Article

Education in Cultural Heritage: A Case Study of Redesigning Atayal Weaving Loom

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Abstract: Employing cultural ergonomics concepts to product innovation for cultural education and sustainable development is the target of this study. Atayal culture is famous for its weaving craft and art. The Atayal tribe of Taiwanese aborigines weave on the Atayal loom. Traditional culture is disappearing rapidly due to colonial history and modernization. The Atayal people consider the weaving loom a cultural object when used as a weaving device. This study attempts to transform the ancient Atayal loom into a teaching device and extend Atayal weaving from execution in daily living to cultural experience and cultural heritage development. This study first explores and identifies the meaning of cultural objects and extracts their cultural features. Then, employing cultural ergonomics, a weaving box is redesigned from an ancient part of the loom into a modern weaving box. Finally, the new weaving device is evaluated and discussed. This case study examines a paradigm of how designers interact with cultural heritage and transform cultural objects into new instructional aids. Through cultural product design, it provides an intertwined experience in theoretical and practical approaches to accomplishing the development of cultural sustainability.

Keywords: cultural ergonomics; cultural education; Taiwanese aboriginal culture; product innovation; cultural sustainability

1. Introduction

Due to the multiple impacts of globalization, aging society, and COVID-19, the continuation and recovery of aboriginal cultural heritage and local revitalization have become more and more important in the creative industry and sustainable development [1,2]. These critical challenges of aboriginal communities and local economies rely on the integrated knowledge of traditional culture and abundant ecology dedicated to regional resilience [3–6]. Most aborigines believe that sustainability results from respect for nature; they strive to preserve that balance for the next generations. For instance, by listening to the birdsong of the grey-cheeked Fulvetta, the Atayal, one of the indigenous tribes in Taiwan, determine the best moment for executing each significant activity. This bird divination (Mita siliq) is the traditional behavior of the Atayal ritual, and attaches emotional attribute to an external object. Aborigines used to learn from nature and obey natural orientations.

Aborigine cultures have contributed to local industries as well as sustainable development. Successful cases in Australia and the United States inspired the authors and triggered this study [7,8]. There are sixteen indigenous tribes in Taiwan, all with diverse characteristics [9]. Following the traditional belief system, spiritual guidance, and social rules of Gaia, the indigenous peoples stress harmony and symbiosis strategies between
humans and nature [10]. As well, sustainability has already become a vital issue in aboriginal communities. It calls for simultaneous and multiple considerations of the environment, society, economy, education, culture, etc. [2,10,11].

Moreover, enhancing cultural education has become increasingly crucial for the sustainable development of aboriginal and traditional cultures in recent decades in Taiwan [2,9]. The result of creative thinking and creative education can be facilitated with the help of practical learning tools [12]. The study of cultural education usually focuses on methodology-based learning. However, this study proposes a methodology-driven project practice that composes methodology-based and project-based advantages [13]. Accordingly, the authors dedicate themselves to integrating the understanding of cultural context into the design process of transforming the innovational product [14].

Based on previous studies [15,16], this article intends to explore and apply the concept of cultural ergonomics to cultural product design for instructional aids. This study re-designs a desktop loom to provide novice weavers with a valuable and tractable device for weaving a successful cross-cultural product and achieving the balance between traditional heritage preservation and innovative education for culturally sustainable development. First, this study attempts to comprehend and illustrate the original meaning of the Atayal weaving loom. Then, the study extracts the cultural features and transforms them into a modern product of weaving boxes by employing the concept and paradigm of cultural ergonomics to product innovation. Finally, the new weaving box is evaluated to offer a convenient learning aid for education in cultural heritage and reflect on its support for promoting sustainable development.

2. Literature Review

2.1. Atayal Weaving Culture and Multiple Identities

The Atayal tribe is famous for its weaving craft and art; however, the weaving culture is disappearing rapidly due to the impact of the colonial period and modernization [9,17,18]. The efforts of cultural revitalization and the reintroduction of traditional weaving have had multiple effects on the contemporary Atayal communities. As a distinguished and significant symbol of aboriginal cultural heritage, Atayal weaving has recently been used to promote regional tourism in Wulai, the small township of northern Taiwan. Nonetheless, the Atayal tribe is barely involved with the tourism business or relative planning [18,19]. Thus, these situations remind rulers, scholars, and designers to re-clarify the purpose of local revitalization and reflect on achieving sustainable development and promoting local culture industries through cultural product design and education. However, in order to meet changing trends, technological progress, and commercial needs, new weavers and weaving studios try to embrace and merge traditional convention and creative invention. They hope to balance production and textile marketing and create different possibilities for future development [19]. Therefore, the sustainable development of the Atayal weaving culture continues to have potential, and the Atayal loom is deserving of in-depth study [18,20].

