An Information Systems Design Theory for Collaborative ePortfolio Systems

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Abstract

An educational ePortfolio usually contains work that a student has collected, reflected on, constructed, and published to demonstrate personal learning and growth over time. This paper proposes Information Systems Design Theory for ePortfolio systems following the methodology by Walls et al. (1992). A new ePortfolio system is designed based on the proposed ISDT. The research model is discussed and the evaluation is planned to examine users’ perceived value of the new system, measured by usefulness as a tool, effectiveness in achieving users’ goals, knowledge, learning, and social effects.

1. Introduction

This paper proposes an ISDT for collaborative ePortfolio systems based upon both literature reviews and industrial practice, guided by Walls’ methodology. The paper then describes a plan of building and evaluating a new ePortfolio system with the purpose of testing the proposed ISDT.

1.1. What are ePortfolios?

An electronic portfolio (ePortfolio) is a collection of digital artifacts that demonstrates what a person knows and can do. It is used in academia assessment, career planning, and for documenting and demonstrating students’ learning and growth over time. Zubizaretta (2004) stated that a learning portfolio should contain three fundamental components: documentation, reflection, and collaboration. Traditional ePortfolio and e-learning systems have focused on personal constructive learning activities such as knowledge collection, reflection and presentation, however, lack options for social constructive learning such as peer review, group collaboration, and community learning [2, 8, 12, 25]. Although recent open source (e.g., Moodle, Sakai) and commercial (e.g., WebCT, Blackboard) learning management systems have made efforts to provide such options, they often lack effectiveness and efficiency due to design problems. New features such as discussion forums, chat rooms, blogs, and wikis and many other new tools are usually limited to the scope of a course or project, thus interaction and collaboration with peers outside the classroom is restricted. Furthermore, there is lack of connection between the knowledge contents created and stored in these tools. For example, there is no direct way for users to link certain blog entries or wiki pages to an assignment or an Open Source Portfolio (OSP) portfolio page in Sakai Collaborative Learning Environment (CLE). The most common way to connect is to link the files from the repository or archive to blog entries or wiki pages. As a result, students and teachers have to create and manage redundant knowledge or information in different tools.

1.2. The original system: KEEP toolkit

KEEP Toolkit is a Carnegie-funded ePortfolio project developed by the Knowledge Media Laboratory (KML). Distinctive features of KEEP include a user-friendly portfolio page (called a “snapshot” in KEEP Toolkit) in which users can edit, add, delete, or move content blocks of the portfolio; and a dashboard that supports portfolio management, e.g., stitching multiple pages together to make a portfolio web site. Furthermore, KEEP allows users to attach evidence to portfolio blocks in various formats (e.g., WORD, PDF, GIF, and JPEG). KEEP also allows users to publish their portfolios to a publicly-accessible URL, but does not allow users to comment on any public snapshot or stitched group. KEEP has made efforts to integrate with other educational systems and web applications such as Sakai CLE, DSpace and FEDORA. KEEP also demonstrates collaborative vision. KEEP version 2.0 allows users to apply tags or keywords to snapshots, stitched groups, and galleries. The open source nature and collaborative vision of the KEEP toolkit made it a suitable platform to design, implement, and evaluate a new ePortfolio system that promotes community-wide
reflection and learning. In November 2009, KEEP was migrated to MERLOT – an online community of resources designed primarily for faculty, staff and students of higher education from around the world to share their learning materials and pedagogy. As a result, KEEP users need to have a MERLOT account (free) to continue using KEEP.

1.3. Information systems design theory

The development and testing of IS design theories is an important priority in the IS discipline. Lacking adequate design theories, IS developers build and users employ applications that are not as effective or efficient as they could be [18]. Design theories not only support the design of the artifact itself, but also provide the means to develop such artifacts. Both the product and process aspects of design theories must be tied to kernel theories from natural or social sciences, or from practice. Design theories differ from these descriptive or normative theories in that they are prescriptive, explicitly recognizing that the intent behind design is to satisfy human goals.

