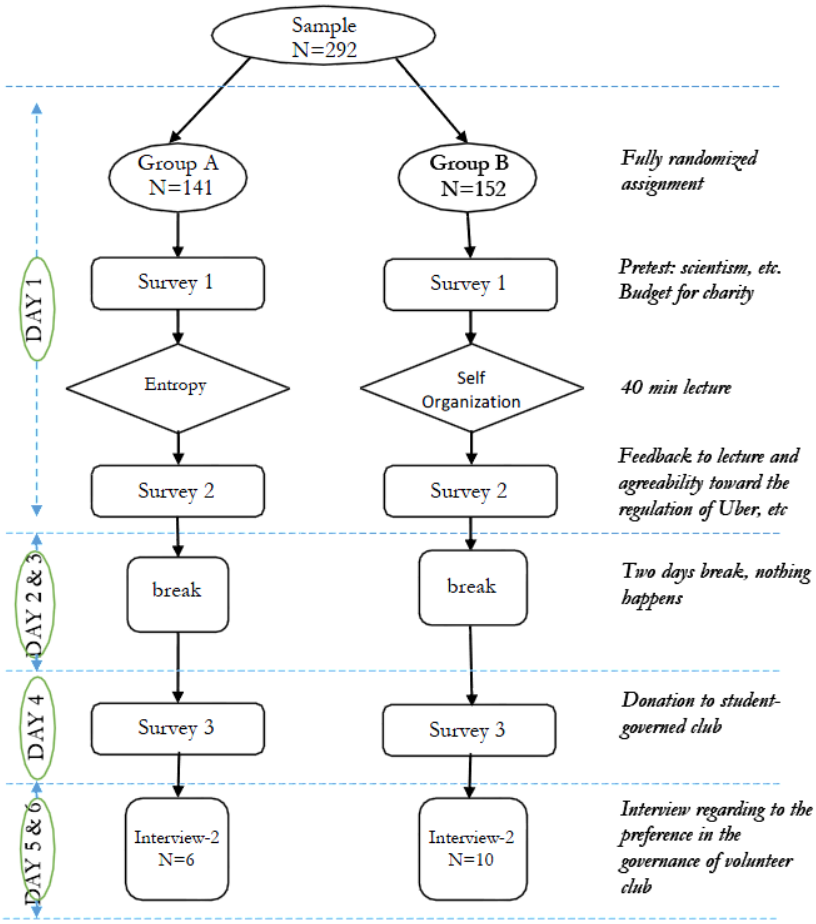


Figure 5.1. Procedure for Study-3

Appendix Z. Descriptive of the pretest information in Study-3.

Table 5.1

Descriptive of Pretest Information

	Entropy Group		Self-Organization Group	
	Mean	Std	Mean	Std
Male	33%	NA	37%	NA
Age	19.24	0.12	19.33	0.11
Scientism	3.27	0.04	3.21	0.04
Transfererience	2.86	0.04	2.85	0.04
Inward Motivation	2.95	0.04	2.96	0.05
Budget for Charity	21.34	0.91	22.93	1.24

Appendix AA. Treatment effect on each items in the first posttest of Study-3.

