

The Effect of Story Narrative in Multimedia Learning

by

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ABSTRACT

E-Learning, distance learning, has been a fast-developing topic in educational area. In 1999, Mayer put forward "Cognitive Theory of Multimedia learning" (Moreno, & Mayer, 1999). The theory consisted of several principles. One of the principles, Modality Principle describes that when learners are presented with spoken words, their performance are better than that with on-screen texts (Mayer, R., Dow, & Mayer, S. 2003; Moreno, & Mayer, 1999). It gave an implication that learners performance can be affected by modality of learning materials. A very common tool in education in literature and language is narrative. This way of storytelling has received success in practical use. The advantages of using narrative includes (a) inherent format advantage such as simple structure and familiar language and ideas, (b) motivating learners, (c) facilitate listening, (d) oral ability and (e) provide schema for comparison in comprehension.

Although this storytelling method has been widely used in literature, language and even moral education, few studies focused it on science and technology area.

The study aims to test the effect of narrative effect in multimedia setting with science topic. A script-based story was applied. The multimedia settings include a virtual human with synthetic speech, and animation on a solar cell lesson. The experiment design is a randomized alternative- treatments design, in which participants are requested to watch a video with pedagogical agent in story format or not. Participants were collected from Amazon Mechanical Turk.

Result of transfer score and retention score showed that no significant difference between narrative and non-narrative condition. Discussion was put forward for future study.

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CHAPTER 1

INTRODUCTION

Elearning, distance learning, has been a fast-developing topic in educational area. Narration and video with auditory narration has been shown to improve Elearning (Mayer, 2017). However, the structure of this narration in video could impact the effectiveness (Craig & Gholson, 2006) with elements such as tutorial dialog (Chi, Hausmann, & Roy, 2008; Craig, Chi, & VanLehn, 2009), questions within the video (Craig et al., 2006), or goal achievement statements (Twyford & Craig, 2017) having an impact. The current project will investigate global narrative element of story structure to determine if it can impact learning from video.

In the domain of intercultural study (Tsou, Wang, & Tzeng, 2006; Richard-Amato, 1988), language course (Isbell, Sobol, Lindauer, & Lowrance, 2004; Ellis, 1997; Colon-Vila, 1997) and moral education (Vural, 2013), teaching with storytelling has been proved more effective than conventional pedagogical method.

Multimedia setting includes material in visual and audio channel. One successful example that can facilitate mathematics and scientific learning was the use of pedagogical agents (Schroeder, Adesope, & Gilbert, 2013). This study intended to investigate the effect of narrative in multimedia learning with a scientific topic.

CHAPTER 2

LITERATURE REVIEW

Narrative has been a traditional education tool that has been applied in literature, language and moral education. Technologies in schools and educational institutes provided students innovative ways to learn online (Šumak, Heričko, & Pušnik, 2011). With a multimedia setting, the communication between teacher and student in classroom can be replaced by a virtual human and learner. Pedagogical agents in multimedia setting were found with facilitation effect in mathematics and scientific domains but not humanities subjects (Schroeder, Adesope, & Gilbert, 2013).

Narrative and Story

Although this storytelling method has been widely used in literature, language (Vural, 2013; Tsou, Wang, & Tzeng, 2006; Isbell et al, 2004; Ellis, 1997; Colon-Vila, 1997; Richard-Amato, 1988) and even moral education (Nair, Yusof, & Hong, 2014). In contrast, stories in scientific and technology were mainly scientists' stories (Klassen, 2009; Clough, & Olson, 2004; Martin & Brouwer, 1991) to promote a motivation to be a scientist in a long term. Few studies in this area focused on the advantage of the narrative itself.

Definition. Learning materials are essential in any form of pedagogical activity. Comparing to other types of learning materials, stories and narratives showed the great advantage on reading, comprehension and memory (Pashler et al., 2007).

Narratives is a form of stories and narrations, taking forms of oral, written, or visual

storytelling, has been widely used in pedagogical area (Riedl, & Young, 2010; Dettori, Giannetti, & Paiva, 2006), especially for language courses (Ceylan, 2016; Ge, 2009; Tsou, Wang, & Tzeng, 2006), moral education (Nair, Yusof, & Hong, 2014), being an integral part of school education (Stein, 1981).

Its previous definition from non-literacy perspective stressed its characteristics as a sequence of events with causations (Ricoeur, 2005; Herman, 2003; Wertsch, 1998; Bruner, 1990). Dettori et al. (2006) further pointed out that the key point in narratives is the presence of relationships, which can support meaning construction and arouse active thinking. Chronicles, annuals are not narrative since their construction on events is not complete (Dettori et al., 2006; Wertsch, 1998). Similarly, scientific reports and lectures are not narratives, unless they are composed of “relational structure, a narrating voice and a conclusion” (Dettori et al., 2006). In the narrative paradigm proposed by Fisher (1985) it is defined as a combination of all stories in imagination or real life, he further argued that all meaningful communications can be considered as storytelling or reporting of events. “Storiness” was proposed as “the expectations and questions that a reader may have as the story develops” (Bailey, 1999).

Although many researchers used the term “narrative” interchangeably of “stories” (Clark, 2010; Riessman, 2008, p. 3; Dettori et al., 2006; Stein, & Glenn, 1975), on the other hand, in the literacy field, narrative, as a part of the novel, is distinct from story and plot. A story is a narrative of events arranged in time sequence and a plot are special narratives focusing on causality (Forster, 2010).

Big gaps were found among definitions around narrative and story. As an

alternative, many researchers attempted to consider the core elements, or structures of a narrative or story, from a finer scale. In the next section, several arguments about elements and structures of narrative will be introduced.

Elements and Structures of Narrative. When it comes to the “elements”, such as characters, settings etc., of a narrative, opinions diverged greatly. A traditional view to a well-constructed story should include setting (characters, time and space), theme (a beginning event leading protagonists to act from a goal or encounter a problem), plot episodes (events that of protagonists’ attempts to goal-accomplishment or problem solving) and resolution (the ending, with goal-accomplishment and problem solution, with possible long-terms consequences) (Mandler & Johnson, 1977; Rumelhart, 1975; Stein,& Glenn, 1979; Thorndyke, 1977). Xiong & Deng (2010) defined event, the fact of state changing, as “little space stories” and the basic cognitive structure for narrative. Bruner (1996) suggested a narrative structure for learning, maintaining that an either actual or fictional narrative, should include (1) agent, (2) act, (3) setting, (4) means, (5) goal, and (6) Trouble.

