

# What Influences Children's and Adolescents' Understanding of the Complexity of the Internet?

Zheng Yan

University at Albany, State University of New York

This study aimed at analyzing complex relationships among Internet use, Internet users, and conceptual understanding of the Internet. It used path models to examine factors related to Internet use (duration of Internet use, frequency of Internet use, and informal Internet classes) and Internet users (age and gender) in affecting understanding of the technical and social complexity of the Internet for 322 elementary and middle school students. The findings of the study indicate that (a) age of young Internet users had predominant effects on both the technical and social understanding of the Internet; (b) frequency of Internet use and informal Internet classes had small but significant effects on social understanding, but no effect on technical understanding; and (c) technical understanding had a unidirectional effect on social understanding. The implications of these findings for the implementation of the Children's Internet Protection Act are discussed.

**Keywords:** Internet, Children's Internet Protection Act, understanding, complexity, artifact

The children's Internet Protection Act was signed into law in 2000, requiring schools and libraries receiving federal e-rate funds to filter online visual depictions that are harmful to children under the age of 17, and representing widely implemented federal policy decisions to protect children from damaging impacts of the Internet (Parsad & Jones, 2005). To developmental researchers, it presents an urgent need to develop theoretical frameworks and research programs for examining factors associated with effects of the Internet on children and informing implementation and improvement of this federal regulation (Huston & Wright, 1998; Thornburgh & Lin, 2002). The present study is such an effort, with specific goals of developing a theoretical model that includes multiple factors in, effects on, and pathways to children's understanding of the complexity of the Internet.

## Children's Understanding of the Internet

The Internet has implications for the physical, cognitive, social, and behavioral development of children and adolescents (Finkelhor, Mitchell, & Wolak, 2000; Finkelhor, Mitchell, & Wolak,

2003; Greenfield, 2004; Huston et al., 1998; Katz & Rice, 2002; Kraut et al., 1998; Subrahmanyam et al., 2001; Thornburgh & Lin, 2002). Children's and adolescents' understanding of the Internet can be considered a specific and important effect of children's Internet experience as well as an interesting and relevant manifestation of conceptual development. In contrast to the extensive developmental literature that has documented when, how, and why children come to understand natural, social, and mental concepts (e.g., Carey, 1985; Gelman & William, 1998; Gopnik, Meltzoff, & Kuhl, 1999; Karmiloff-Smith, 1992; Keil, 1989; Wellman & Gelman, 1998), research into children's understanding of complex artifacts, such as the Internet and computers, is sparse. Nevertheless, concepts of artifact kinds are rich, important, and pervasive (Keil, 1989).

The Internet is all the more interesting as a locus of conceptual development research because it is a hybrid of artifactual (e.g., computer screens and keyboards), social (e.g., communications with people), and mental-like systems (e.g., invisible virtuality). For these reasons, to study understanding of the Internet challenges the boundaries between the traditional categories of cognitive development, social-cognitive development, and social development.

As an artifact system with enormous technical complexity, the Internet is a gigantic but almost invisible universe that includes thousands of networks, millions of computers, billions of users across the world, and includes multilayer communication protocols (e.g., TCP/IP and SMTP), various physical connection devices (e.g., cables and satellites), and numerous application programs (e.g., e-mail and WWW). According to the *Encyclopedia of Computer Science* (Ralston, Reilly, & Hemmendinger, 2000), multiple networks are the core technological feature of the Internet.

As an artifact system with enormous social complexity, the Internet has not only had pervasive positive impacts on modern society, but also has caused various societal concerns about privacy, security, pornography, a digital divide, Internet crime, virtual community, and intellectual property rights. Like almost every

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Zheng Yan, Department of Educational and Counseling Psychology, University at Albany, State University of New York.

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Correspondence concerning this article should be addressed to Zheng Yan, Department of Educational and Counseling Psychology, University at Albany, State University of New York, Albany, NY 12222. E-mail: zyan@uamail.albany.edu

technology that human beings have invented, the Internet is essentially another double-edged sword that has profound positive and negative social consequences (Katz & Rice, 2002). The present study focused on how children understand the two fundamental features of the Internet, the technical complexity of networking, and the social complexity of both positive and negative social experiences.

As an artifact system with enormous social complexity, the Internet contrasts with TV. As an artifact system with enormous technical complexity, the Internet contrasts with the personal computer. Thus, the Internet combines enormous technical complexity with enormous social complexity, and this unique combination makes children's understanding of the Internet both challenging and important. It is *challenging* for children to recognize the technical and social complexity of the Internet through available inputs—namely, their hands-on experience with e-mail, WWW, chat rooms, or instant messages. The task is challenging because the Internet is (1) fairly new (social scaffolding and formal instruction are not always available), (b) essentially virtual (the entire cyberspace is not immediately accessible to children's senses), (c) highly connective (being online makes one subject to intrusion in one's virtual life without one's consent or awareness), and (d) extremely open (freedom from control is such that, in principle, anyone in the world can, at any time, post any materials online at low cost and high speed). Thus, it is not easy for young minds to figure out how complex the Internet really is, technically and socially.

As challenging as this understanding is, it is also *important* for young users to understand the complexity of the Internet. Just as children's epistemological knowledge of learning directly contributes to their learning (e.g., Hofer & Pintrich, 1997; Hofer & Pintrich, 2002; Schommer, 1990; Schommer, 1993), epistemological knowledge about the Internet could substantially impact their online attitudes and online behaviors. For example, knowledge of the technical complexity of the Internet should help children understand how to better search for material for a school research project and how online predators can read messages children send to their friends via instant messages or cell phones. Having a basic understanding of the social complexity of the Internet, children might become aware of the differential reliability of information found on different web sites according to the competence and motives of the sponsoring organization and understand the commercial intentions of many Internet web sites aimed at children. Knowledge of children's understanding of the technical and social complexity of the Internet is therefore critical in both guiding children in their positive uses of the Internet and protecting them from negative experiences. However, very limited developmental evidence is available to guide these important endeavors (Denham, 1993; Luckin, Rimmer, & Lloyd, 2001; Yan, 2005).