Today, the ritual patterns and meanings of facial tattoos can be transformed into new visual motifs through cultural education associated with user experience and emotional design. In this way, the unique culture of indigenous groups is presented to the world in a new form, which helps to perpetuate this cultural education. When balancing local cultural industries, understanding and integrating traditional and environmental knowledge are essential for achieving a sustainable future [21].

During the colonial occupation, the Atayal were forced to abandon their vital socio-culture activities; more exactly, they were prohibited from weaving, facial tattooing, and headhunting [22]. Meanwhile, some Atayal women reconstructed their textile culture by weaving for museums, and others were involved in the local market by weaving for tourists [18]. However, hand-weaving struggles to compete with factory-made woven products, especially considering the confusion of cultural identity. Nevertheless, there are multiple identities and effects on the Atayal community that take place through the reintroduction of its weaving culture. There are profound meanings and various identities...
involved in weaving reconstruction, including weaving for living, gender identity, ethnic, cultural, and place identity, and collective ethnic identity as the Atayal [18,19,22]. As Yoshimura [18] has indicated, the revitalization of Atayal weaving not only required weavers to retrace their weaving history or revive lost skills, it required them to explore new opportunities to create new motifs, especially by adopting imported looms or new weaving devices [18,19,23]. Today, the Atayal proudly claim their weaving culture not only, as usual, as a matter of gender identity among Atayal females, but as the collective ethnic identity of all Atayal [18].

2.2. Cultural Ergonomics in Atayal Loom

In traditional Atayal society, operating a weaving loom to accomplish weaving tasks is women’s most important skill and mission [17,22,24,25]. This study focuses on a weaving loom, the Atayal ground loom with a back strap, shown in Figure 1. We employ the subject of the Atayal weaving box to explore cultural ergonomics based on a systematic and scientific approach. According to the physical needs of weavers and their tribe’s custom, the width of the weaving box can be from 60 to 90 cm. Usually, the wooden box is made from the wood of the Camphor tree, Beech tree, or Formosan Michelia tree because of their properties of sturdiness and firmness [17]. The continuous warp threads go around the weaving box, completing the circular path, and are fastened by a pair of cloth beams held near the weaver’s body by a strap secured at each end and passing behind her back. The weaver sits on the ground and presses her feet on the major part of the Atayal loom, the weaving box, sometimes called the warp case, to alternately tighten and loosen the tension of the warp threads. Utilizing the strain and relaxing the warp threads to regularly create an open shed, the shuttle passes the horizontal weft thread through the vertical warp threads repeatedly until the patterns and cloth are woven completely [17,23,26].

Figure 1. An Atayal woman weaving on her backstrap loom. (Adapted from (left): [26]; (right): [17]).

In conjunction with the analysis framework of the human–system design, the authors argue that an ergonomic study of the Atayal weaving box should employ the user–tool–task paradigm [21,27–29]. Essentially, through detailed analysis and discussion to realize the weaving loom design, the interaction and feedback among the three objects of user (weaver), tool (weaving loom), and task (weave cloth) are explained, as shown in Figure 2. First, the “manipulation interface” (ergonomics) between the user (weaver) and tool (box loom) is analyzed. The review of user-friendly factors that exist in the user–tool interface includes the concerns of operability, portability, safety, comfort, etc. Second, the “engagement interface” (technology) is clarified in order to identify the relationship between the tool (weaving box) and the task (weave cloth). Examination of tool-useable aspects harbored in the tool–task interface involves consideration of the box shape, tool storage, suitable materials, haptic sensation, etc. After ergonomics research and human factors analysis, this study obtains practical results and understandings about the interrelationship between the weaver, Atayal box loom, and weaving product.
The weaving loom has been used in the traditional Atayal tribes for centuries. Recently, under the impact of globalization and the aging community, people have retraced and rethought the meaning of Atayal weaving culture to respond to the concerns and demands on cultural identities and sustainable development [17,18]. Meanwhile, in addition to applying human system design, adopting a cultural ergonomics approach is necessary to explore human–cultural interactions, extract their cultural characteristics, and transform them into modern products for preserving aboriginal culture [30–32].