A story always includes (1) a main agent or character, (2) setting, (3) changing state, and (4) the theme or the main question needed to be settled. However, these are only basic elements that consist of a narrative. However, scientists still need to understand the role that these narratives play in comprehension. These elements can be seen as explorations toward cognitive structures behind a story.

Theories of Narrative as Cognitive Tool. There has been a consensus that narratives can be considered as a cognitive tool for situated learning (Riedl& Young,

2010; McKoon & Ratcliff, 1992; Gerrig, 1993). Two theories, Schema Theory and Script Theory support the rationale of narrative facilitating comprehension.

Schema Theory by Bartlett (1932) proposed “prior experience” played a necessary role in one’s memory for narrative information (Stein, 1981) and people use schema to quickly access to their memory. Greasser and Nakamura (1982) defined schema as a generic including a series of “components, attributes, and relationship that typically occur in specific exemplars.” A schema clarifies critical elements in certain relations while leave rooms for other optional elements (Nelson, 1981). A schema, or schemata, is characterized by four essential traits: (1) variables are found in schemata, (2) schemata can be embedded with others, (3) schemata are general concepts with differences on level of abstraction and (4) schemata represent knowledge, not definition (Nelson, 1981; Rumelhart & Ortony, 1977).

Another theory provided more concrete theoretical framework. Script Theory (Schank & Abelson, 1977) proposed that part of human knowledge is organized around a number of stereotypic situations with routine procedural activities (Bower, Black, & Turner, 1979), such as riding a bus, asking for directions, visiting a dentist, an airplane trip and so on. The term “script” was used to describe the memory structure that one has encoding his or her general knowledge of a certain situational routine.

According to Schank and Abelson (1977), a script is defined as “a structure that describes appropriate sequences of events in a particular context.” It provides a set of information for common activities or situations in a culture. As schemata has variables, a script consists of the following “slots”, in which “Roles” are persons in the event, “Props”

being slots for representing objects involved in events; “Entry Conditions” showing the initial state, a condition that must be met before event occurrence; “Results” showing the ending state, a condition that must will be true after an occurrence of an event, “Scenes” indicating the ordering of events that are usually represented in conceptual dependency form. In recent literature, “Settings” which indicate the place was added (Mueller, 2002). For example, A script of Restaurant from recent literature (Mueller, 2002) is provided as below (See Table 1).

Table 1

Script for Restaurant (Mueller, 2002)

Roles	S-Customer, W-waiter
Props	T-tables, M-menu, F-food, D-Money, C- check
Settings	R-restaurant
Entry conditions	S is hungry; S has D
Results	S has less D; S is full; W has more D
Scenes	1. Entering: S goes to R. S sits at T. 2. Ordering: S reads M. S chooses F. W comes to T. C ordered F from W. 3. Eating: S eats F. 4. W brings C to S. S leaves D to W. S leaves R.

Moreover, any script should be written from one particular role’s point of view (Mueller, 2002; Schank & Abelson, 1977, p. 41), which was suggested to be an additional item as “Point-of-View” by Barr, Feigenbaum and Roads(1982). In the case above, a “Point-of-View” is a hungry person.

In addition, there is more than one alternative of action sequence for eating in a restaurant. A script can be accommodated in other certain types of variations. “Track” shows alternative situations for a script. For example, a restaurant script might have a

cafeteria script, or a fast food track (Schank & Abelson, 1977, p.42). One advantage that the script can provide is that it provided “stereotypic sequences of actions in a well-known situation” (Schank & Abelson, 1977, p. 41), which facilitate people making inference.

When actions became script actions, it is not easy to be recalled, comparing to atypical information, even for children (Hudson, 1988). Thus, in the experiment, we assume that when narrative used as script-based stories, it will not distract student learning.

From researches above, we can conclude that important elements consisting of narratives are “characters”, “settings” and “state of changing” that is caused by “events” with causation or temporal order. Moreover, it is not necessary for a narrative to be entertaining. The following research will continue to use the word “narrative” and take it as a story which is based on causation and temporal events, which is consistent with the definition of narrative of Mostafazadeh’s work (2016) as “anything which is told in the form of a causally (logically) linked set of events involving some shared characters”.

Learning Effect of Narratives/Stories. Schema Theory and Script Theory provided theoretical support for narrative facilitating memory. Moreover, the facilitation effect of narrative has been evidenced by empirical studies (Nair et al., 2014; Ge, 2009; Dettori et al., 2006; Tun, 1989).

The potential of narratives facilitating learning is attributed to their role as the mediators between similar real events and already-existed human cognitive structure, helping people better understanding the world (Bruner, 1990). Narratives also provide

entertainment function to motivate students (Klassen, 2009; Ge, 2009). In moral education, comparing to conventional teaching method, teaching with storytelling method can increase pupil's interest, motivation and achievement significantly (Nair et al., 2014). Narratives have also been suggested in storytelling education which takes place in language education (Tsou, Wang, & Tzeng, 2006; Richard-Amato, 1988) to increase their listening skills (Isbell et al., 2004; Ellis, 1997; Colon-Vila, 1997).

The motivating effect is still maintained in narratives applied in multimedia settings. Narratives in other forms (such as video and games) have potential to be applied in learning domain, which is consistent to the definition of narratives by some researchers (Riedl & Young, 2010). Observation of narrative videos can also facilitate learning. Ogan et al. (2009) used narrative video to guide student to understand ill-defined topics such as intercultural events and received a significant finding. Due to its motivating effect, narratives are suggested embedded in games (Qin et al., 2009; Dickey, 2006; Hakkarainen, 2004; Juul, 2001).

Moreover, narrative has its advantage on modality. Comparing to expository, narratives have simpler text structures for identifying (SÁ & Fuchs, 2002), familiar language and ideas (SÁ & Fuchs, 2002; Greasser, 1991), less demand of prior knowledge on structures and characteristics, and thus, are easier for audience, especially for poor readers (SÁ & Fuchs, 2002). Result from dual-task procedure showed that the genre of narrative produced better performance and can facilitate learning for senior citizens (Tun, 1989).

Clark (2010) categorized the learning effect of narratives in three separate aspects.

First of all, people learn from hearing a story or narrative, such as moral tales, personal experiences (Martin & Brouwer, 1991), myths and parables hearing. Then, they can learn from telling a story, such as illness narrative (Tan, Liu, & Xi, 2016; Wang, 2016; Sakurai, 2015; Combs, 1996), digital storytelling (Yang & Wu, 2012; Robin, 2008; Sadik, 2008) or story construction (Bower & Clark, 1969). Finally, they learn from recognizing the narratives where we are positioned (Clark, 2010), such as an American travels to the non-Western settings, realizing that his positioning is Western-narrative, which is rights over responsibilities, individual over the community (Clark, 2010). The last effect is quite related to the concept of schema, whose function is to help people recognizing, based on memories.