Using children's drawings as their research data, Luckin, Rimmer, & Lloyd (2001) found no significant improvement in 21 9-year-olds' understanding of the Internet after one year of initial online experience between 1998 and 1999. Furthermore, the non-significant improvement that took place in this longitudinal study could have also been a function of age. In the present study, age and experience will be deconfounded. In a well-cited study, Denham (1993) examined the computer-related mental models of 285 children from three groups aged 9–10, 10–11, and 11–12 years. The results suggested that older children tended to perceive the

computer as a system with multiple connections to multiple components, whereas younger children tended to consider a computer as a system with few or no connections to few components. This cross-sectional study assessed the effect of age, but had no way of comparing the roles of age and experience or the possible relations between them. The author's research program fills in this gap. In addition, this program is the first to investigate not just the development of technical knowledge of the Internet, but also social knowledge of the Internet.

### A Research Program on Children's Technical and Social Understanding of the Internet

*The previous study.* In my previous study (Yan, 2005), I compared one Internet-user factor, age groups, and one Internet-use factor, online experience, and tested a series of nested hierarchical logistic regression models in order to deconfound statistically the effects of age and experience on technical and social understanding. Four age groups participated in the study: 5- to 8-year-olds, 9- to 10-year-olds, 11- to 12-year-olds, and adults. To indicate their understanding, children produced both verbal and visual representations of the Internet. The results indicated that age groups were a more powerful predictor of technical understanding than online experiences and the only significant predictor of social understanding.

For technical understanding, there was a significant difference between the 9- to 10-year-olds and the 11- to 12-year-olds. In contrast, 5- to 8 year-year-olds were not significantly different from 9- and 10-year-olds; nor were 11- and 12- year-olds significantly different from adults. The same pattern of developmental difference was found for the social complexity of the Internet, with an important difference: There was a significant difference in understanding between 9- and 10-year-olds and the 11–12-year-olds and between 11- and 12-year-olds and adults. The distribution of response categories suggested that technical understanding of the Internet seems in advance of social understanding: For example, more than twice as many 11- and 12-year-olds reached the sophisticated or scientific level of understanding the technical complexity of the Internet as reached these levels of understanding of its social complexity. This discrepancy between children's technical understanding and social understanding became a motivation for an examination of the relation between technical and social understanding in the present study.

*The present study.* The results of the previous study suggested two new questions: (1) Are different factors responsible for the development of technical understanding and social understanding of the Internet? (2) Are there influences between technical and social understanding of the Internet and, if so, does the earlier developing technical understanding influence social understanding or is the influence reciprocal?

(1) *Are different factors responsible for the development of technical and social understanding of the Internet?* Contributing factors can be generally grouped into two major categories: factors related to various external experiences of *Internet use* and factors related to various individual characteristics of *Internet users*. Internet-use factors generally include (a) *direct* online experiences, often measured by duration (e.g., years of using the Internet, hours

of Internet use at home a week) and frequency (e.g., minutes spent online per day, number of logon sessions a day) and (b) *indirect* online experience obtained through informal Internet classes, daily media exposure, accidental observations, or casual overhearings.

Internet-user factors consist of various characteristics of Internet users, including (a) conventionally labeled *demographic* variables (e.g., age, gender, race, parental education, family income, and geographical locations) and (b) various *psychological* variables (e.g., such as reasoning, memory, personality, emotional arousal, puberty, and brain maturity). To developmental researchers, the variable of age certainly has a special significance since children of different ages manifest different levels and paces of physical, cognitive, and social development, as well as a different quality and quantity of direct and indirect experiences.

The previous study had three major limitations that needed to be overcome to answer questions concerning the possibility of different factors contributing to the technical and social understanding of the Internet. First, the study included only one Internet-user variable, age group, but other Internet-user factors such as gender, personality, or race might compete with age (Kraut et al., 1998; Roberts & Foehr, 2004; Jackson et al., 2006). For example, gender differences favoring boys were found when personal computers first became popular (Subrahmanyam et al., 2001; Roberts & Foehr, 2004); but these were greatly reduced as communication functions of the Internet became diffused within a given peer group (Gross, 2004). In the present study, gender was selected as an additional Internet user variable.

Second, the study utilized only one Internet-use variable, direct online experience; this variable aggregated frequency and duration of Internet use. However, frequency and duration of Internet use could have had different effects, not to mention measures of

indirect online experience such as informal Internet classes not assessed in the study (Jackson et al., 2006; Yan, 2006). The present study treated frequency and duration of Internet as separate measures of direct online experience and added informal computer classes as a measure of indirect online experience.

Third, only direct pathways between predictors (age group and online experience) and outcome variables (technical and social understanding) were estimated. However, indirect pathways through mediating and moderating factors might also be at play.

(2) *Are there influences between technical and social understanding of the Internet, and, if so, does technical understanding influence social understanding or is the influence reciprocal?* Direct bidirectional pathways from one outcome variable to another might also be important and needed to be tested (Huston, Wartella, & Donnerstein, 1998; Zillmann & Bryant, 2002).

In sum, a larger sample, new, more differentiated variables, and more direct and indirect pathways enabled the present study to address these questions by moving beyond regression analysis to test more complex path models. Specifically, the present study focused on how multiple factors influenced children's understanding of the Internet. It selected a total of seven variables—two Internet-effect ones (understanding of technical and social complexity of the Internet), three Internet-use ones (duration of Internet use, frequency of Internet use, and informal Internet classes) and two Internet-user ones (age and gender). Using these variables, the investigator developed a path model (see Figure 1) to test the following three sets of effects: (a) *Direct* effects of duration of Internet use, frequency of Internet use, and informal Internet classes on technical and social understanding of the Internet. (b) *Direct* and *indirect* effects of age and gender on technical and