Based on the experiential interaction with weaving loom and combining the user–tool–task model (Figure 2) with the above scenario, a framework that enhances understanding of cultural ergonomics in developing the cultural product design related to the Atayal weaving box is illustrated in Figure 3 [27,30]. In the case of the weaving loom, “scenarios” indicate the need to operate a weaving loom to weave textiles for daily life or specific dress for particular events or ceremonies. Moreover, “factors” refer to the loom’s function, timing of usage, operating location, user experience, etc. Finally, “levels” provides attention to the specific formation, interactive behavior, and cultural meaning of the weaving loom [31]. From the perspective of cultural ergonomics, the development of the Atayal weaving loom comprises three levels [33]. First, the outer level (user) focuses on the weaving loom formation related to the user’s demands, lifestyle, and feelings. Second, the middle level (tool) connects to everyday life function, usability, and behavior regarding the weaving loom. Third, the inner level (task) reflects the cultural meaning of the ceremony, reflection, and emotion derived from the weaving loom [30,31,34–37].

The integration of human–system design (Figure 2) and cultural ergonomics (Figure 3) facilitates weavers to improve textile quality and enhance productivity. Furthermore, ergonomics knowledge helps to prevent cumulative trauma to weaving laborers’ health. For example, apprehending and sympathizing with aboriginal weavers in Guatemala, Piegorsch [39] designed an adjustable bench and provided an additional way to reduce suffering in the traditional weaving process by employing cultural ergonomics knowledge and strategies. Moreover, based on this empirical study, she proposed a cycling approach with five stages: health, productivity, quality, culture, and self-esteem. Similarly, the traditional weaving posture of sitting on the ground for a long time causes cumulative trauma of the back to Atayal weavers. Moreover, many studies have evaluated the prevention of low back pain among handloom weavers [40,41]. Atayal people have recently sought alternative ways to weave and transform weaving art for extending Atayal culture. Thus,
the present study employs the weaving loom as a case study in order to illustrate how to transform cultural features and design a cultural product that can aid cultural learning.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Factors</th>
<th>Scenarios</th>
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<tbody>
<tr>
<td>User</td>
<td>Demand Life Style Feeling</td>
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<td></td>
<td>Manipulation Interface</td>
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<td>Tool</td>
<td>Function Usability Behavior</td>
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<td></td>
<td>Engagement Interface</td>
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<td>Task</td>
<td>Ceremony Reflection Emotion</td>
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<td></td>
<td>Interaction and Experience</td>
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**Figure 3.** Cultural ergonomics in product design with scenarios relating to the weaving loom. (Adapted from [26,31,38]; redrawn for this study).

### 2.3. Transformation and Inkle Loom

The date of the first loom can be traced back to the ancient Egyptians and Greeks [42]. In the archaic period, there were three major weaving devices: the horizontal ground loom, the vertical loom with winding beams, and the vertical loom with warp weights; of these, the ground loom is the oldest and most historical type [43,44]. The Atayal loom is one of the original portable backstrap types that belong to the horizontal ground loom category [17,45]. In the past, Atayal weaving was a delicate and meticulous mission. Usually, the weaving yarns were made from ramie and dyed with specific herbs. After ripping, cleaning, drying, and poaching, the ramie threads could be used for weaving. With changing technology, now Atayal people use wool or cotton in weaving instead of ramie [17]. Numerous tools were necessary during the traditional procedures of Atayal weaving. Relying on their professional and ingenious weaving skills, Atayal women created beautiful cloth [46]. However, due to the complicated instruments and overweight tools, the traditional weaving apparatuses are not convenient for fetching and carrying. Inevitably, the continual posture of sitting on the ground for hours hurts the back and waist of the weaver. Thus, seeking alternative ways to resolve problems related to traditional weaving for its cultural creation and sustainable development has become urgent for the Atayal people [17,47].

To reduce the trauma on indigenous weavers caused by the traditional ground loom, the American Catholic Fathers imported the New Zealand floor-standing loom to Taiwan in the 1960s [48]. Later, a new type of table-top weaving device was invented known as the desktop “Inkle loom”. When operating the desktop inkle loom, the weaver manually controls the lifting and lowering of warp threads to create the shed for the weft threads to shuttle through and accomplish weaving tasks [49]. The term “Inkle” refers to the “tape” or “ribbon” used by such looms. The inkle loom is usually used for weaving narrow works, and is suitable for straps, trims, belts, and narrow bands [50–52]. Because of the
convenience and portability of the desktop model, inkle weaving became very practical and efficient in operation and promotion. There are five major parts composing the setup for table-top Inkle weaving, as shown in Figure 4.