Every IS design theory has two aspects: the design product and the design process. Different from explanatory and predictive theories found in the natural or social sciences, Information Systems Design Theory (ISDT) is prescriptive, integrating normative and descriptive theories into design paths with the contingent goal of producing more effective information systems. ISDT examines both the application of scientific theory and the use of the scientific method to test design theories. For the design product, kernel theories from natural or social sciences governing design requirements are determined; then meta-requirements are specified to describe the class of goals to which the theory applies; then testable design product hypotheses are used to test whether the meta-design satisfies the meta-requirements. In the design process, another group of kernel theories are established for managing the design process itself; then design methods are specified to describe procedures for artifact construction; and finally testable design process hypotheses are used to verify whether the design method results in an artifact that is consistent with the meta-design. The most significant reason for ISDT is the absence of theoretical basis for general information systems design and development. Furthermore, the lack of theoretical support often makes it difficult to benefit from other disciplines. Information systems without a theoretical basis often assume or predict that systems will work based on the designer’s or developer’s own knowledge, skills, experiences, and interpretations of the users’ requirements.

2. An ISDT for collaborative ePortfolio systems

2.1. Design product phase

The kernel theories of the design product for this study include: Social Constructive Learning Theories [4, 13, 21, 23], Communities of Practice [11], and Social Presence Theory [16].

“Learning is the process of direct and indirect experience and observation”, and “knowledge is an internalized result of learning through individual efforts and social interactions” [14]. Human beings learn in different ways: concrete experience, observation and reflection, abstract conceptualization, and active experimentation [10]. One’s knowledge of everyday life is structured in terms of relevance, is socially distributed, and “is possessed differently by different individuals and types of individuals” [3]. Thus, the social distribution of knowledge of certain elements of everyday reality can become highly complex and even confusing to outsiders. Constructivist learning theories [4, 13, 21, 23] also support that learning is an active, social process.

Communities of Practice (CoP) refer to “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.” [20]. Wenger further extended the work of CoP to organizational and educational learning. His “Social Theory of Learning” model integrates the following components necessary to characterize social participation as a process of learning and of knowing: “Meaning (learning as experience); Practice (learning as doing); Community (learning as belonging); and Identity (learning as becoming)”. Wenger suggests that learning should be primarily a practice of identity formation and modes of belonging, and not just accumulating skills and information.

Social presence refers to a person’s awareness of the presence of others in a communication or interaction medium, and the interpersonal relationships [16]. The social effects of a medium are principally caused by the degree of social presence which it supports to its users. Research demonstrated that social
presence in online education environments positively affects students’ perceptions of learning and satisfaction with the instructor [15].

Based upon the analysis of current design and implementation of the ePortfolio systems in practice, including OSP and the original KEEP Toolkit, three levels of the ISDT were proposed:

- Layer 1: System development environment
- Layer 2: System Functionalities
- Layer 3: Knowledge management activities

Then with the guidance of the aforementioned Social Constructive Learning Theories, Communities of Practice, and Social Presence Theory, the fourth level of the ISDT design product for ePortfolio systems was built: Social/Collaborative Learning Activities (see Table 1).

Each level is further supported by a group of meta-requirements and the derived meta-design products. Level 1 provides the fundamental architecture for web-based applications. Level 2 specifies detailed system functionalities. Level 3 states the commonly supported activities for knowledge management systems and learning systems. Level 4 contains advanced social learning features. These functionalities and activities are interactive with each other. Each level supports the level above it. Note that Level 2 requires a stronger sense of security in order to facilitate Level 4. For example, for a successful implementation of annotation (Level 4) without being spammed, authentication and human-check mechanisms (Level 2) must be implemented. The testable design product hypotheses are listed as H1, H2, and H3 in Table 4.

2.2. Design method phase

The kernel theories of the design method include: Evolutionary Prototyping [5], Usability Testing Theory [7], and Emergent/Agile Development [17]. The meta-design method derived from relevant kernel theories and meta-requirements is described in Table 2. The testable design process hypothesis is listed as H4 in Table 4.

2.3. Research framework

Design research consists of two basic activities: build and evaluate. They parallel with the discovery and justification processes in natural science research. Building is the process of constructing an artifact for a specific purpose, while evaluation is the process of determining how well the artifact performs. Figure 1 shows the research framework for this study based on the design research method. The ultimate goal is to generate a working ISDT for ePortfolio systems through the research processes.