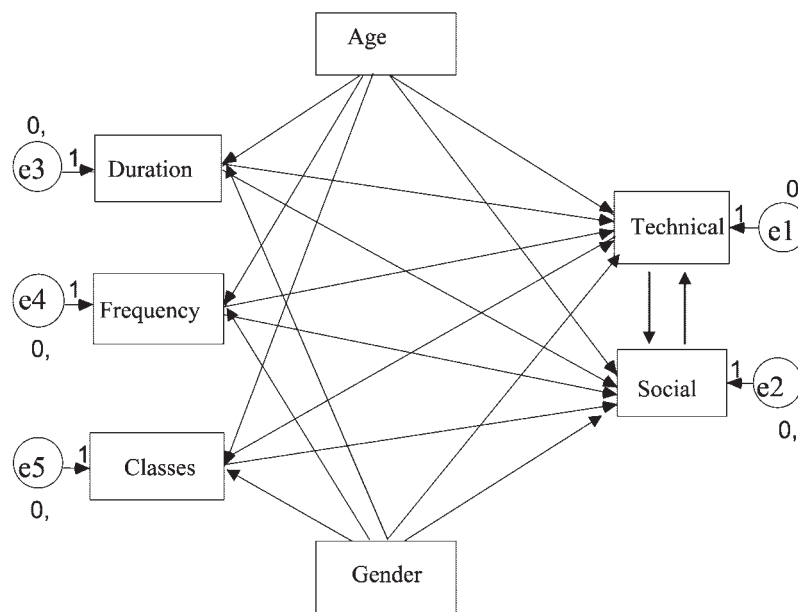


Figure 1. The hypothesized path model examining effects of three Internet-use variables, duration of Internet use (Duration), frequency of Internet use (Frequency), and informal Internet classes (Classes), and two Internet-user variables, Age and Gender, on two Internet-effect variables, children's understanding of the technical complexity of the Internet (Technical) and children's understanding of the social complexity of the Internet (Social).

social understanding of the Internet. (c) *Reciprocal* effects between technical and social understanding.

## Method

### Participants

Participating in the study were 322 elementary and middle school students, 176 girls and 146 boys. Among them were 76 fourth graders with 46 girls and 30 boys (age  $M = 9.11$ , age  $SD = .42$ ), 87 fifth graders with 53 girls and 34 boys (age  $M = 10.10$ , age  $SD = .34$ ), 51 sixth graders with 24 girls and 27 boys (age  $M = 11.14$ , age  $SD = .35$ ), 50 seventh graders with 25 girls and 25 boys (age  $M = 12.14$ , age  $SD = .35$ ), and 58 eighth graders with 28 girls and 30 boys (age  $M = 13.12$ , age  $SD = .38$ ). Participants were from six elementary schools and one middle school in a suburban school district in the New England area (Information about participants' ethnicity was not collected). After participants' assents and parental consents were obtained, a 20-min anonymous survey was administered in the regular classroom during the 2004–5 academic year. The study was approved by the Institutional Review Board of the State University of New York at Albany.

In relation to the previous study (Yan, 2005), the absence of developmental difference between the youngest (age  $M = 6.5$  years) and the next age group (age  $M = 9.33$ ) in the first study led to the elimination of the youngest group in the present study. In addition, the fact that the adult level of understanding social complexity was not yet attained by the oldest group of children, fifth and sixth graders, in the prior study led to the inclusion of still older children (seventh and eighth graders) in the present study.

### Measures

**Duration of use of the Internet (Duration).** This Internet-use variable was based on participants' responses to a 4-point Likert scale (1 = 0–1 year, 2 = 2–3 years, 3 = 4–5 years, and 4 = over 5 years) to two survey questions, "How long have you been using the Internet at home?" and "How long have you been using the Internet at school?" The highest number on either of the two questions was used as the final score.

**Frequency of use of the Internet (Frequency).** This Internet-use variable was based on participants' responses to a 4-point Likert scale (1 = never used, 2 = every month, 3 = every week, and 4 = every day) to two survey questions, "How often do you use the Internet at home?" and "How often do you use the Internet at school?" The highest number on either of the two questions was used as the final score.

**Informal Internet classes attended (Classes).** This Internet-use variable assesses how much informal Internet education children have received. It was based on participants' responses to a 4-point Likert scale (1 = never, 2 = once, 3 = twice, and 4 = three or more) to one survey question, "Have you taken a class or a workshop about the Internet at school or somewhere else?"

**Understanding of the technical complexity of the Internet (Technical).** This Internet-effect variable assesses participants' understanding of the technical complexity of the Internet from a cognitive perspective. Nine questions were first asked to probe from different angles how much participants knew about the networking complexity of the Internet: (1) What is the Internet? (2) Why do you think it is named "Internet"? (3) Where is the Internet? (4) How big is the Internet? (5) How many computers are there on the Internet? (6) How did you know about that? (7) How many websites are there on the Internet? How did you know about that? (8) If you could walk into the Internet, what would it look like inside? (9) If you stand a long distance away from the Internet, what does it look like? Among these nine questions, Questions 1, 3, 8, and 9 were the questions asked in the previous study (Yan, 2005). The present study added five more questions (Questions 2, 4, 5, 6, and 7) to have a richer and more accurate assessment of participants' verbal representations of technical