Figure 4. Major apparatus and materials for inkle weaving. (Source: this study).

The specific instructions are as follows. (1) Desktop inkle loom: this is the foremost part of the table-top weaving equipment, and substitutes the vertical thread sorting shelf. (2) Beater: this is used to push weft threads tightly together. (3) Shuttle: this is made from bamboo or wooden pieces; its primary function is to carry the weft thread between the warp threads. (4) Scissors: used to cut vertical and horizontal threads. (5) Thread materials: vertical (warp) and horizontal (weft) threads for weaving [26].

Typically, cultural products have been regarded as souvenirs for tourism in the cultural industry system. Most are imitations or counterfeits of native products without authorization from the aboriginal tribe [53]. However, indigenous women have handwoven Atayal textiles for the exhibitions in the Wulai Atayal Museum following its opening in 2005. The museum displays its materials and traditional artifacts and organizes the weavers to perform live demonstrations in order to show the tribe’s techniques at sightseeing attractions [17]. The museum is diligent in promoting and selling the works made by the weaving association members. It selects talented members as its instructors to design and execute cultural learning activities, such as DIY programs inspired by the user experience strategy [17,54,55].

The new type of table-top Inkle loom is convenient for strap creation or promoting cultural learning by employing ergonomics strategies that foster user experience. Indeed, the imported loom already has had effects on modern Atayal weaving [18]. The new desktop loom changes the way of sitting or standing to weave directly by penetrating the shuttle in order to create beautiful patterns. Furthermore, the new type of loom is much more time-saving than the traditional ground loom in weaving textiles, and it has become a popular tool for modern indigenous peoples seeking to revive the weaving crafts and arts [48]. However, the preparation and procedures required for the new imported weaving loom nonetheless takes time and space. As a result, in the native education of Atayal weaving courses and learning activities, the primary school and local workshop can only teach students vertical thread sorting and strap weaving by the Inkle loom [17,56] because of empirical limitations on practical learning, especially time limitations, apparatus storage, operation ergonomics, and culture transmission. This study argues that the imported desktop Inkle weaving device for Atayal cultural learning needs to be reviewed and redesigned by applying cultural ergonomics [26]. By enhancing our understanding of cultural meaning, cultural ergonomics contributes to contemporary cultural research and education through improved design implementation and product innovation [57].
3. Materials and Methods

3.1. User, Tool, and Task

Similar to the other indigenous people in Taiwan, after suffering from the extermination of traditional tribe culture in the past colonial period, the Atayal people have been trying to retrieve their textile tradition and weaving culture by tracing back and relearning from their ancestors’ wisdom [19]. Thus, this research examines three essential objects connected with this design case of Atayal Weaving loom transformation from the cultural ergonomics perspective: users with distinct concerns, tools in various eras, and tasks for different expectations.

• User (expert/novice): Yuma Taru is an outstanding weaver and prominent artist from the Atayal tribe in Miaoli County. She is one of the most important spirits who inspired and facilitated this empirical research. With her workfellows, they not only have worked to preserve the Atayal weaving tradition for decades, they have endeavored to extend the Atayal weaving arts to modern audiences. In the past, the Atayal tribe utilized oral transmission without literal writing. Thus, daughters had to learn their weaving knowledge from their mother’s in-person instruction and verbal description, which all relied on excellent memories. Through their efforts, much of the abundant data and special presentations about beautiful aboriginal patterns have been preserved in modern weavers’ notation [17,26,58]. Furthermore, Taru is trying to improve a school for the impoverished village children on the hills above Miaoli, and has established the Lihang workshop as a cultural center to promote Atayal cultural learning and creation [59]. While Taru was teaching the Atayal loom at the Lihang workshop in Miaoli, several children were attracted and wanted to know how to weave. Taru realizes that the classroom situations in rural primary schools need to be greatly improved for effective cultural learning, especially regarding cost, budget, space, and suitable devices. She believes that through such improvement, children and beginners will have a fair opportunity to learn and enjoy a relatively inexpensive and easily-learned introduction to this valuable and enjoyable art and craft. Thus, in this study, kids from the rural primary school are the major participants invited to operate and compare two kinds of new inkle devices.