3. The new system: KEEP SLS

3.1. System development

As mentioned in the Introduction section, the open source nature and collaborative vision of the KEEP toolkit made it a suitable platform to design, implement, and evaluate the new ePortfolio system under the guidance of proposed ISDT. The development environment was coordinated with the original design of the KEEP Toolkit, and uses Windows 2000 server as the operating system, Apache as the Web server, MySQL as the database, PHP as the server-side scripting language, and an Apache Tomcat Java servlet container for repository support. The server is co-located at an Internet Service Provider (ISP). To maintain the object oriented programming approach of KEEP, existing libraries for the original Toolkit were extended to add new modules, and new scripts were created following the same structure and style.

During system development, we maintained close communications with the KEEP developers, focus groups, and end-users via email, meetings, and the KEEP forum. We continuously reviewed and refined the system design based upon users’ feedback and suggestions. We developed the system in small iterations starting from the easiest module, and tested with a focus group at the completion of each milestone. We used CVSNT (Concurrent Version System) as the version control utility to track the changes (what, when, how, and where each change was made), and provide backup. We also used a development weblog to record day-to-day progress. We conducted two rounds of usability tests with a small group of doctoral students and faculty members to assess the usability and efficiency of the new KEEP features (i.e., KEEP SLS) to perform tasks easily, efficiently, with only a few tolerable or non-catastrophic errors, with satisfaction, and at a fast pace.
3.2. KEEP SLS features

The original KEEP Toolkit features remain the same in KEEP SLS, including creating, editing and previewing snapshots and stitched groups. The new SLS features focus on enhancing interaction, knowledge and information sharing, and social learning effects among users, which is the essence of Web 2.0. These features enable users to easily search and browse public snapshots and stitched groups, comment on snapshots, connect to external blogs, and collaborate in groups (See Table 3).

4. Evaluation of the design artifact

4.1. Evaluation measures

Using Communities of Practice (CoP) as a kernel theory, KEEP SLS was designed and built to promote community-wide sharing, interaction, collaboration, reflection, and learning. We adapted some of the evaluation measures from a previous study [24], in which a two-staged information processing model was developed and tested to analyze the CoP impact on organizational level performance. In the first stage, CoP activities including information exchange and networking influence network position; in the second stage, network position influences performance of the primary organizational unit as measured by knowledge, business performance, and socialization effects.

4.1.1. Independent variables. Participation in Social Learning Activities - we measured participation in KEEP SLS activities using a multi-item constructs adapted from the “Information Exchange” and “Networking” measures from [24].

- Knowledge Synthesis and Diffusion – users’ participation in searching and browsing others’ public snapshots and stitched groups;
- Annotation – users’ participation in commenting on others’ public snapshots and stitched groups;
- Blog Connection – users’ enabling the connection to external blogs, linking portfolio contents to related blog entries, and blogging about others’ public snapshots and stitched groups; and
- Group Collaboration – users’ participation in collaborating in groups.

Perceived Social Learning Position. Similar to everyday life, different people present different attitudes in social learning activities within the ePortfolio community. For example, some KEEP users may be happy to present and discuss their portfolio work to others, while others may not feel comfortable presenting or discussing their work. These attitudes form a social learning position for the user. Similar to the network position in CoP, social learning position in an educational community may influence the user’s subjective points of view of the value of the educational medium.

Perceived Ease of Use. In the Technology Acceptance Model (TAM) [6, 22], perceived usefulness of an information system is seen as being directly impacted by perceived ease of use. How easy the users feel it is to use KEEP SLS might impact their perceived value of KEEP SLS.

4.1.2. Dependent variables. The main dependent variable is perceived value of the system. This variable is measured as a combination of the following three elements in addition to the perceived usefulness of the tool and the perceived effectiveness in achieving users’ goals. Each of these measures also connects to the design product’s kernel theories. Perceived value of an information system is often considered as an independent variable to predict the long-term usage of the system, based on TAM and related theories. However, subjects of this study had used the system for only one month. They were not required to use the system to create any specific or mandatory portfolio contents. Considering the time and scope constraints, we found the users’ perceived value, rather than the actual system use, to be a more practical and meaningful measure for evaluating the design artifact.