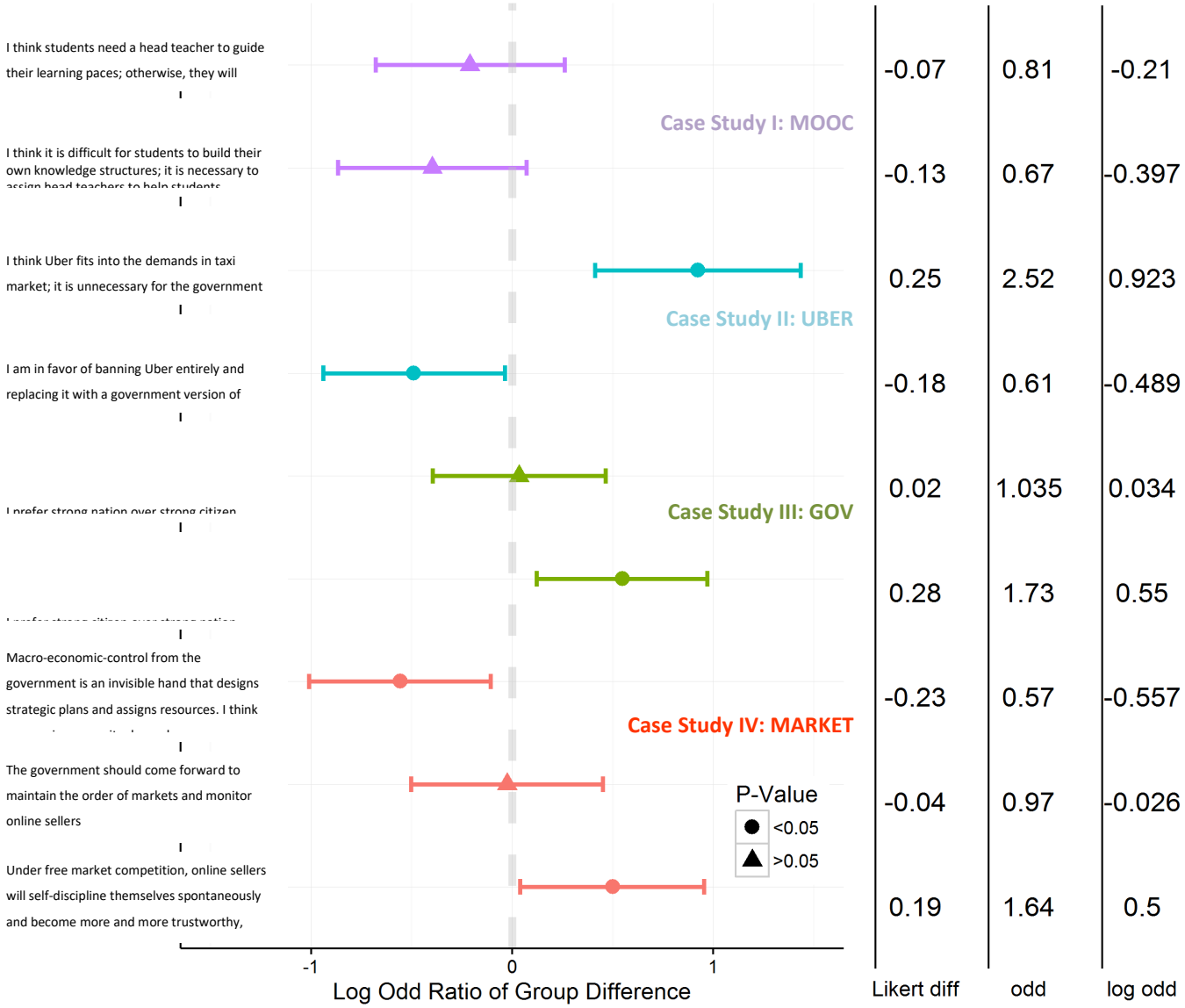


Figure 5.2. The mean log odd ratio between self-organization group and entropy group on each of the post-test items. When the bar of an item locates on the left side of the dash line, it means the entropy group score higher than self-regulation group on this item. When the bar locates on the right side of the dash line, it means the self-organization group scored higher than entropy group on this item. The color of the bars denotes the topic of the case studies, as marked in the graph. The shape in the center of the bars denotes the p-value.

Appendix AB. An interaction effect between treatment and baseline budget for charity on the amount willing to donation in the second posttest of Study-3.