• Tool (object/product): The Atayal traditional weaving box (Figure 1, before), called a weaving loom in the Atayal language, is the subject of this study. In the studies and reviews in Section 2 this study illustrates the relations and interactions in the three cultural levels, as shown in Figures 2 and 3. One of the characteristic appearances of the Atayal traditional loom is its wooden box with storage space, called a warp case. Its primary usability is recognized as a fundamental part of the Atayal horizontal backstrap weaving loom. However, the weaving posture of sitting on the ground usually causes cumulative trauma to the weaver’s back and waist. In brief, the cultural meaning of the weaving loom is its symbolization of multiple identities: gender identity among Atayal females in the past, and the collective ethnic identity of Atayal culture today [18,19,22]. Thus, this research argues that the Atayal loom is a cultural object that could be transformed from a traditional weaving tool into a cultural product.

• Task (weave/experience): In the past, Atayal people had to weave textiles for daily life and specific dress for particular events and ceremonies. In contemporary times, Atayal people have woven for museum displays or tourism markets. In the ancient period, Atayal people wove textiles with tribal patterns. Recently, the Atayal and their fellow tribal people keep trying to retrace their ancestors’ wisdom and revive local communities. Although they are from different generations, most of these weavers are looking forward to accomplishing their life duties or artistic ideals by weaving. In addition to weaving for their livelihood, museums, or markets, other concerns may include seeking alternative ways to pass on their inherited traditions and preserve their culture. Today, the Atayal proudly claim that the weaving culture has been recognized as the collective ethnic identity of the Atayal [18]. As Kreifeldt...
has mentioned, the artifacts of a culture are its external expression, and our modern products need a connection with a spiritual foundation [60]. Thus, according to the preceding discussions and looking into the future, this study extracts and re-identifies the adaptive meaning of “weaving loom” culture as “weaving for pleasure” conducted with the user experience strategy to meet demands and balance in the new era. This study expects the redesigned modern weaving box to facilitate and propel the improvement in tribal culture learning capably both affordably and sustainably.

3.2. Design Transformation

3.2.1. Sustainable Model of the Cultural Ergonomic Cycle

Applying the concept of cultural ergonomics, Lin et al. [31] proposed a cultural research framework to provide a valuable reference in cross-cultural product design. Based on previous studies [21,31,53], the present study organizes an empirical model of a cultural ergonomics system with a sustainable cycle, as shown in Figure 5. The circulatory research model consists of two primary circles: human–system design and the cultural ergonomic approach, as well as three essential sections: cultural object, design transformation, and cultural product.

The first circle (Figure 5, left) analyzes the influences and interactions of the user–tool–task paradigm and emphasizes the three subjects of design: user (human), tool (cultural object), and task (goal) along with the two interfaces: manipulation interface (ergonomics) and engagement interface (technology). The second circle (Figure 5, right) places cultural ergonomics in the core. It reconstructs the three subjects on different cultural levels (user on the outer level, tool on the middle level, and task on the inner level) into an mutually supporting triangle.

Figure 5. Sustainable model of cultural ergonomic cycle for Atayal loom. (Adapted from [17,31,38]; redrawn for this study).

After the human–system design method analyses, as shown in the first circle (Figure 5, left), the “cultural object” is identified in its historical context with a contemporary perspective. The designers keep discussing the design information and extracting the design elements when they move on to the next stage of design transformation (Figure 5, middle). In addition to applying and integrating the cultural ergonomics approach, as shown in the second circle (Figure 5, right), the “cultural object” (traditional Atayal loom) is redesigned and transformed into a new cultural product (modern weaving box). This
model proceeds with three steps: (1) Identification: extracting cultural features from the original cultural object; (2) Translation: translating the features into design information and design elements; and (3) Implementation: designing a cultural product. Moreover, the redesigned cultural product may subsequently be recognized as a valuable inherited cultural object in successive generations, thereby repeatedly returning through the cycles to launch the continuous circulation of cultural ergonomics research and accomplish the sustainable development of cultural design, learning, and diffusion.

3.2.2. Transforming the Traditional Atayal Weaving Loom into a Modern Weaving Box

This case study of the Atayal weaving box adopts the sustainable model of the cultural ergonomic cycle and mainly executes three steps of the design transformation process: (1) Identification; (2) Translation; and (3) Implementation (Figure 6).