Perceived Knowledge Effect. ePortfolio participation has a knowledge effect. With KEEP SLS users can access others’ public portfolio work through searching, browsing, or inviting group members to participate. Users may gain more knowledge through evaluating, reusing, transforming or further developing others’ public portfolio work. It also may be easier for users to recognize and contact knowledge experts in the KEEP SLS community. We measured the perceived knowledge effect using five items adapted from the “Knowledge Effect” measure from [24].

Perceived Learning Effect. Perceived learning has been commonly used as a dependent variable in studies of online learning and e-learning systems [1]. As an instance of e-learning systems, ePortfolio systems may enable users to learn through knowledge created and shared, through group collaboration, and through the processes of integrating facts, knowledge, and ideas from different people. Learning effect is a critical net
benefit for educational communities, and it is similar to business performance for organizational units. We measured perceived learning using five items adapted from the “Business Performance” measure from [24].

Perceived Social Effect. Introducing social learning activities may change the existing social structure within an ePortfolio system such as KEEP Toolkit. With KEEP SLS, users are able to search, browse, or comment on other users’ public portfolios without having to know the name or email address of the author beforehand. With these new abilities, users can increase chances of getting to know each other and each other’s portfolio work more. Trust among KEEP SLS users may also change in these new activities. We measured perceived social effect using three items adapted from the “Socialization” measure [24].

4.2. Evaluation method

4.2.1. Planned data gathering. The evaluation of the system will be conducted through two online surveys, i.e., pre-test and post-test. The pre-test survey requires participants to have experience with the original KEEP Toolkit features, i.e., have created a snapshot and/or a stitched group, edited the contents, customized the layout, renamed or deleted a snapshot or a stitched group, added a tag, sent a copy of the snapshot to other users, or sent the URL of a snapshot to others via email. The pre-test surveys will also examine users’ demographic Information, technology proficiency, perceived ease of use, and perceived value of the original KEEP. The post-test requires participants to have experience with the new KEEP SLS features in addition to the original KEEP features. Post-test surveys will examine SLS participation and Perceived Social Learning Position regarding the new SLS features; these were in addition to the same items in pre-test. Validity and reliability of both questionnaires will be examined using Cronbach's alpha. The sample population of this study includes general KEEP toolkit users and developers worldwide. The following actions have been taken to facilitate the data collection process:

- A KEEP SLS test drive site was set up with its registration open to the public.
- An online download page was setup so users could download the KEEP SLS source code and install it on a server.
- An online survey page was set up so that the public could provide feedback and suggestions.

4.2.2. Planned data analysis. Quantitative data from the pre-test and post-test surveys will be analyzed using statistic software such as SPSS 13.0. Table 4 shows the statistical methods proposed for testing the hypotheses. Demographic and computer technology proficiency of the participants will be charted and analyzed. Comparison of Perceived Value in Pre-Test and Post-Test will be conducted using descriptive statistics (i.e., N, Mean, and Standard Deviation). A paired-samples t-test will be used to determine whether there is a statistically significant difference between the pre- and post-test perceived value. A scatterplot will be used to examine whether the variables are approximately normally distributed and have no outliers, so that Pearson correlation coefficient will work the best in finding out the correlations between the variables. And finally, linear regression will be used to predict users’ perceived value of the KEEP SLS (dependent variable) from independent variables, i.e., SLS participation, perceived ease of use, and perceived social learning position.

5. Conclusion

Walls et al. (2004) speculated that one reason for lack of use in ISDT may have been that researchers found their framework/methodology difficult to use. Another reason may be that the discipline has not yet accepted design research as a method with equal status to quantitative and qualitative methods. Orlikowski and Iacono (2001) reviewed 10 years of IS literature and showed that the IS field has not embraced the information technology (IT) artifact. They propose that IS researchers begin to theorize specifically about IT artifacts, and then incorporate these theories explicitly into their studies” (p. 121). Another reason may be that software designers find the design theory approach to be constraining or unnecessary.