In conclusion, narrative has characteristics including (a) format advantage such as simple structure and familiar language and ideas (SÁ & Fuchs, 2002; Greasser, 1991) and they can (b) motivate learners (Nair et al., 2014; Klassen, 2009; Ge, 2009), (c) facilitate listening (Tussyadiah & Fesenmaier, 2008), (d) oral ability (Tussyadiah & Fesenmaier, 2008) and (e) provide schema for comparison in comprehension (Clark, 2010). In the next section, I will discuss some specific form of narratives in previous study.

Multimedia Learning

Narrative has been a tool in traditional education for carrying messages. When narratives were spoken in a storytelling way, they are in spoken modality. When narratives were written on a book for reading, they are in written modality. However, with the development of modern computer and technology, nowadays people can have both spoken and written modalities at the same time. The way of presenting material using

both pictures and words is called multimedia (Mayer, 2002b). Multimedia instructional message is referred as communications to promote learning using words and pictures (Mayer, 2002b). Typically, a multimedia explanation constitutes of words such as narration, and pictures such as animation which give an explanation on the principle of some causation systems (such as the formation of lightning) (Mayer& Chandler, 2001).

Learning can be facilitated by multimedia instructions, a kind of instructional message with both pictures and words (Mayer, 2002a). Learning is fundamentally cognitive as knowledge of learner change before and after learning process (Mayer & DaPra, 2012).Designed accordingly to the human mind works, multimedia instructional messages can greatly promote learning. According to Mayer (2009), the design of multimedia learning can benefit from the following principles: Coherence, signaling, redundancy, spatial contiguity, temporal contiguity, segmenting, pre-training, modality, multimedia, and personalization, voice and image principles.

Modality Principle in Cognitive Theory of Multimedia Learning. One of the principles in Cognitive Theory of Multimedia Learning is Modality principle. Modality Principle suggested that learners learn better with speech than on-screen texts. The explanation is that working memory capacity can be expanded in certain circumstances when part of the information is presented in visual channel while other part is presented in audio channel (Schroeder et al., 2013; Low & Sweller, 2005).In 1999,Moreno and Mayer compared two groups of students' performances on watching an animation of lightning formation, with one group reading text on screen while the other group have audio speech. Result showed that audio narration group outperformed significantly than on-screen text group (Moreno,& Mayer, 1999). In the following studies, students were

asked to click questions on the screens to get answers in audio narration or on-screen text. Result again showed that audio group solved more problems in the following test (R. Mayer, Dow, & S. Mayer, 2003).

Observation and Learning. Although many education theories have been pointed out that the interaction and self-pacing multimedia environment may contribute to learning (Anderson, 2008, p.43; Baylor, 2002; Mayer, & Chandler, 2001), video-watching or animation which based on observation has been proved to be another effective learning material. Evidence showed that students who are more active in video-clip watching as pedagogical resources achieve higher grades (Romanov & Nevgi, 2007).

Modeling is a more effective approach to learning than trial and errors (Bandura, 1977). Specifically, Collins, Brown and Newman (1988) proposed Cognitive Apprenticeship, a theory that assumes people learn from one another through observation, imitation and modeling (Collins, Brown,& Newman, 1988; Bandura, 1977), with stress on situated environment (Dennen, & Burner, 2008).

Vicarious learning, or observational learning, modeling and social learning proposed that learning can be facilitated from simply exposure to the activity of a model, without intentional training of direct incentives (Roberts, 2010; Craig, Gholson, Ventura, & Graesser, 2000; Rosenthal,& Zimmerman, 1978). It is characterized by listening reflectively and listening actively (Robert, 2010;Nehls, 1995).Students can learn vicariously from many sources, including discussions or discourse, competition from a more competent other (Topping, 2005) and storytelling (Ashworth, 2004; Ellis, Calvo, Levy, & Tan, 2004; Davidson, 2004; Northedge, 2003).

With modern multimedia environment, researchers can establish a virtual environment, with virtual agent for learners to observe. Some evidence showed that this approach is effective, such as learning from virtual agents' voice (Craig & Schroeder, 2017); learning companied by animated models (Wouters, Paas, & van Merriënboer, 2009; or animated virtual agents (Mayer & DaPra, 2012; Craig et al, 2004).

Pedagogical Agents

Agents are a potential technology to implement story narratives within learning videos. These agents can be used to represent characters in the story to support the learning (Craig & Schroeder, 2018) or model behaviors that the story is set up to teach (Bandura, 1986; Craig et al., 2006). These are often used within educational technology and video learning environments and have been shown to be effective for learning (Schroeder et al., 2013).

Definition. Pedagogical agents refer to agents used in pedagogical area (Anderson, 2008, p.51). In recent literatures, they are defined as visible characters in the learning environment that are deliberately designed for facilitate learning (Craig & Schroeder, 2017; Schroeder, Adesope, 2013, 2015; Moreno, 2005; Johnson, Rickel, & Lester, 2000). However, they are not necessary to be fully anthropomorphizing to real human (Schroeder et al., 2013).

Categories. In terms of the designing difficulty, there are animated pedagogical agents and static pedagogical agents (Schroeder et al., 2013). A static pedagogical agent is static a character that respond through visual stimuli while an animated pedagogical agent are more life-like, providing visual signaling, gestures and auditory cues

(Schroeder et al., 2013).

In terms of the aim of use, two types of pedagogical agents can be differentiated: pedagogical agents, which only deliver the instruction message (Schroeder et al. 2013), and conversational agents, which can answer student questions (Louwerse, Graesser, McNamara, & Lu, 2009). Conversational agents are much more “intelligent”, specifically conversational in their behaviors, displaying humanlike interactions (Cassell, Bickmore, Campbell, Vilhjálmsón, & Yan, 2000). Animated pedagogical agents are designed to facilitate learning using computerized characters (Craig, Gholson, & Driscoll, 2002).

Virtual Agent’s Effect on learning. *Empirical Studies.* Meta-analysis showed that animated pedagogical agents produced a small but significant effect on learning while a static pedagogical agent produced a neither positive nor a negative effect on learning (Schroeder et al., 2013). In terms of the subject domain, meta-analysis suggested that pedagogical agents be placed in science ($k = 19, g = .28, p < .05$) and mathematics area ($k = 8, g = .27, p < .05$) while their effects in humanities ($k = 16, g = .06, p > .05$) were insignificant (Schroeder et al., 2013).