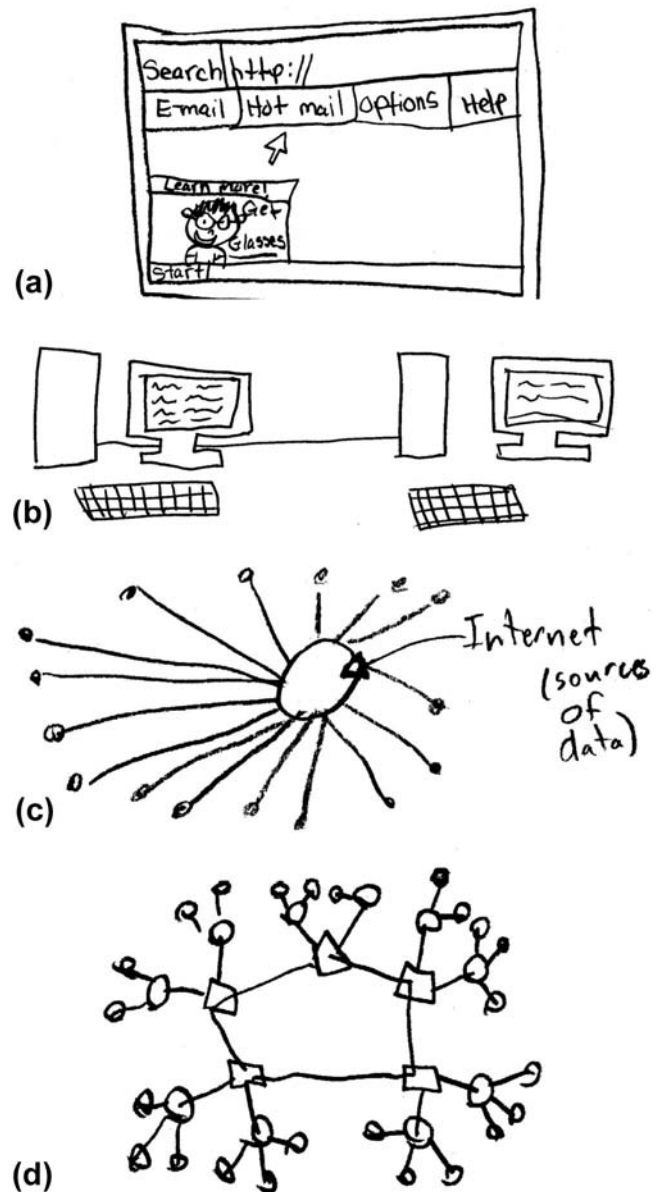


Figure 2. Four student's drawings of the Internet that shows (a) a minimal level of understanding of the technical complexity of the Internet, (b) a partial level of understanding of the technical complexity of the Internet, (c) a sophisticated level of understanding of the technical complexity of the Internet, and (d) a scientific level of understanding of the technical complexity of the Internet.

complexity. Participants were then asked to draw a picture of the Internet to show what the Internet looks like, the same task used in the previous study. The drawing task was intended to elicit children's visual representations of the technical complexity (see Figure 2 for four examples from the present study).

Coders assigned participants' technical understanding to one of four levels: minimal, partial, sophisticated, and scientific, based on both verbal evidence obtained from children's answers to the nine questions and visual evidence demonstrated in their drawings. *Minimal understanding* was assigned to those who perceived the Internet as one computer and had little sense of its participation in a network (e.g., saying that Internet is a



computer or drawing a picture of one computer). *Partial understanding* was assigned to those who perceived the Internet as either several computers with no indication of connections among them or simple connections of several computers (e.g., saying that the Internet has only two computers or drawing a straight line linking two computers); such a representation showed an ambiguous understanding of network complexity. *Sophisticated understanding* was assigned to those who considered the Internet a network-like system in which a computing center links with multiple computers, showing a well-developed understanding of network complexity (e.g., saying that the Internet is a network or drawing a picture of a computer network). *Scientific understanding* was assigned to those who understood the Internet as a complex system with multiple connected networks, demonstrating an expert-like understanding of technical complexity (e.g., saying that the Internet is a network of networks or drawing a picture of multiple networks).

In their treatment of the verbal evidence, coders examined students' answers to all nine questions and found the answer with the highest level. In their treatment of the visual evidence, coders examined students' drawings to see how well they represented the networking feature, according to the levels defined above. The highest score of verbal or visual representations for each participant is the final score of technical understanding.

*Understanding of the social complexity of the Internet (Social).* This Internet-effect variable represents participants' conceptual understanding of the social complexity of the Internet. Assessing participants' social understanding was based on both verbal evidence obtained from children's answers to the 10 questions and visual evidence demonstrated in their drawings. For verbal evidence, 10 questions were first asked to probe from different angles how well participants understood the positive and negative social consequences of the Internet: (1) What kinds of things do you like most on the Internet? (2) What kinds of things do you dislike most on the Internet? (3) What kinds of good things could the Internet do for us? (Please give 3–5 examples) (4) What kinds of bad things could the Internet do for us? (Please give 3–5 examples) (5) What kinds of good things could happen to us when we use e-mail? (6) What kinds of bad things could happen to us when we use e-mail? (7) What kinds of good things could happen to us when we go to websites? (8) What kinds of bad things could happen to us when we go to websites? (9) Do you need to be careful when you go to the WWW? (10) Do you need to be careful when you use e-mail? Among these 10 questions, Questions 5, 6, 7, and 8 were new probing questions that have not been asked in the previous study (Yan, 2005); it was hoped that their greater specificity would lead to a more accurate picture of participants' understanding of the social complexity of the Internet. For visual evidence, participants were then asked to draw a picture to show what kinds of people one would see on the "street" if one could walk into the "city" of the Internet, a new task that was not used in the previous study. The drawing task was intended to obtain children's visual representations of social complexity (see Figure 3 for four examples from the present study). The similar procedure to assess technical and social understanding were used in the present study to remove a possible confound between the understanding of technical complexity compared with social complexity in the earlier study in which only technical complexity understanding had been assessed using drawings.

Like their technical understanding, participants' social understanding was coded at four levels: minimal, partial, sophisticated, and scientific.

*Minimal understanding* indicates that an individual knows little about positive or negative social consequence of the Internet (e.g., concerned only about the slowness of opening web pages) and expresses little precaution when using the Internet (e.g., claiming that the Internet would never hurt a person), showing a naïve understanding of the social complexity of the Internet. *Partial understanding* indicates that an individual has a general but limited sense of the positive and negative social consequence (e.g., reporting only 1–2 superficial social consequence(s) such as seeing too many pop-up advertisements and spending too much time in a chat room), and a vague precaution related to using the Internet (e.g., believing that a bad thing could happen when e-mailing someone). This level of understanding reflects an awareness of the social complexity of the Internet. *Sophisticated understanding* indicates a strong understanding of the profound social consequences of the Internet (e.g., discussing 2–3 important societal concern(s) such as online privacy or the digital divide) and a thoughtful attitude toward Internet use (e.g., explicitly expressing precautions in using e-mail and browsing websites). *Scientific understanding* indicates a comprehensive, profound, and balanced understanding of the positive and negative social consequences of the Internet (e.g., explicitly specifying various serious problems on the Internet: teenage pornography websites, stealing personal information, intruding personal mails, sending spyware programs, posting false advertisements, and online attacks by hackers) and a thorough knowledge of online protection strategies (e.g., discussing firewalls, filtering programs, and password protections), showing an expert-like understanding of the social complexity of the Internet.