In this study, an ISDT was developed for ePortfolio systems through building and evaluating the artifact of a new ePortfolio system, following the design methodology of Walls et al. (1992). Establishing this ISDT helps to instantiate new learning paradigms, collaboration techniques, and artifacts to reach the goal of enhancing educational benefits. This study contributes to ISDT literature by following rigid empirical methods and applying multiple measures for the design artifact. This not only enhances the reliability of the study, but also establishes a benchmark for future ISDT studies. Furthermore, this
study is different from previous ISDT studies in the following aspects:

- It compares a system designed under an ISDT (i.e., KEEP Toolkit) and one without (i.e., KEEP SLS).
- It provides a graphical ISDT articulation to make the work comprehensive to general readers, which helps to bridge the gap between IS researchers and practitioners.
- It develops an ISDT from theories. The ISDT is continuously refined throughout system development, usability testing and evaluation processes. The particular considerations of practice, practical knowledge and technology availabilities add a new aspect to the theory-oriented Walls et al. ISDT method.

However, this study also presents several limitations with respect to Walls et al.’s methodology. In the design process, we did not design the original system (i.e., KEEP Toolkit), nor did we know the design methodologies or processes used by the development team who developed the original system. We assume that it is not based upon ISDT as we did not find any related literature or documentation. Also, in our hypotheses, we did not propose to examine the learning effects of each individual tool, or how the effect of the same tool differs if implemented in different situations. We also did not propose to examine to what extent these tools should be implemented with the goal of achieving ultimate system effectiveness and efficiency. That is, we did not plan to determine whether more (communication, social learning tools, and other related features) is always better (usefulness, effectiveness, learning, knowledge, and social effects).

Finally, the concept of a design theory is rooted in the idea that it can be reused across a family/class of artifacts. If this is possible, then ISDT can positively impact the Science of (software) Design. Assuming the evaluation is successful, further research should test the ISDT developed from this study to see if the developed ISDT for a certain instance (e.g., KEEP Toolkit) can be applied to the creation of another software product (e.g., Sakai OSP) in the same class of information systems (ePortfolio systems).

6. References


<table>
<thead>
<tr>
<th>ISDT Elements</th>
<th>Meta-Requirements =&gt;</th>
<th>Meta-Design</th>
</tr>
</thead>
</table>
| Level 1: System Development Environment | Accessibility => | • Service-oriented application  
• Platform and browser independence  
• Open source software  |
| Reliability => | • Service-oriented application  
• Database tuning  
• Exception handling  |
| Conciseness, Interoperability, Scalability, Extensibility => | • Platform and browser independence  
• High-level scripting language for dynamic Web pages  
• Object-oriented design pattern  
• Open source software  |
| Level 2: System Functionalities | Security => | • Authentication and access control  
• Registration with human check mechanism  
• Javascript filter for publishing user submitted contents (to prevent browser hacking)  
• Other security mechanism (e.g., anti-spam, anti-Denial of Services)  |
| User Administration => | • Registration  
• Account management  
• Content management  
• Presentation management (stylesheet, theme, skin)  
• Plug-in management  |
| Maintainability / System Administration => | • Backup and restores  
• Usage tracking  
• Integration with other applications (e.g., Learning/Course Management System, virtual community, ERP)  |
| Level 3: Knowledge Management Activities | Knowledge Collection => | • A central digital repository (or gallery) of multimedia (files, images, audio, video) and templates available for uploads and downloads  
• A searchable public archive of portfolios  
• Social bookmarking  
• External knowledge  |
| Knowledge Construction => | • WYSIWYG editor  
• Drag-and-drop implementation for layout or template creation  
• Internal/external links  
• Multimedia attachment  
• Snapshots preview  
• Tagging knowledge contents  |
| Knowledge Presentation => | • Publicly accessible contents  
• Publicly accessible related blog entries  
• Publicly viewable tags and comments  
• Podcast, RSS or ATOM  |
| Level 4: Social / Collaborative Learning Activities | Knowledge Synthesis and Diffusion => | • A central digital repository of multimedia, templates, galleries and other resources  
• A searchable public archive  
• A sortable browse function with abstract of each result  
• A public tag cloud  
• A user rating/voting feature  
• Reader’s digest or customizable web syndication (e.g., RSS, ATOM)  |
| Annotation=> | • Login-restricted or human-check supported commenting to |
ISDT Elements  |  Meta-Requirements => |  Meta-Design
---|---|---