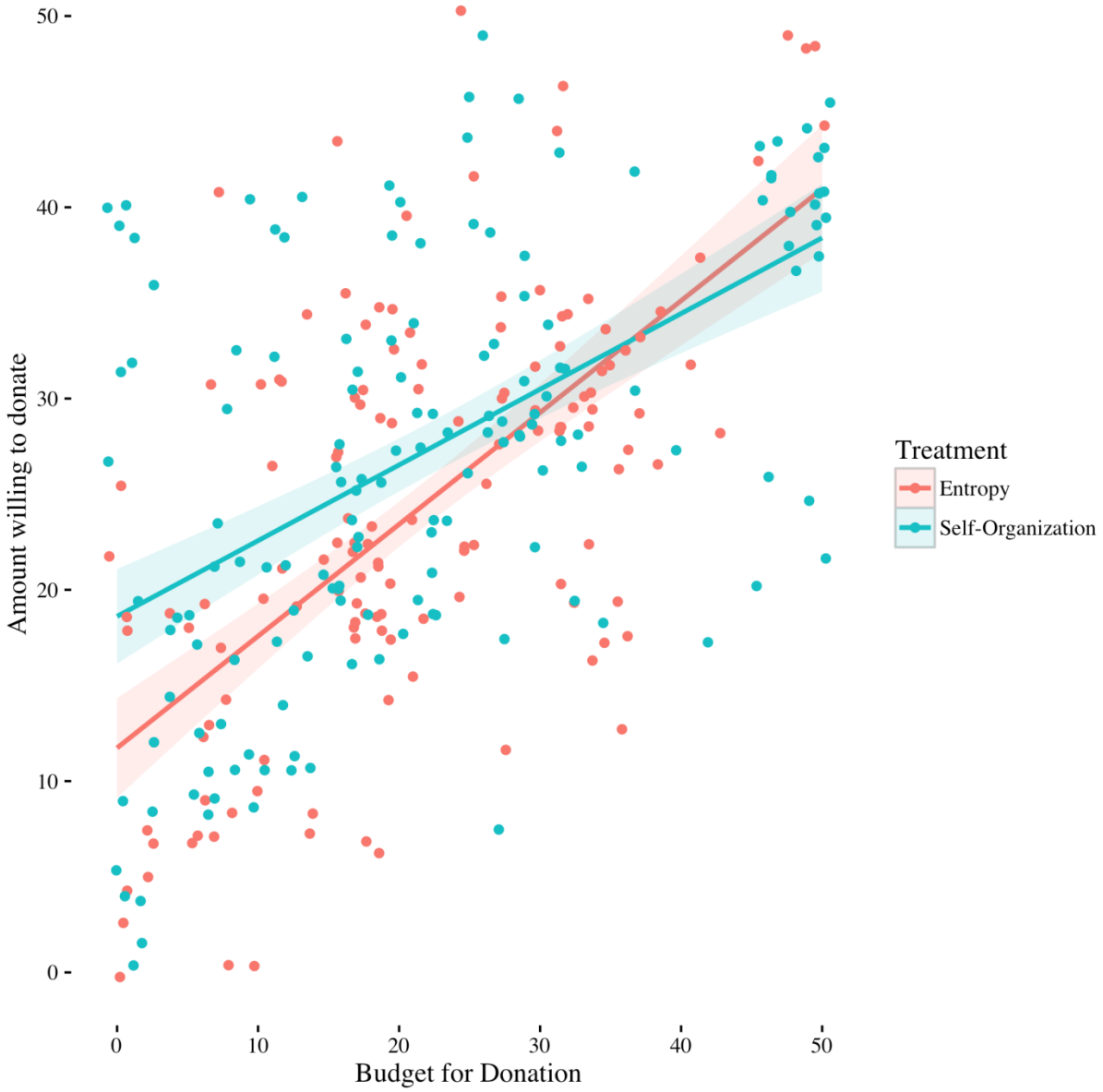


Figure 5.3. An interaction effect between treatment and baseline budget for charity. This means that participants who had a low budget for charity were more sensitive to the treatment, while at the

Appendix AC. An interaction effect between treatment and one of the items from the first posttest in predicting the donation in the second posttest. This interaction effect suggest the consistency between the two posttests.