As was done for the assessment of technical understanding, verbal evidence was sought through an examination of students' answers to all the 10 questions to see how well they understand the social complexity of the Internet (e.g., examining their answers to Question 5 or 6 to see if they would list a few specific bad things in using e-mails). Again, the highest level that manifests in response to any of the questions was the level scored. As in the procedure for technical complexity, drawings were evaluated according to the same four levels defined above. The highest score for the verbal or visual representation of each participant was the final score for social understanding.

To test for interrater agreement, the author and a graduate assistant trained as the second coder independently coded 21% of the data on the variables of children's technical and social understanding of the Internet. A Kappa coefficient for the technical understanding was .82 and for the social understanding .83. According to Bakeman and Gottman (2000), the interrater agreement for the coding of each variable is excellent. Coding discrepancies between coders were resolved through discussion and mutual agreement before data analysis.

## Results

### Descriptive Statistics

Table 1 lists means, standard deviations, and correlation coefficients for variables duration of use of the Internet, frequency of use of the Internet, Internet classes attended, age, understanding of technical complexity, and understanding of technical complexity.

*Figure 3 (opposite).* Four student's drawings of the Internet that shows (a) a minimal level of understanding of the social complexity of the Internet, (b) a partial level of understanding of the social complexity of the Internet, (c) a sophisticated level of understanding of the social complexity of the Internet, and (d) a sophisticated level of understanding of the social complexity of the Internet. Note that none of 322 children and adolescents in the study drew a picture representing a scientific level of understanding of the social complexity. Thus, two drawings (c and d) representing the sophisticated understanding are provided here, one showing the profound understanding and another the balanced view. Putting these two drawings together, one could sense what the scientific understanding that is comprehensive, profound, and balanced could look like visually.

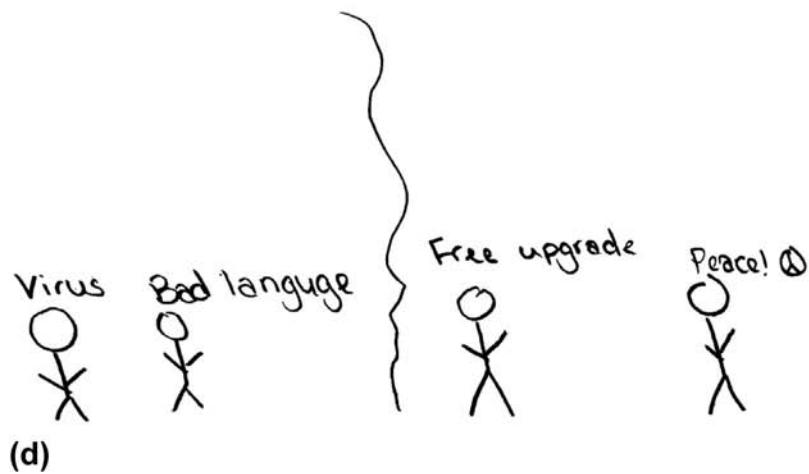
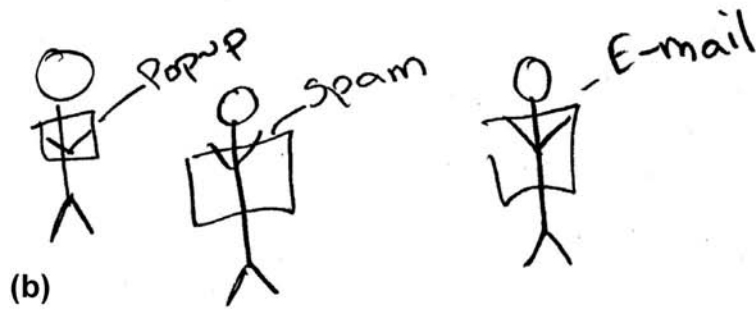
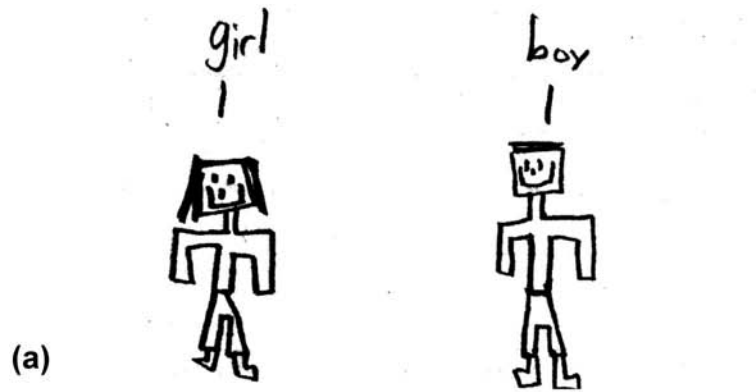


Table 1  
Means, Standard Deviations, and Correlation Coefficients of Duration of Internet Use (Duration), Frequency of Internet Use (Frequency), Informal Internet Classes Attended (Classes), Age, Understanding the Technical Complexity of the Internet (Technical), and Understanding the Social Complexity of the Internet (Social) ( $N = 322$ )

	Mean	SD	1	2	3	4	5	6
1. Duration	2.90	.923	1.000	.310**	.121*	.173**	.082	.084
2. Frequency	3.38	.744		1.000	.032	.217**	.125*	.193**
3. Classes <sub>lg</sub> <sup>a</sup>	.160	.218			1.000	.119*	-.011	.181**
4. Age	10.89	1.486				1.000	.298**	.309**
5. Technical	1.80	.666					1.000	.296**
6. Social	1.93	.586						1.000

<sup>a</sup> Classes<sub>lg</sub> = transformed Classes after log transformation of Classes. The mean and SD of original Classes before transformation are 1.66 and .989, respectively.

\*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

As shown in Table 1, on average, students who participated in the study have used the Internet for nearly 4–5 years either at home or at school based on the four-level variable Duration ( $M = 2.9$ ,  $SD = .923$ ) and they went on the Internet daily or weekly based on the four-level variable Frequency ( $M = 3.38$ ,  $SD = .744$ ). Students on average took more than 1 informal class about the Internet based on the untransformed four-level variable Classes ( $M = 1.66$ ,  $SD = .989$ ). The average level of these students' understanding of the technical and social complexity of the Internet was nearly reached the level of partial understanding based on the four-level variables Technical and Social ( $M = 1.80$ ,  $SD = .666$ ;  $M = 1.93$ ,  $SD = .586$ , respectively).