Knowledge content
- Owner of the knowledge content can manage, delete, activate or deactivate comments

Connection to External Knowledge =>
- Links to external digital repository, web sites and related applications
- Blog Connection
- Configuration to external blog sites
- Blog-this
- Related blog entries
- Wiki Connection

Collaborative Writing =>
- Rules in forming a group
- Collaborative content writing with locking or wiki mechanism
- Keep records of history of changes
- Remove a group member or group content

Traditional Communication Tools =>
- Video-conferencing
- Discussion forums
- Chat rooms
- Email

Table 1. Design Product

Kernel Theories =>
- Emergent/Agile Development
  - Maintain close communication with developers for the original system, focus group, and end-users, welcome feedback and suggestions.
  - Minimize risk by developing software in small iterations. Improve user satisfaction with rapid, continuous delivery of useful software modules/functions.
  - Integrate with existing learning process rather than require change, unless the change is initiated by the users.

- Evolutionary Prototyping
  - Maintain a close relationship with developers of the original system, focus group, end-users.
  - Continually refine and rebuild the system prototype based upon a cycle of collecting user requirements, redesigning the prototype, and evaluating the prototype with users.
  - Use research methods such as preliminary study, focus group, and usability tests to achieve the goal of building a robust prototype

- Usability Testing Theory
  - Study time, accuracy, recall, and emotional response when users use the system (or system prototype) to complete desired tasks. Consider the results for improving the system and the system prototype design.

Design Method
- Usability, Customization, Integration

- Conciseness, Portability, Customization

- Accessibility, Reliability, Usability, Security

Table 2. Design Process
**SLS Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>Search</td>
<td>With the search feature, users can easily find and share public snapshots and stitched groups created by others either by entering any keyword(s) (simple search) or by snapshot title, KEEP username, tags, and content (advanced search).</td>
</tr>
<tr>
<td>Browse</td>
<td>With the browse feature, users can browse and sort (by Snapshot Title, KEEP Username, Last Updated, or Creation Date) public snapshots and stitched groups even when they do not know what to search for.</td>
</tr>
<tr>
<td>Annotation</td>
<td>With the annotation feature, users can add a comment to a public snapshot or stitched group created by other users. The snapshot author can control the enabling, displaying and deleting of the comments. KEEP SLS enforces login-restricted commenting for anti-spam and anti-abuse reasons. And the registration requires a visual confirmation to prevent bots from auto signing up and spamming web sites.</td>
</tr>
<tr>
<td>Blog Connection</td>
<td>With the blog feature, users can connect to an external blog site by one-time configuration (providing URL and API endpoint of the external blog site, user name and password). Once the blog connection is set up successfully, users can blog about publicly snapshots within KEEP SLS without having to login to his/her external blog site. Using tags, KEEP SLS automatically matches related blog entries with the snapshot and displays them.</td>
</tr>
<tr>
<td>Group Collaboration</td>
<td>With the group feature, users can create a group, share and collaborate on snapshots, and then stitch multiple snapshots into a whole group project.</td>
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**Table 3. SLS Features**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Statistical Methods</th>
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<tbody>
<tr>
<td>H1: Users perceive higher positive values of KEEP SLS than the original KEEP.</td>
<td>The comparison of descriptive statistics for the pre-and post-test, especially the changes in mean; and paired sample t-test between pre and post test.</td>
</tr>
<tr>
<td>H2: Users’ participation in social learning activities within an ePortfolio system, users’ perceived ease of use of the system, and users’ perceived social learning position, are positively associated with the users’ perceived value of the system.</td>
<td>Scatter plots and Pearson’s correlation coefficient.</td>
</tr>
<tr>
<td>H3: Users’ perceived value of an ePortfolio system can be predicted by the users’ participation in social learning activities within the system, their perceived ease of use of the system, and their perceived social learning position within the community.</td>
<td>Linear regression.</td>
</tr>
<tr>
<td>H4: The ISDT design processes help in the design and development of a better system than one without following these processes.</td>
<td>Based upon the statistical results of the above three hypotheses.</td>
</tr>
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**Table 4. Hypotheses and Statistical Methods**