The effectiveness of agents does vary based on the learner. In terms of the educational level of learners, pedagogical agents are found most effective among students in K-12 education (specifically grades 4-7) and slightly effective among secondary students (Schroeder, et al., 2013). A series of favor characteristics of pedagogical agent has been investigated. In terms of K-12 Engineering outreach, researchers have concluded preferred traits of agents –similar external characteristics to the user and knowledgeable to the domain in internal characteristics (Johnson, DiDonato, & Reisslein, 2013).

The effect of pedagogical agents in classroom are significantly better than that in the lab (Schroeder, et al., 2013). In terms of gender of agents, though some evidence showed that male agents were rated more engaging, more facilitating and more intelligent (Kim, Baylor,& Shen, 2007). Female agents also showed their effects for female students (Rosenberg-Kima, Baylor, Plant.,& Doerr, 2008).

Social Agency Theory. One of the benefit from pedagogical agents is related to the motivation (Mayer & DaPra, 2012; WANG, LI, XIE & LIU, 2017). The facilitative effect from an agent is supported by Social Agency Theory (Mayer, 2005). This theory takes instruction as a form of communication, and thus, a social activity between instructor and learner. Therefore, a multimedia lesson is also a form of communication in which (a) the instructor should present a social stance to communicate with the partner (learner) and (b) the learner should present a social stance to communicate with the instructor (instructor). Learner and instructor interact with each other during the communication process.

In the process, 4 steps are involved according to Social Agency Theory for animated pedagogical agents (Mayer, 2012). At first, the virtual agent exhibits social cues such as gesture, facial expression, movements, voice, personal conversational style, politeness, eye gaze, visible author. Then, the learner adopts social stances, which is reflected from learners' ratings of social characteristics and learner's posture, learner's social expression, eye fixations, or pupil size during learning. In the third step, learners are proposed to activate deep cognitive deep cognitive processing during learning, for example, learner's activity in learning based on observation or log files, or physiological measures such as brain activity. Finally, the learner builds meaningful learning outcome, which can be

tested via transfer test performance. Pedagogical agents can provide the benefit of (a) creating the communication relationship with learners, (b) facilitate learning in mathematics and technology domain.

Research Hypothesis

Modality Principle showed that people learn better with audio narration rather than on-text screen (Mayer, Dow, & Mayer, 2003; Moreno & Mayer, 1999). This implied that the changing of modality can affect learners' performances. Narrative has its advantage and has been applied in literature, language (Vural, 2013; Tsou, Wang, & Tzeng, 2006; Isbell, et al. 2004; Ellis, 1997; Colon-Vila, 1997; Richard-Amato, 1988) and moral education (Nair et al., 2014).

It is hypothesized that story narrative condition will produce better performance in learning, comparing to the information-narrative condition. Specifically, it is predicted that performance in the narrative condition will receive higher transfer and retention score.

CHAPTER 3

METHOD

Participants

A population of 60 participants was collected from Amazon Turk. This number is based on previous study (Craig & Schroeder, 2017). Criteria for recruitment were limited to (1) location in United States, (2) workers with 95% approval rating, (3) workers with a minimum number of completions of 100. These requirements are suggested by previous observation study for vicarious learning (Twyford & Craig, 2017).

The study collected 40 effective participants after data cleaning. There are several criteria for data cleaning. First, a test question was set. “If you are reading the question, please answer “Agree” and participant data that did not choose “Agree” were excluded. Samples whose duration which measures total time that one participant used to complete the whole test shorter than 300 *secs* (5 mins) was excluded since the whole video last 4 mins 55*s* (295*s*). In addition, samples with retention score as zero were excluded.

According to the Power Analysis, 102 participants were required in the study ($d = .35$, $\alpha = .05$; power = .8). In this test, originally 60 participants were designed to be included in the study (Craig & Schroeder, 2017). However, 40 participants were acceptable though the meta-analysis showed that the effect of virtual agents were rather small but significant (Schroeder et al., 2013). However, in previous study, 20 participants for one condition have been found with effects (Mayer & DaPra, 2012), which suggest 20 participants for each condition is acceptable.

Among the participants, 26 were male and 13 were female. Participants Age ranged from 22 to 45 ($M = 28.05$, $SD = 5.25$). SAT score of participants ranged from 500 to 1900 ($M = 1202.84$, $SD = 315.88$). For self-rated computer use ability, 10 of the participants rated themselves as "Average" and 29 rated themselves as "Good". For self-rated knowledge of electricity, 1 of the participants rated themselves as "Bad", 21 of them rated "Average" and 17 of them rated "Good".

Design

This experiment employed randomized alternative-treatments design with Pretest. Participants have their pretest first, then assigned randomly into either information-narrative condition or story-narrative condition and have other tests again. Participants in the pretest are expected to have no difference. The A number of 60 participants were recruited from Amazon Mechanical Turk, with 30 participants in the story-narrative group, and another 30 participants in the information narrative. The number of participants in both conditions was suggested from previous work (Mayer & DaPra, 2012). After data cleaning, 19 participants were assigned to story-narrative condition and 20 participants were assigned to information condition.

Materials

Learning Materials. All the materials and test in the study are based on the study of Mayer and DaPra (2012). It was originally presented by Mayer in 2012, in a form of a multimedia lesson which includes a short, narrated slideshow that explains the conversion

rationale of a solar cell from sunlight to electricity. The learning material is "the lesson of solar cell", which has been proven to be an effective material with the assistance of fully-embodied virtual agent (Mayer & DaPra, 2012). There were 81 main idea units in a script of 800 words. The whole lesson session will continue about 5 minutes. The lesson started with introducing silicon-atom, the doping process, and the creation of electric flow within the solar cell. It was presented and was originally in multimedia environments with virtual humans.

Since the effect of virtual human has been proved in previous study (Mayer & DaPra, 2012), we mainly test the effect of script-based story. Thus, this study replicated Mayer and DaPra's material in 2012 based on script. There are two conditions in the study, information-narrative condition and story narrative condition. The information narrative condition remain the same content as Mayer and DaPra's work in 2012 based on their script (Mayer & DaPra, 2012), with animation redesigned using Adobe Flash Professional CC 2015 and Microsoft PowerPoint. The virtual agent in the study is named as "Ben". The voice was generated from NeoSpeech Paul, a high-quality speech synthesis voice.

In information-narrative condition, we continued to follow Mayer's work. However, the story-narrative condition provides the same content with a narration form.