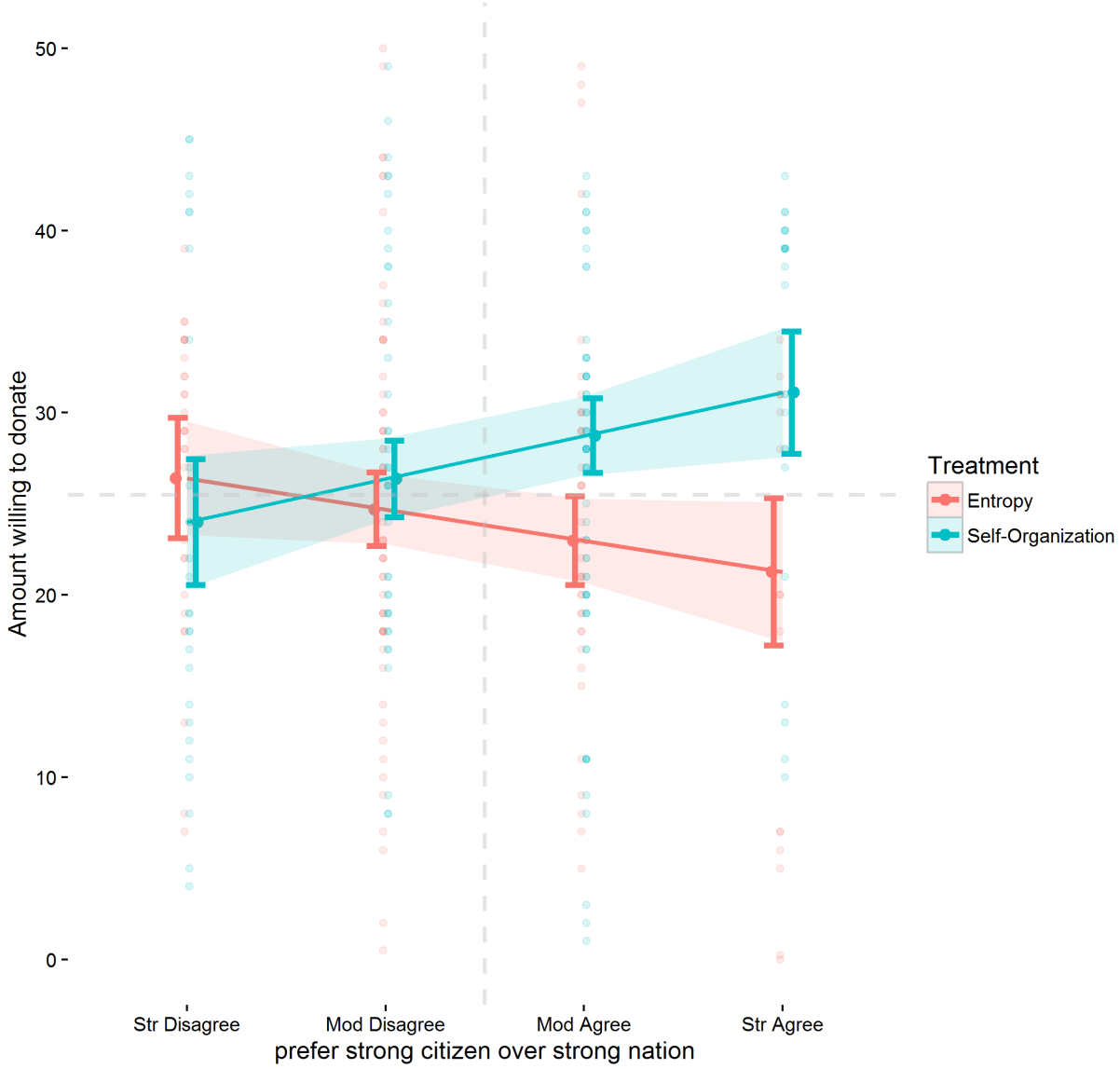


Figure 5.4. An interaction effect between treatment and an item from first post-test items ("I prefer strong citizen over strong nation) in predicting the donation in the second post-test (donation ~ treatment × strong-citizen). There were more participants from the self-organization group located in the first quadrant and more participants from the entropy groups located in the fourth quadrant. This means, for those who favored a strong citizen over a strong nation after the self-organization intervention, they would donate more to the student-governed club. However, for those in the entropy group, even if some favored a strong citizen over strong nation after the treatment, they would donate only at the average level.

Appendix AD. Basic information for the participants in Study-4.

Table 6.1
Basic information for participants in Study-4

ID	Name	Group	Gender	Age	Major
E1	Tong	ENT	Female	19	Agriculture
E2	Lu	ENT	Female	18	Marketing and sales
E3	Bing	ENT	Female	19	Electric engineering
E4	Kun	ENT	Male	18	Finance
E5	Tsai	ENT	Male	18	English literature
E6	Kai	ENT	Male	19	Electric engineering
S1	Zeng	SEO	Male	19	English literature
S2	Lin	SEO	Male	18	Agriculture
S3	Wei	SEO	Female	19	Marketing and sales
S4	Jie	SEO	Female	19	Finance
S4	Wen	SEO	Male	18	Marketing and sales
S6	Hui	SEO	Female	18	Electric engineering