![Figure 6. Design transformation process of Atayal weaving box. (Adapted from: [17,26]. Redrawn for this study).](image)

- **Identification:** This study retrospect and discriminates the significant meaning of the Atayal weaving culture and traditional loom (Figure 6, left). Based on previous research, this study identifies the Atayal weaving culture and cultural object (weaving loom), in terms of both gender identity among Atayal females and the collective ethnic identity of the Atayal.
- **Translation:** Based on the cultural ergonomics approach, this study analyzes the interrelations between the cultural subject (Atayal weaver), cultural object (loom), and cultural activity (weaving) from the three aspects of user, tool, and task. Integrating the historical and contemporary understanding of cultural heritage in Atayal weaving, researchers and designers extract cultural features as design information and translate them into adoptable design elements in the translation step, as shown in Figure 6. Before weaving on a loom, the traditional Atayal preparations (planting the ramie, harvesting, stripping, spinning, poaching, dyeing, sun curing, sorting, etc.) require laboring and toiling with mind and body, undoubtedly taking much time. As a result, school instructors can only teach students vertical thread sorting and simple weaving procedures on a modern loom. Due to the practical limitations (time, space, budget,
etc.), a simple device such as a desktop Inkle loom (Figure 4) is convenient and suitable for teaching weaving in school or a workshop.

- Implementation: Following the cultural ergonomics approach, this study redesigns a cultural product (Figure 6, right). The authors intend to inherit and transfer the box form and function to fulfill the appearance, storage, and portability connections between the original loom (cultural object) and creative box (cross-cultural product). In addition, while the lozenge on the cap of the outer box is used functionally as a grip handle, it additionally suggests the eye of the ancestors, which has great symbolic spiritual meaning. This single diamond shape with red striped patterns and decoration with a red frame carries ritual and religious meaning, and is an essential cultural signification in Atayal tradition. The user can manually assemble and install this re-designed product with the simpler weaving apparatus. This study demonstrates three steps of design transformation from a traditional Atayal warp case to a modern weaving box (Figure 6).

3.3. Evaluation Methods and Processes

In this case study, a weaving box is redesigned for sustainable development in cultural education to be suitable for primary schoolchildren’s weaving practices and cultural learning. Thus, primary schoolchildren, schoolteachers, and experts were invited for this case’s evaluation. In order to determine the usability and improve any defects, a modern weaving box and a New Zealand mini-ribbon loom with similar designs were evaluated together and compared.

- Surveyed schoolchildren: In this study, five aboriginal schoolchildren were invited for the evaluation, andae coded as A, B, C, D, and E. Schoolchildren A and B were ten-year-old girls; C and D were nine-year-old girls; and E was an eight-year-old boy. It was the first time for all five schoolchildren to operate the modern weaving box and New Zealand mini-ribbon loom.

- Evaluation samples: This experiment evaluated a modern weaving box and a New Zealand mini-ribbon loom. The bodies of both looms are made of wood, while certain parts are metal; the appearance and dimensions are shown in Table 1.

- Focus group: One Atayal teacher with more than twenty years of weaving and teaching experience, one designer with standing industry experience in product design, and five senior experts with academic and empirical backgrounds in cultural education, cultural research, and creative industry design were involved in this consulting committee.

- Evaluation objectives: Based on the records and descriptive documentation, seven experts reviewed the experiment of five schoolchildren’s operation of both looms. They aimed to evaluate the efficiency of the redesigned weaving box and its effectiveness as a teaching aid for cultural education.

This evaluation experiment was conducted in a meeting room at an aboriginal primary school. All the surveyed schoolchildren had no experience using either mini-loom. In the beginning, an experienced weaving teacher taught a brief outline of the operation of the mini-looms to the schoolchildren. With approximately 5 min of practice, the schoolchildren were able to handle and master the operation procedures. After that, the schoolchildren operated the looms for another 5 min by themself. This study used a digital camera to record the teaching process and independent operation. Figure 7 shows how a schoolchild learned to use a modern weaving box, and Figure 8 shows how a schoolchild learned to use a New Zealand mini-ribbon loom. In the end, the following questions were asked orally: (1) Do you think the operation process is complex? (2) Do you think it is hard to operate the ribbon loom, and where do you think it is hard to use? (3) Which ribbon loom do you think works fine?
The senior scholar of this research team hosted the focus group and led the discussions in five virtual meetings. The experienced weaving teacher, who was a member of this research team, described and documented her teaching discoveries and situations in this experiment executed at the aboriginal primary school: in response to the following questions (1) Which loom is easier for schoolchildren to operate and weave? (2) Does the redesigned weaving box facilitate the weaving learning of cultural education? (3) What will be the schoolteachers’ primary concern, demand, or challenge when executing the weaving learning for cultural education? Moreover, after evaluating the possibility of the redesigned modern weaving boxes as a teaching aid, the experts of this focus group concluded with suggestions and comments.