Story-Narrative Condition. Comparing to atypical information, script actions are is not easy to be recalled, even for children (Hudson, 1988). Script-based stories are stories that based on scripts (Hayward, Gillam, & Lien, 2007). While scripts are intended to deal with mundane activities, script-based stories are depicted as "little boring stories"

(Schank et al., 1975). However, the advantage that a script can provide is its facilitative effect on making reference, which might be useful for retention. Moreover, students should focus on learning material instead of the story itself. Thus, in the experiment, we assume that when narrative used as script-based stories, it will not distract student learning.

Narrative in the study was selected from RocStories corpus (Mostafazadeh et al., 2016) 2017Winter edition which consists of 52665 high- quality five-sentence everyday commonsense stories, full of stereotypical sequences of events. Stories in the corpus was produced from a task asking hundreds of workers to write a five-sentence story on Amazon Mechanical Turk (AMT). Since scripts are designed for action sequence, we selected a story

John took a new job in an inside sales role. John had never made sales telephone calls before. John read books and watched videos on how to make sales calls. John began working very hard at being good on the phone. John wound up being the number two salesman that quarter!

This story can be written with a script of “Learning a certain Knowledge”:

Table 2

Script for “Learning a certain knowledge”

Roles	L-learner
Props	B-books, V-videos, K-knowledge, E-efforts, P-position, O-organization
Entry conditions	L received P in O; L has no K for P
Results	L has more K for P; L is happy
Scenes	Learning: L learns K using B and V Practicing: L practices K in P

The story was as follows:

Ben joined a student technology organization and was asked to create a solar cell. Ben had no idea about the solar cell. Ben read books and watched videos on how to make solar cells. Ben began working very hard at creating the solar cell based on the instructions from the book. Ben wound up being the number two good member that year!

In the story-narrative condition, the animated agent “Ben” standing at the right side of the screen with his side-view teaching how solar cells work based on scripts. An example is presented in Figure 1. In the beginning and end of the video, Ben also showed his front side since he was in a story. An example is presented in Figure 2.

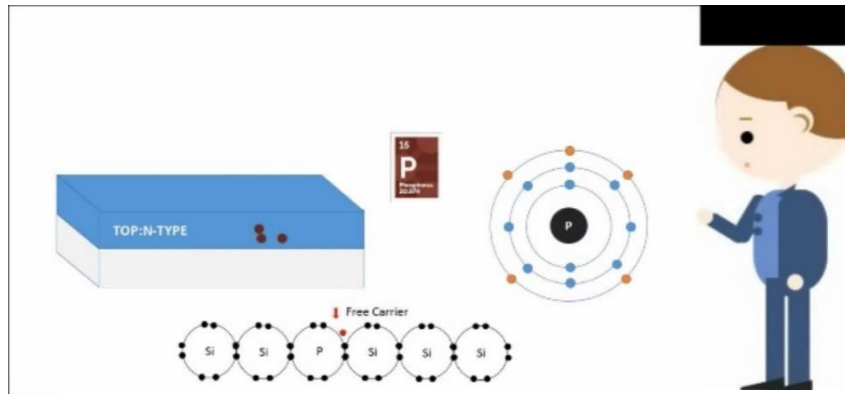


Figure 1 Example of Information Narrative Condition



Figure 2 Example of Story Narrative Condition

In the information-narrative condition, the animated agent “Ben” standing at the right side of the screen with his side-view teaching how solar cells work based on scripts. An example is presented in Figure 2.

The script of the lesson (script of the information narrative condition) is attached in Appendix A. Scripts of the script-based story are attached in Appendix B. Scripts of the story-narrative condition is attached in Appendix C.

Assessments

Demographic survey. Demographic Survey provided IVs in this test. The demographic survey was suggested by previous work (Mayer, DaPra, 2012). It included participant’s gender, age, year in school, SAT scores, self-rated computer use, self-rated knowledge to electricity.

Retention Test. Retention test was provided from Mayer and DaPra’s work in 2012. It measured learner’s memory in learning material. Participants was given 5 minutes to answer the question “Please explain how solar cell works”.

Scoring in retention test is by calculating the correctness of participants’ answers in 81 main idea units. When answers can reflect the key points that the material presented, they get scores. For example, “solar cells consist of silicon atoms”, “phosphorus atom has five atoms”. A second rater is asked to score the transfer test and raters work together to reach consensus.

Transfer Test. Transfer test was provided from Mayer and DaPra’s work in 2012. The test measured the degree of success in applying their learning in new situations. It consists of 5 questions. The five questions were “It’s a sunny day but there is no power

coming from the solar cell. Why not? Name as many reasons you can think of” “What does the sunlight have to do with creating electricity in a solar cell?” “You want to increase the amount of power output from a solar panel. What could you do?” “What would happen if gallium atoms were substituted for phosphorus atoms? (Note: gallium atoms have three electrons)” and “What does adding phosphorus and boron atoms to silicon have to do with electron flow?” For each question, participants were assigned 3 minutes to answer.

Scoring for Transfer Test is by adding the score of all five questions. One point was assigned to one acceptable answer. For the first question, acceptable answers include no doping, no free carriers, disconnected wires, and no photons hitting electrons. For the second question, acceptable answers include photons knock the electron loose. For the third question, acceptable answers include create more bonding sites, add more impurities, create a larger surface area and use a larger (or better) conducting material. For the fourth question, acceptable answers include no free electrons and unused bonding sites. For the fifth question, acceptable answers include creating a difference in charge, creating free electrons and creating bonding sites. The highest score for transfer test is 14 points. A second rater is asked to score the transfer test and raters work together to reach consensus.

Cohen’s κ was conducted to determine if there was agreement between two raters’ judgments on individuals in the retention test scoring. There was a good agreement between the first question between the two raters, $\kappa = .6673$ (95% *CI*, .422 to .930), $p < 0.001$.

Cohen’s κ was run to determine if there was agreement between two raters’ judgments on individuals in the transfer test scoring. There was a good agreement

between the first question between the two raters, $\kappa = .667$, (95% CI, .421 to .912), $p < 0.001$. For the second question, a good agreement was found as $\kappa = .621$ (95% CI, .343 to .900), $p < 0.005$. For the third question, a good agreement was found as $\kappa = 0.736$ (95% CI, .519 to .952), $p < 0.001$. For the fourth question, a good agreement was found as $\kappa = 0.667$, (95% CI, .357 to .976), $p < 0.005$. For the fifth question, there was good agreement between the two raters, $\kappa = .538$ (95% CI, .034 to 1.040), $p = 0.06$.

Agent Persona Instrument (API). The Agent Persona Instrument (API) developed by Ryu and Baylor in 2005 was used in this test. It measured participant's perception to virtual agent in four dimensions: facilitating learning (10 items), credible (5 items), human-like (5-items) and engaging (5 items) in a 5-point Likert scale (Ryu & Baylor, 2005).