To meet the normal assumption of structural equation modeling, normality for the six variables Duration, Frequency, Classes, Age, Technical, and Social was checked. Univariate skewnesses and kurtoses were found to be acceptable within the range of  $\pm 1.0$  (Bollen, 1989; Muthen & Kaplan, 1985) for all the variables except for Classes, skewness  $Z = 1.316$ , kurtosis  $Z = .462$ . A log transformation for Classes was conducted, resulting in Classes<sub>lg</sub> with skewness  $Z = .889$ , kurtosis  $Z = .746$ . Thus, Classes<sub>lg</sub> instead of Classes was used for all the subsequent analyses.

#### *Fitting Nested Models to Best Represent Relationships Among Age, Gender, Internet Use, and Children's Understanding of the Internet*

The goal of the analysis here was to find the model that best fits the data, as a first step toward understanding the relations of various factors in affecting children's understanding of the Internet. To fit models, a series of nested path models was tested using the maximum-likelihood method in AMOS 5.0. Four indices were used to assess goodness of fit for a model (Bollen, 1989; Hu & Bentler, 1999): The  $\chi^2$  goodness-of-fit statistics (values of .05 or greater are desirable), the comparative fit index (CFI; values of .95 or greater are desirable), the Tucker-Lewis index (TLI; values of .95 or greater are desirable), the root-mean-square error of approximation (RMSEA; values of .06 or less are desirable).

As shown in Table 2, summarizing the results of fitting nested models, the baseline model Model<sub>0</sub> does not have a good model fit,  $\chi^2(4, N = 322) = 47.865$ ,  $p < .001$ , TLI =  $-.167$ , CFI =  $.689$ , RMSEA =  $.185$ . This baseline model includes all paths of the

model specified in Figure 1, but not those allowing reciprocal relations to be tested. Nor does it include gender pathways; gender as a nominal variable will be tested in a separate multigroup model presented at the end of this section. Model<sub>1</sub> allows e3 (the error term for duration of Internet use) and e4 (the error term for frequency of Internet use) to covary, further improving the model fit compared with Model<sub>0</sub>,  $\Delta\chi^2(1, N = 322) = 26.918$ ,  $p < .001$ . Model<sub>2</sub> removes four nonsignificant paths, resulting in a more parsimonious model without reducing the model fit,  $\Delta\chi^2(4, N = 322) = 2.419$ ,  $p > .05$ . Model<sub>3</sub> estimates a reciprocal effect between technical understanding and social understanding, resulting in a significant improvement in model fit,  $\Delta\chi^2(2, N = 322) = 6.105$ ,  $p < .001$ . However, the unstandardized path coefficients of the two paths between technical understanding and social understanding are not significant, while the path from social understanding to technical understanding is negative and much weaker,  $\hat{b} = .204$ ,  $p > .05$ ;  $\hat{b} = -.010$ ,  $p > .05$ , respectively, suggesting no reciprocal relationships. Model 4 removes the weaker path from social understanding to technical understanding, producing a more parsimonious model,  $\chi^2(6, N = 322) = 6.106$ ,  $p > .05$ , TLI =  $.998$ , CFI =  $.999$ , RMSEA =  $.007$  with a significant path from technical understanding to the social understanding,  $\hat{b} = .197$ ,  $p < .001$ . Thus, this model is the best-fitting model.

Following Byrne's (2001) suggestions, the bootstrap procedure was used to validate the model fit and parameter estimation of the data with minor nonnormality falling within the acceptable range. The results of using Model<sub>4</sub> to fit 1000 bootstrap samples indicate that all the model fit indices and parameter estimates with the 1000 bootstrap samples matched well those with the original sample using Model<sub>4</sub> in Table 2, confirming the robustness of the model fit and parameter estimation in Model<sub>4</sub>. Thus, this model was used to generate the major results of the path analysis (see Figure 4).

#### *Estimating Path Coefficients to Quantify Relationships Among Age, Gender, Internet Use, and Children's Understanding of the Internet*

**Duration of Internet use.** As shown in Figure 4, no significant path exists either from duration of Internet use to technical understanding or from duration of Internet use to social understanding; this result indicates that there are no direct effects of duration of

Table 2  
Parameter Estimates and Model Fit Statistics of a Series of Nested Path Models ( $N = 322$ )

	$M_0$	$M_1$	$M_2$	$M_3$	$M_4$
Parameter Estimation (Standard Error) <sup>a</sup>					
DUR <sup>b</sup> → TEC	.015 (.039)	.015 (.041)			
DUR → SOC	-.015 (.033)	-.015 (.035)			
FRE → TEC	.051 (.049)	.051 (.051)			
FRE → SOC	.109** (.042)	.109* (.044)	.104* (.042)	.092* (.041)	.092* (.041)
Classes <sub>lg</sub> → TEC	-.152 (.164)	-.152 (.164)			
Classes <sub>lg</sub> → SOC	.397** (.141)	.397** (.141)	.391** (.141)	.420** (.137)	.419** (.137)
AGE → TEC	.129*** (.024)	.129*** (.025)	.134*** (.025)	.135*** (.024)	.134*** (.045)
AGE → SOC	.105*** (.021)	.105*** (.021)	.104*** (.021)	.077* (.036)	.078*** (.021)
AGE → DUR	.108** (.034)	.108** (.034)	.108** (.034)	.108** (.034)	.108** (.034)
AGE → FRE	.109*** (.027)	.109*** (.027)	.109*** (.027)	.109*** (.027)	.109*** (.027)
AGE → Classes <sub>lg</sub>	.017* (.008)	.017* (.008)	.017* (.008)	.017* (.008)	.017* (.008)
e3 ↔ e4		.187*** (.038)	.187*** (.038)	.187*** (.038)	.187*** (.038)
TEC → SOC				.204 (.224)	.197*** (.047)
SOC → TEC				-.010 (.316)	
Model Fit					
$\chi^2$	47.865***	20.947***	23.366*	6.105	6.106
df	4	3	7	5	6
TLI	-.167	.363	.751	.976	.998
CFI	.689	.873	.884	.992	.999
RMSEA	.185	.137	.085	.026	.007
$\Delta\chi^2$		26.918***	2.419	17.261***	-0.001
$\Delta df$		1	-4	2	-1

<sup>a</sup> All the parameter estimates included in the table are unstandardized.