Appendix AE. Connecting each participant to each of the positions that they made

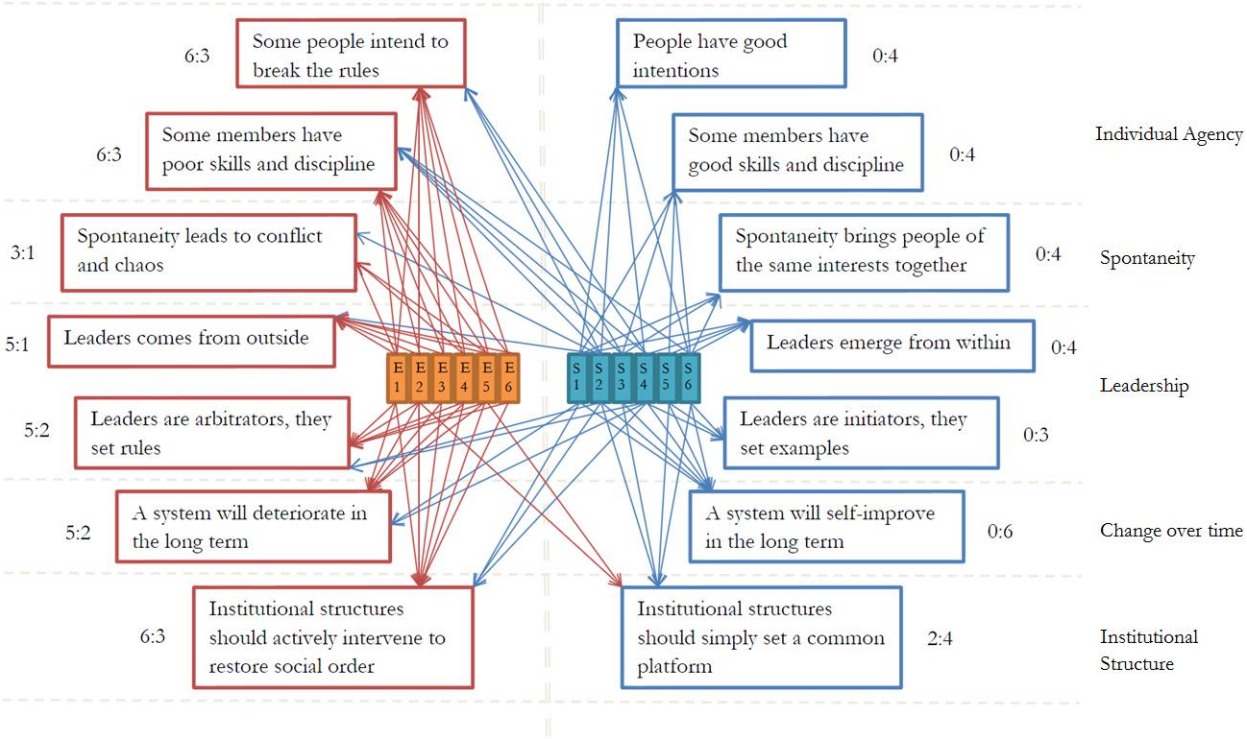


Figure 6.1. Connecting each participant to each position that they made.

Appendix AF. Cycle of science inquiry

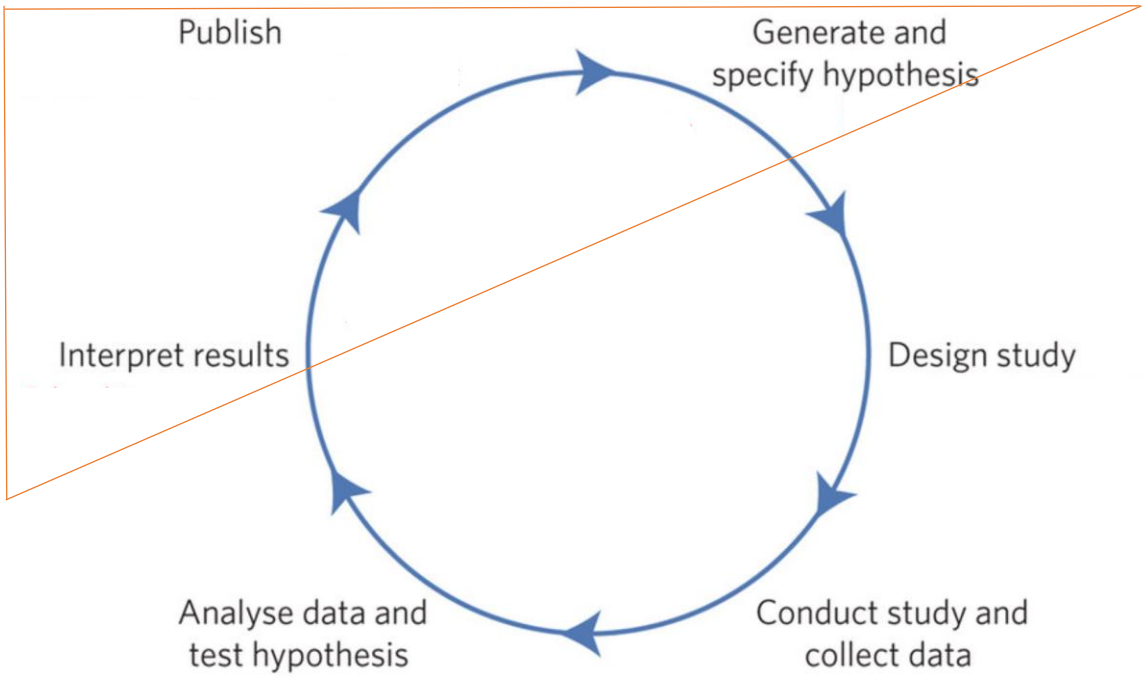


Figure 7.1. The cycle of scientific inquiry among scientists from generating hypothesis to publication and back to new hypothesis. The red triangle includes the three steps that students go through in Romantic transfer or informal science learning.