Table 1. The two kinds of mini-loom evaluated in this study. (Source: this study).

<table>
<thead>
<tr>
<th>Loom Type</th>
<th>Dimension (cm)</th>
<th>Appearance</th>
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<tr>
<td></td>
<td>(Length × Width × Height)</td>
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<tr>
<td>Outer Box</td>
<td>(36.6 × 13 × 5)</td>
<td><img src="image1" alt="Outer Box" /></td>
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<tr>
<td>Redesigned Modern Weaving Box</td>
<td>In Use (36.6 × 23 × 14.5)</td>
<td><img src="image2" alt="Redesigned Modern Weaving Box" /></td>
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<tr>
<td>New Zealand Mini Ribbon Loom</td>
<td>In Use (38 × 11 × 17)</td>
<td><img src="image3" alt="New Zealand Mini Ribbon Loom" /></td>
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</table>

Source: this study.

Figure 7. Process of how a schoolchild learns to use a redesigned modern weaving box. (Source: this study).
4. Results
4.1. Feedback from the Schoolchildren

After completing the weaving learning and experience on each kind of mini-loom, each schoolchild separately had a relaxed conversation with the teacher to express their feelings or opinions about the complexity of the operation, the possible reasons for difficulty, preference in manipulating, and other responses or feedback to the two kinds of the loom. The results of schoolchildren’s responses are excerpted below.

- Do you think the operation process is complex?

  Result: All five schoolchildren were able to operate the looms independently after about 5 min of instruction, and they responded that the operation procedure was not complex. Obviously, the operation procedures of both kinds of mini-looms were simple and easy.

- Do you think it is hard to operate the ribbon loom, and where do you think it is hard to use?

  Result: All five schoolchildren considered the redesigned modern weaving box to not work well because of “small sheds.” In the weaving steps, the first group of warp threads (upper warp threads) are lifted to produce a shed (opening) between the lifted and unlifted warp threads; next, a beater is inserted to hold the shed open and let the weft shuttle (carrying the weft threads) pass through the shed. Then, the beater is used to pack down the weft threads. Afterwards, the second group of warp threads (lower warp threads) is pushed down to produce a counter-shed. The counter-shed is held open with the beater and the weft shuttle passes through it. Finally, the beater is used to pack down the weft threads as before, and these steps are repeated to weave the cloth.

  Result: When the schoolchildren lifted or pushed the warp threads, the sheds produced by the modern weaving boxes were small (Figure 9, left); hence, the schoolchildren spent much time finding the sheds and expanding the openings with their fingers. The sheds of New Zealand mini-ribbon looms were large and conspicuous (Figure 9, right), and the schoolchildren easily found the shed’s location and expanded the openings with their fingers.
fingers. Therefore, five schoolchildren evaluated the usability of the redesigned modern weaving boxes more poorly than the mini-Inkle loom.

![Image of weaving boxes and looms](image-url)  

**Figure 9.** “Shed” on both mini-looms. (**Left**: smaller on a modern weaving box; **Right**: larger on a New Zealand ribbon loom).

- **Which ribbon loom do you think works fine?**
  
  **Result:** As it was hard to find the sheds on the modern weaving box, all five schoolchildren thought the New Zealand mini-ribbon looms worked better. Hence, further tests shall be conducted on the relative location and distance of the redesigned modern weaving box’s adjustable bar, support bar, and harness bar to help produce large sheds and aid schoolchildren in weaving more easily.

- **Other feedback:** Other responses and feedback to the modern weaving box included comments on the roughness caused by its handcrafted fabrication, defects in mutual conjunction, space between cylinders, length of the banister, stability of the loom, size of sheds, and storage. Selected descriptions are as follows for reference.
  