<sup>b</sup> DUR = duration of Internet use (Duration). FRE = frequency of Internet use (Frequency). Classes = informal Internet classes attended (Classes). TEC = understanding the technical complexity of the Internet (Technical). SOC = understanding the social complexity of the Internet (Social).

<sup>c</sup> Classes<sub>lg</sub> = transformed Classes after log transformation of Classes.

Internet use on children's understanding of the technical and social complexity of the Internet.

**Frequency of Internet use.** Frequency of Internet use does not have a direct effect on technical understanding of the Internet, but does have a small but significant positive direct effect on social understanding of the Internet,  $\hat{\beta} = .12, p < .05$ .

**Informal Internet classes attended.** Similar to frequency of Internet use, attending informal Internet classes has no direct effect on children's technical understanding of the Internet, but does have a small but significant positive direct effect on their social understanding of the Internet,  $\hat{\beta} = .16, p < .01$ .

**Age.** In terms of *direct* effects of age, older children have greater technical and social understanding of the Internet. As shown in Figure 4, there is a path from Age to Technical Understanding,  $\hat{\beta} = .30, p < .001$ , and a path from Age to Social Understanding  $\hat{\beta} = .20, p < .001$ . In addition, while there is no *indirect* effect of age on technical understanding, there are multiple *indirect* effects of age differences on social understanding through a variety of pathways. Specifically, as shown in Figure 4, there is (a) an indirect path from Age to Social Understanding via Frequency of Internet Use,  $\hat{\beta} = .22 * .12 = .0264$ ; (b) an indirect path from Age to Social Understanding via Internet Classes<sub>lg</sub>,  $\hat{\beta} = .12 * .16 = .0192$ ; and (c) an indirect path from Age to Social Understanding via Technical Understanding,  $\hat{\beta} = .30 * .22 = .066$ . Together, these paths produce a total indirect effect of .112 (.0264 + .0192 + .066 = .1116  $\approx$  .112). Overall, the total effect of Age on Technical Understanding is .30 and that of Age on Social Understanding is .312 (the direct effect .20 + the total

indirect effect .112 = .312). This indicates that a 1 *SD* increase in children's age is associated with a .30 *SD* increase in their technical understanding of the Internet and with a .312 *SD* increase in their social understanding of the Internet.

**Relationship between technical understanding and social understanding.** Children's technical understanding of the Internet affects their social understanding,  $\hat{\beta} = .22, p < .001$ , but not vice versa.

**Gender.** Multiple-group analyses indicate that the unconstrained model (Model<sub>4</sub>) with invariant path coefficients across genders has a good fit,  $\chi^2(20, N = 322) = 25.411, p > .05$ , TLI = .949, CFI = .966, RMSEA = .029. Furthermore, the model constraining all the path coefficients across genders does not improve model fit comparing with the unconstrained model,  $\Delta\chi^2(8, N = 322) = 6.800, p > .05$ . These results indicate that there are no gender differences in the effects of duration of Internet use, frequency of Internet use, informal Internet classes, and age on children's technical and social understanding of the Internet.

## Discussion

### Technical and Social Understanding of the Internet

The major new and surprising finding is that the relationship between understanding of technical complexity and understanding of social complexity is unidirectional and asymmetrical rather than reciprocal and symmetrical. The shift from regression in the previous study to structural equation modeling in the present study



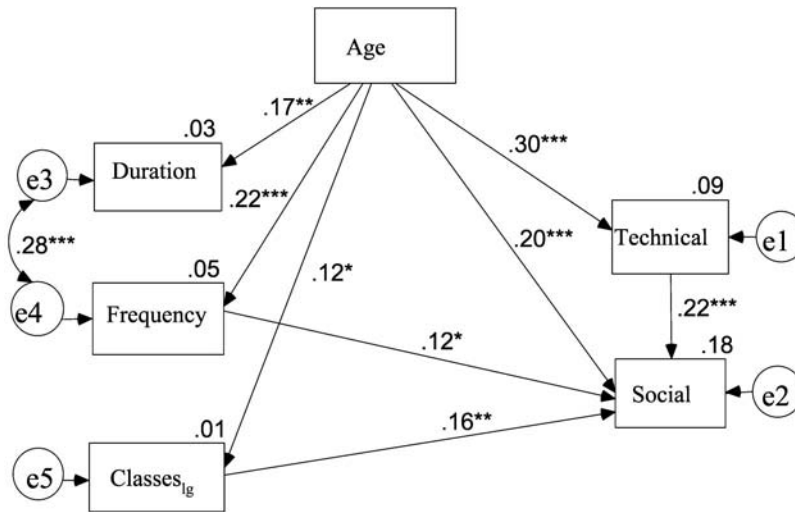


Figure 4. The best fitting model with the estimated standardized path coefficients of all significant paths, estimating how much each of four variables, duration of Internet use (Duration), frequency of Internet use (Frequency), informal Internet classes (Classes), and age affects children's technical understanding of the Internet (Technical) and social understanding of the Internet (Social). A separate multigroup model based on the above model was tested to estimate the effect of the dichotomous variable Gender.

made it possible to estimate a reciprocal relationship between variables (Bollen, 1989; Holbert & Stephenson, 2002). One possible explanation is that cognitive understanding of the Internet and social understanding of the Internet interact with each other unidirectionally and asymmetrically because the Internet is first and foremost a technological system, like a car or an airplane, rather than a social system, like a school or a village. Children's knowledge of the technical complexity of the Internet helps them better understand the social complexity (e.g., inadvertent pornography or online predators); a good understanding of social complexity might motivate children to learn more about Internet technology, but would hardly automatically advance their conceptual understanding of the Internet as a complex artifactual system that is relatively new, almost invisible, highly connective, and extremely open.