Procedure

Participants recruited from Amazon Mechanical Turk were asked to use their own computer and complete a test distributed by Qualtrics to complete the whole study. First, participants were asked to sign in a consent form and answer the demographic survey. Then, they were assigned randomly into either story-narrative condition or information-narrative condition. One of the two videos, one in story form and another in information form, was randomly assigned to participants to watch, with the instruction "Please do not taking notes watching the video". Both videos are about the solar cell lesson about how electricity is generated from sunlight by solar cell. Third, after watching the video, they were given a 5-min retention question about how solar cell works and 3-min for each question in transfer tests. Finally, they were asked to fill out API for their perception to

the virtual agent's persona. After all the questions completed, participants were given debriefing on the purpose of the study. The whole study last 45 minutes to complete and participants were allowed to complete the study within 45 minutes.

CHAPTER 4

RESULTS

The Impact of Story-narrative on learning

Retention Test and Transfer Test. An Independent sample t-test was conducted on retention score to test for difference between the levels of the conditions. This test indicated a non-significant result for condition, $t(37) = -0.43$, $p = 0.66$, Cohen's $d = 0.14$. Participants receiving narrative condition ($M = 6.26$, $SD = 4.57$) did not differentiate from those in the information condition ($M = 6.9$, $SD = 4.62$). See Table 3 for all Means and Standard deviations. Further, Cohen's effect size value ($d = 0.14$) implies low practical significance.

An Independent sample t-test was conducted on transfer score to test for difference between the levels of the conditions. This test indicated a non-significant result for condition, $t(37) = 0.64$, $p = 0.51$, Cohen's $d = 0.3$. Participants receiving narrative condition ($M = 1.47$, $SD = 1.07$) did not differentiate from those in the information condition ($M = 1.15$, $SD = 1.04$). Further, Cohen's effect size value ($d = 0.3$) implies low practical significance. See Table 3 for all Means and Standard deviations.

Table 3

Means Scores (and SDs) on Retention Test and Transfer Test under two Conditions

Test	Story-narrative(N=19)		Information-narrative(N=20)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Retention Test	6.26	4.57	6.9	4.62
Transfer Test	1.47	1.07	1.15	1.04

The Impact of Story-Narrative to Perception of the Virtual Human. An Independent Sample t-test was conducted on agent facilitated learning to test for difference between the levels of the conditions. This test indicated a non-significant result for condition, $t(37) = -0.43$, $p = 0.66$, cohen's $d = 0.08$. Participants receiving narrative condition ($M = 6.26$, $SD = 4.57$) did not differentiated from those in the information condition ($M = 1.47$, $SD = 1.07$). Further, cohen's effect size value ($d = 0.08$) showed low practical significance. See Table 4 for all Means and Standard deviations.

Independent Sample T-test was conducted to compare the effect of narration form to participants' perception to the agent in four dimensions. There was not a significant difference in the scores for "agent facilitated learning" for story narration ($M = 3.66$, $SD = 0.88$) and information narration ($M = 3.73$, $SD = 0.8$), $t(37) = -.024$, $p = 0.81$, cohen's $d = 0.14$. No significant findings on other three dimensions. For "Agent was credible", story narration ($M = 3.93$, $SD = 0.79$) and information narration ($M=3.82$, $SD=0.8$) show no difference, $t(37)= 0.4$, $p=0.67$. Further, cohen's effect size value ($d = 0.14$) showed low practical significance. For "Agent was Engaging", story narration ($M = 3.43$, $SD = 0.8$) and information narration ($M=3.44$, $SD=0.98$) show no difference, $t(37) = -0.02$, $p=0.97$, cohen's $d = 0.01$. Further, cohen's effect size value ($d = 0.01$) showed low practical significance. For "Agent was Human-like", story narration ($M = 3.32$, $SD = 0.83$) and information narration ($M=3.25$, $SD=1.04$) show no difference, $t(36)= 0.25$, $p=0.80$, cohen's $d = 0.09$. Further, cohen's effect size value ($d = 0.09$) showed low practical significance. See Table 4 for all Means and Standard deviations.

Table 4

Means Scores (and SDs) on Four Dimensions of the Agent Persona Instrument under two Conditions

Dimension	Story-narrative (<i>N</i> =19)		Information- narrative (<i>N</i> =20)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Agent facilitated learning	3.66	0.88	3.73	0.8
Agent was credible	3.93	0.79	3.82	0.8
Agent was engaging	3.43	0.8	3.44	0.98
Agent was human-like	3.33	0.83	3.25	1.04

CHAPTER 5

DISCUSSION

In terms of the retention and transfer score comparison between conditions and perception to the virtual human between conditions, no significant findings were found.

The study hypothesized that story can facilitate learning which can be reflected on their retention and transfer question scores. The study aimed to investigate the score difference of retention test, transfer test and Agent Persona Instrument under story narrative or information narrative conditions. Though retention and transfer test score did not support hypothesis directly.

The study made an attempt to promote learners' performances in scientific topic using narrative, following previous studies in explorations on scientific stories (Roach & Wandersee, 1995; Solomon, Duveen, Scot & McCarthy, 1992). However, scientific education has been focusing on cultivating good scientists (such as involving historical component into science education such as reading a scientist's story) (Klassen, 2009; Metz, 2007; Clough, & Olson, 2004; Roach & Wandersee, 1995; Solomon et al., 1992), instead of improving students' reading and writing skills (Vural, 2013). Science stories (Klassen, 2009; Clough, & Olson, 2004; Martin & Brouwer, 1991) was developed to stress its effect on promote teaching and learning in science in the long term. Martin and Brouwer (1991) discussed the involvement of narrative science education, suggesting that narrative is a representation of personal experience (Martin & Brouwer, 1991), stressing the motivation effect that narrative might bring. They proposed to involve "narrative

mode” into the “paradigmatic mode”, which is, to have stories or anecdotes with historical settings (Martin & Brouwer, 1991). The study tended to create a new approach to a introducing a scientific topic by using script-based story found that scripted-based story will not distract learners from their learning materials.

The insignificance finding on transfer and retention score between the two conditions showed that the current findings have no implications toward the learners’ memory or working memory. By adding a scripted story into a scientific topic narration video, learners’ memory on learning material was not improved, nor deteriorated, implying that scripted-based stories still have their advantage such as easy to remember, which is consistent with that scripts are easy to recall in the Script Theory (Schank & Abelson, 1977). Thus, the study provided an implication on the potential use of scripted-based stories in future learning materials.

Amazon Mechanical Turk

Amazon Mturk can provide a convenient crowdsourcing approach for research that has been used successfully in several research areas (Schroeder & Craig, 2017; Cheung, Burns, Sinclair, & Sliter, 2017; Yu, Willis, Sun, & Wang, 2013). This approach reduces the time and expense cost compared with traditional lab research (Yu et al., 2013; Ribeiro, Florencio, & Nascimento, 2011). By setting the requirement to workers who have a 95% or above Human Intelligence Task (HIT) approval rating, the Amazon Mturk was proposed to collect attentive and reliable participants (Craig & Schroeder 2018; Paolacci & Chandler, 2014). Especially in the area of E-learning, workers from Amazon Mturk experience similar environment to online learners, implying

them to be more qualified participants (Craig & Schroeder, 2018).

The current study applied Amazon Mturk in data collection while did not receive significance. Many factors may have led to the insignificant findings. Participants' inattentiveness, selection bias, demand characteristics, repeated participation, range restriction, consistency of treatment and study design implementation, extraneous factors, sample representativeness and appropriateness, consistency between construct explication and study operations and method bias were concluded as concerning factors for any Mturk study (Cheung et al., 2017). Some successful researches in virtual agent applied Amazon Mturk recruitment (Schroeder, Yang, Banerjee, Romine, & Craig, 2018; Craig & Schroeder, 2017; Craig et al., 2015). One of the research asked participants to listen to a sound first, and then watch videos on a lightning formation consisted of 19 knowledge points and the answer transfer, retention questions (Craig & Schroeder, 2017; Craig et al., 2015). This study applied similar procedure as the previous study (Craig & Schroeder, 2017; Craig et al., 2015). However, The 2015 and 2017 studies implemented several experimental controls. In the 2015 study, sound checks were embedded instructions within the video to allow the participant to move forward. In the 2017 study, although participant cannot control system-paced videos, their answers were limited to a minimum answer length and minimum time on task with a visible counter in the assessment, and a control verification question was set to make sure that participants are reading questions.

From the studies above, it is concluded that experimental control need to be implemented in the recruitment stage and experimental stage. This study had recruitment control. However, the learning material did not receive experimental control, such as minimum answer length limitation in previous study. This may cause inattentiveness to

participants and determine the internal validity.

Based on comparisons above, several recommendations in research in the area of E-learning can be concluded. Controls on both experiment or recruitment must be implemented. For the experiment control, first, the task should be as simple as possible to keep participants attentive, for example, short and small videos. Then, several measures can be made to prevent inattentiveness, such as adding detecting and screening out inattentiveness responding and inform participant that if their respond is found ineffective they will not get compensation (Chueng et al., 2017). By monitoring their behavior, participants will pay closer attention to their task. For the recruitment control, participant's location in the United States, and approval rating above Human Intelligence Task (HIT) over 95%, and a minimum number of completion over 100 are suggested.

(Schroeder, Yang, Banerjee, Romine, & Craig, 2018).

Limitation

The study investigated the role that story plays in multimedia learning, it still needs to be improved. First of all, sample size is required to be enlarged. 40 effective participants in 60 were maintained after screening. Several criteria were set in the data cleaning. First of all, a test question was set. "If you are reading the question, please answer "Agree" and samples answers except "Agree" were excluded. Then, samples whose duration which measures total time that one participant used to complete the whole test shorter than 300 *secs* (5 *mins*) was excluded since the whole video last 4 *mins* 55*s* (295*s*). In addition, samples with retention score as zero were excluded. Then, the study utilized self-rated questions (self-rated knowledge of electricity and self-rated computer

use ability) instead of pretest on these aspects, disturbing the internal validity. Moreover, future studies could focus more behavior measurement to investigate this topic.

Thus, result in the study came out for two aspects: (1) small sample and (2) insufficient narrative effect to participants. On one hand, after three time screening, effective participants has been reduced from 60 to 40. The recorded duration and nonsense answers in retention test and transfer test also showed participants might not focus on their task. On the other hand, a scripted-based story with scientific topic might not work as well as that in literature art, language education or moral education. First of all, the use of narrative in literature art and language education is due to the motivation effect of narrative to increase student listening and oral ability. In the three aspects of learning effects of narratives categorized by Clark (2010), people were argued to learn from hearing a story or narrative, such as moral tales, personal experiences (Martin, & Brouwer, 1991), myths and parables hearing. The motivation effect should be inherent in the narrative itself. The study, on the contrary, in order to get rid of the plot disturbance to the learning material, used routine narratives which was much too familiar to learners. Words, phrases were also easy for learners. And listening ability and oral skills was not the main aim of the study, which undermined the result.

In terms of the perception to virtual human, no significant findings were found on the perceptions to virtual human between in narrative settings are non-narrative settings. This reflected that the two conditions were not differentiated from each other. Previous study attributed the learning effect of narrative-centered environment (such as the narrative in educational games) was due to compelling plots (McQuiggan, Rowe, & Lester, 2008), which was replaced by scripted-story in the study. In narrative-centered

virtual world, narrative-transportation (Gerrig, 1993) that audience feeling being involved in the story plays an important role. This study applied virtual human in both conditions so participants actually learned the lesson in observation in similar way and caused insignificance finding. Thus, participants in narrative condition in the study did not become active learners as others in studies on narrative-centered virtual environment (McQuiggan, Rowe, & Lester, 2008). Another explanation comes from the experiment setting (e.g. lab and classroom). The insignificance of API might also showed that environment influence the perception to virtual agents as suggested in previous study (Schroeder, & Craig, 2017).

Conclusion

In conclusion, the study made progress in attempting to promote learners' performances in scientific area using narrative. Future studies could focus on developing effective narrative learning materials such as creating more narrative transportation and engagement by adding first person elements (Tussyadiah & Fesenmaier, 2008), using multiple characters to elevate realness (Tussyadiah & Fesenmaier, 2008) while avoid adding extra burdens to learners' memory at the same time.

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APPENDIX A

SCRIPT FOR SOLAR CELL LESSON

(SCRIPT FOR INFORMATION-NARRATIVE CONDITION)

SLIDE 1: "Solar cells are used to convert solar power to electricity that is used to run electrical devices. Solar cells are made up of silicon atoms, the same material found in sand."

SLIDE 2: "A silicon atom has 14 positively charged protons and 14 negatively charged electrons. The positive and negative charges are balanced and so each silicon atom is neutral in charge."