#### Age and Gender

Another major finding of the study is that one Internet-user factor, Age, is the most influential one among all the five Internet-user and Internet-use factors. It has twice the total effect that the three Internet-use variables, duration of Internet use, frequency of Internet use, and informal Internet classes attended, have together on children's technical and social understanding of the Internet. This age effect is consistent with the previous study (Yan, 2005), but further confirmed with a larger sample size ( $N = 332$  vs.  $N = 111$ ) and a smaller age range (between 8 and 14 vs. between 5 and adult). Furthermore, compared with the students in Grades 3–4 and 5–6 in the previous study, the students in Grade 4, 5, and 6 in the present study show similar levels of technical and social understanding, most of them being at the levels of minimal and partial understanding. Compared with those students of lower grades, the students in Grades 7 and 8 in the present study show relatively higher levels of technical and social understanding, most

of them being at the levels of partial and sophisticated understanding, with relatively similar distributions of understanding levels to the adults in the previous study.

Putting the findings of the two studies together, we see that by Grades 5 and 6, children have reached the adult level of understanding the technical complexity of the Internet. However, it is not until Grades 7 and 8, early adolescence, that children reach the adult level of understanding the social complexity of the Internet. However, the previous study showed that, even for adults, the scientific level is rare (Yan, 2005). These findings are generally comparable with studies on children's understanding of the natural, social, and mental systems in which children's conceptual understanding becomes increasingly sophisticated over time (e.g., Carey, 1985; Keil, 1989; Wellman & Gelman, 1998).

It is unlikely that this dominant effect of age on understanding the Internet is due to potentially confounding effects of children's experiences of using the Internet. Although age differences in children's direct and indirect online experiences are substantial, as evidenced by direct effects of age on duration of Internet use, frequency of Internet use, and informal Internet classes, these Internet use experiences do not directly and consistently produce higher levels of understanding. There are no direct effects of duration of Internet use, frequency of Internet use, and informal Internet classes on children's technical understanding of the Internet, whereas the effects of the three Internet-use variables on children's social understanding of the Internet are diverse, ranging from zero, small, to substantial.

In other words, the structural equation modeling approach used in this study allows one to partition the total age effect into two components, that is, the direct effect and the indirect effect. While the direct effect of age (primarily due to age differences in developmental levels) on both technical and social understanding is large, there is no indirect effect of age (mainly due to age differ-

ences in online experiences) on technical understanding, despite the significant age effect of age on all dimensions of online experience. The situation with understanding of social complexity is different. Here age operates both directly (through developmental levels) and indirectly (through more frequent Internet experience and more informal Internet classes as children get older).

In contrast to age, which has dominant effects on children's technical and social understanding of the Internet, gender, another Internet-user factor that was not studied in the previous study, has no direct and indirect effects. This is consistent with the existing literature that the initial gender difference in Internet skills has substantially decreased with the wide use of the Internet (e.g., Gross, 2004; Yan & Fischer, 2004).

Essentially, the age effect observed in the study brings up a general issue in conceptual development: How do children learn and understand concepts that are *newly emerged* and *highly complex*? The Internet is a *new* concept that just entered human life a few decades ago at most, whereas classic concepts such as energy were established several hundred years ago at least (Liu & McKeough, 2005). Additionally, the Internet is a *complex* concept that is difficult to learn through direct experiences or intuitive thinking, different from understanding much simpler concepts such as a ball or a teapot. As observed in the study, many children had 4–5 years of online experiences, used the Internet daily or weekly, and had attended at least one informal Internet class. However, when (a) direct experiences are plentiful but consist mainly of self-directed exploration (Kuhn, 1989), (b) educational opportunities are available but ineffective (Dawson, 2002), (c) social scaffolding (e.g., media exposure or family support) is present but not optimal (Fischer & Bidell, 1998; Yan & Fischer, 2002), and (d) concepts are important but too new to be supported either by fundamental knowledge (Wellman & Gelman, 1998) or by core knowledge (Spelke et al., 1992), then children ought to rely heavily on domain-general resources such as developmental maturity (Carey, 1999). The Internet and experience with it has all four of these characteristics, and, collectively, two studies have now shown the overriding importance of the age factor, a proxy for developmental maturity.

### Internet Use

In the present study, none of the three Internet-use factors, duration of Internet use, frequency of Internet use, or informal Internet classes attended, had an effect on technical understanding of the Internet. In contrast, frequency of Internet use and informal Internet classes had small but significant effects on social understanding. This finding differs from the finding of the previous study (Yan, 2005). In that study, the aggregated variable of duration and frequency had a small but significant impact on technical but not social understanding. Further research is needed to examine this discrepancy. The variable of informal classes is a new addition to the present study for assessing children's indirect online experience. It was found to have a slightly larger effect on social understanding than frequency of Internet use, with no effects on technical understanding. It is possible that informal Internet classes that the students have attended might focus more on the social complexity of the Internet rather than the technical one (anecdotally, quite a few students mentioned Internet safety work-

shops given by policy officers, librarians, or social workers, but hardly reported any technology-based Internet talks).

### Implications for the Implementation of the Children's Internet Protection Act

The findings of the study have three implications for children's Internet safety: (a) *Age matters*. Since age plays a dominant role in children's understanding of the Internet, schools, libraries, families, and other social systems should take age differences seriously and develop a variety of developmentally proper strategies to protect children under the age of 17. For very young Internet users, for example, not only should highly restricted filtering programs be used, but also, and perhaps even more desirably, carefully selected websites that are specifically designed for young children should be provided. For older children and adolescents, much less restrictive filters could be used, together with quality educational programs to educate them on how to use the Internet safely and intelligently and certain online monitoring programs for tracking Internet use and detecting problems. (b) *Multiplicity counts*. Two Internet use factors are associated with an understanding of the social complexity of the Internet, frequency of Internet use and Internet classes. Thus, to complement filtering, the best nontechnical Internet protection strategy for fostering children's virtual "immune systems" is to encourage frequent positive uses of the Internet and provide informal Internet instruction. (c) *Technological understanding is important*. Since the relation between technical understanding and social understanding is unidirectional and asymmetrical, it is essential to teach children more scientific knowledge about how the Internet works in order to induce the social understanding that will lead to appropriate caution about online safety. These efforts will help children and adolescents better understand the technical and social complexity of the Internet and better nurture them online and offline.

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