SLIDE 3: "There are four electrons on the outer shell of a silicon atom as well as four bonding sites for electrons. The four electrons can bond perfectly onto the bonding sites of neighboring silicon atoms. Because of this, there are no electrons left to create an electric current. Thus, the pure silicon must be altered somehow to allow for the movement of electrons."

SLIDE 4: "The first step in creating a solar cell is a process known as *doping*. This process is carried out by mixing small amounts of impurities with the silicon. By adding these impurities, electrons are allowed to flow."

SLIDE 5: "Phosphorus atoms are added to the silicon on the top side of the solar cell. This creates n-type or negative silicon. Phosphorus atoms have five electrons, one more than the available bonding sites in a silicon atom. The extra electron moves to find a place to bond, but because there are only four bonding sites, one electron cannot find a place to fit. The moving electron is called a *free carrier* because it can move freely about and carries a small electrical current."

SLIDE 6: "Boron atoms are added to the silicon on the bottom side of the solar cell to create p-type, or positive silicon. Boron atoms have three electrons, one less than the available bonding sites in a silicon atom. Thus, when boron and silicon are combined,

there is an empty bonding site present in the silicon atom that can accept another electron.”

SLIDE 7: “In the second step, the solar cell develops an electrical charge. Free electrons from the top flow within the solar cell and bond to the empty sites in the bottom. As a result of losing electrons, the top side, or n-type side, is positively charged and as a result of gaining electrons, the bottom side or p-type side, is negatively charged. This creates a barrier between the sides and electrons can now only flow in one direction within the cell, from the negatively charged side on the bottom to the positively charged side on the top. This barrier is what causes the electrical charge of the solar cell.”

SLIDE 8: “Third, when sunlight in the form of photons hits the solar cell, it knocks loose the free carrier electrons from their shell. The electrons now move to find a place to bond. When electrons in the negatively charged bottom level that are near the barrier with the top layer get knocked loose, they are attracted to the positively charged layer on top and move across the barrier.”

SLIDE 9: “Fourth, a chain reaction is initiated in which an incoming electron bumps one electron out of its shell and takes its place, so that electron bumps out an electron from a neighboring atom, and so forth.”

SLIDE 10: “A metal contact allows electrons to flow outside and around the cell from the n-type side on top back into the p-type side on the bottom. The incoming electrons, into the bottom layer, fill the empty sites left by the flowing electrons through the cell. The electrons leave the cell from the negative terminal connected to the n-type side on top and enter the cell at the positive terminal on the p-type side on the bottom. The electrons flowing outside the cell create an electrical current because of the electrical charge they hold.”

SLIDE 11: "The process continues as long as sunlight hits the solar cell. A number of solar cell are arranged in large panels that use metal wires to channel the current to power devices that run on electricity.

APPENDIX B

SCRIPT OF SCRIPT-BASED STORY

Ben joined a student technology organization and was asked to create a solar cell. Ben had no idea about the solar cell. Ben read books and watched videos on how to make solar cells. Ben began working very hard at creating the solar cell based on the instruction of the book. Ben wound up being the number two good member that year!

APPENDIX C

SCRIPT OF STORY-NARRATIVE CONDITION

Ben joined a student technology organization and was asked to create a solar cell. He had no idea about the solar cell. He read books and watched videos on how to make solar cells.

He already knew that solar cells are used to convert solar power to electricity that is used to run electrical devices. Solar cells are made up of silicon atoms, the same material found in sand.

Then, he discovered that a silicon atom has 14 positively charged protons and 14 negatively charged electrons. The positive and negative charges are balanced and so each silicon atom is neutral in charge.

There are four electrons on the outer shell of a silicon atom as well as four bonding sites for electrons. The four electrons can bond perfectly onto the bonding sites of neighboring silicon atoms. Because of this, there are no electrons left to create an electric current.

Thus, the pure silicon must be altered somehow to allow for the movement of electrons.”

After understanding the basics of atoms, he investigated the actual procedure in a solar cell. The first step in creating a solar cell is a process known as doping. This process is carried out by mixing small amounts of impurities with the silicon. By adding these impurities, electrons are allowed to flow.”

Phosphorus atoms are added to the silicon on the top side of the solar cell. This creates n-type or negative silicon. Phosphorus atoms have five electrons, one more than the available bonding sites in a silicon atom. The extra electron moves to find a place to bond, but because there are only four bonding sites, one electron cannot find a place to fit. The moving electron is called a free carrier because it can move freely about and carries a

small electrical current. Boron atoms are added to the silicon on the bottom side of the solar cell to create p-type, or positive silicon. Boron atoms have three electrons, one less than the available bonding sites in a silicon atom. Thus, when boron and silicon are combined, there is an empty bonding site present in the silicon atom that can accept another electron.

However, Ben found that there is a second step in the process. In the second step, the solar cell develops an electrical charge. Free electrons from the top flow within the solar cell and bond to the empty sites in the bottom. As a result of losing electrons, the top side, or n-type side, is positively charged and as a result of gaining electrons, the bottom side or p-type side, is negatively charged. This creates a barrier between the sides and electrons can now only flow in one direction within the cell, from the negatively charged side on the bottom to the positively charged side on the top. This barrier is what causes the electrical charge of the solar cell.

Ben found out that sunlight comes into the process in the next step. Third, when sunlight in the form of photons hits the solar cell, it knocks loose the free carrier electrons from their shell. The electrons now move to find a place to bond. When electrons in the negatively charged bottom level that are near the barrier with the top layer get knocked loose, they are attracted to the positively charged layer on top and move across the barrier.

Ben then discovered a chain reaction in a solar cell. Fourth, a chain reaction is initiated in which an incoming electron bumps one electron out of its shell and takes its place, so that electron bumps out an electron from a neighboring atom, and so forth.”

A metal contact allows electrons to flow outside and around the cell from the n-type side

on top back into the p-type side on the bottom. The incoming electrons, into the bottom layer, fill the empty sites left by the flowing electrons through the cell. The electrons leave the cell from the negative terminal connected to the n-type side on top and enter the cell at the positive terminal on the p-type side on the bottom. The electrons flowing outside the cell create an electrical current because of the electrical charge they hold.

Now he is familiar with the process happening in one solar cell. The process continues as long as sunlight hits the solar cell. A number of solar cell are arranged in large panels that use metal wires to channel the current to power devices that run on electricity.

Ben began working very hard at creating the solar cell based on the instruction of the book. Ben wound up being the number two good member that year!

APPENDIX D

DEMOGRAPHIC SURVEY

1. Gender: Male Female

2. Age:

3. SAT score:

4. Year in School:

5. How would you rate your knowledge of electricity?

Bad Average Good

6. How would you rate your ability of using computers?

Bad Average Good