  1. **When a ribbon box is expanded for use, and the user feels that the pull-out is not smooth, the reason being that the wooden materials are handcrafted.** There are defects in positioning the cylinder used to manage the braids and box hole. Further fine grinding is required according to the tensile strength of the cylinder.
  2. **During weaving, there is incline from heavy stress due to the different bearing capacities of the cylinders used for winding.** The space between cylinders needs to be adjusted to enhance the stress level.
  3. **The banister is too short to reach the optimum comfortable, scale and cannot fully satisfy users, especially in length.**
  4. **In observing the schoolchildren using the ribbon looms, it was found that the ribbon looms waggle, slide, and even incline; hence, the future design should increase their stability.**
  5. **During weaving, sheds must be expanded to make the weft shuttle pass through more easily.** During use, it was found that the schoolchildren would turn their heads sideways to find the sheds (Figure 10), causing neck fatigue and discomfort.
  6. **The adjustable bar, support bar, harness bar, and weaving tools can be stored in the redesigned modern weaving box after weaving.** However, the semi-finished weaving cannot be stored in the box together, which reduces the originally-designed storage effects.
4.2. Feedback from the Schoolteacher and Experts

After reviewing the records and documentation of the experiment process, the seven experts evaluating the possibility of the redesigned modern weaving box as a teaching aid summarized their suggestions and comments as follows for reference.

- Which loom is easier for schoolchildren to operate and weave?

Result: Focusing on the research objectives and experiment purposes, the experts are primarily concerned with the operatable quality of the teaching devices. According to the records and documentation of the schoolchildren’s responses and the related descriptions from the schoolteacher, all seven experts agreed that the New Zealand mini-ribbon loom worked better than the redesigned modern weaving box, mainly because the “small sheds” were hard to see and find when weaving on the redesigned weaving box.

- Does the redesigned weaving box facilitate the weaving learning of cultural education?

Result: Despite the redesigned weaving box not working better than the imported New Zealand mini-ribbon loom, the schoolteacher mentioned that the redesigned weaving box transformed from the Atayal ancient loom had kept ritual symbols carrying cultural meanings and provided a functional form for cultural experience. These enhance emotional motive, reasonable representation, and accessible interaction much more, helping to facilitate weaving learning for cultural education.

- What will be the schoolteachers’ primary concern, demand, or challenge when executing the weaving learning for cultural education?

Result: Raising the learning motivation of schoolchildren is the primary concern of teachers when executing cultural education in primary schools or workshops. Schoolteachers need an innovative product as an instructional aid in order to encourage the schoolchildren’s learning interest. In addition, executing weaving learning for cultural education in a time-limited period is a difficult challenge.

Moreover, limitations exist in promoting cultural education in an aboriginal community. Due to the aging society, it is hard to find enough human recourse to inherit or extend the traditional Atayal weaving culture appropriately. It was challenging to find many schoolchildren without Inkle weaving experience to participate in this experiment in the aboriginal community of the impoverished village on the hills above Miaoli. Furthermore, not all Atayal women know how to weave using the traditional looms as their ancestors did, nor have the new generations accumulated enough knowledge or experience to translate the old motifs into a new subject for modern life through redesign of modern weaving boxes.

Figure 10. This schoolchild turns his head sideways to find where the shed is. (Source: this study).
5. Discussions

This study focuses on the aboriginal weaving culture as a case study to demonstrate how to combine human–system design and cultural ergonomics in cross-cultural product design as a cultural learning tool to aid sustainable development. Based on previous studies, this study explores and identifies the meaning of aboriginal objects. The designer extracted the cultural features from the traditional Atayal “weaving loom” and redesigned a modern weaving box. Schoolchildren, schoolteachers, and experts evaluated and discussed this redesigned modern weaving box. It was found that the redesigned modern weaving box needs improvement to address several ergonomic problems.

Despite these drawbacks, this case study provides interfaces and references for examining how designers interact with cultural objects and the interwoven experiences across cultures. Furthermore, the circulatory paradigm (Figure 5) proposed by this study and the evaluation and discussion executed with schoolchildren, schoolteachers, and experts all facilitate adaptive innovation in design transformation. By considering, adopting, or transferring multiple identities and cultural meanings between traditional and contemporary societies, this paper goes into further detail about the unique experience of cultural learning and specific approaches that integrate theoretical research and practical experience to promote cultural sustainability.

This study proposes the sustainable cycle of cultural ergonomics, as shown in Figure 5. Five foci are reviewed and summarized based on the previous discussions related to the interactions among vital subjects of user–tool–task, as shown in Figure 11.

![Figure 11. The five foci of cultural education in with ergonomics evolution. (Source: this study).](image-url)
• From Nature to Culture

Humans are used to learning from nature and developing our culture with the balance of nature. This composes the essential parts of sustainable culture and coheres the humanity’s core values.

• From Passion to Expectation

According to the cultural analysis on the outer level, users in the case study may have varied demands, lifestyles, and feelings, with multiple identities in different scenarios. This case study illustrates the humanity of passion and expectation, which echo the user character transfers between novice and expert.

• From Traditional to Creative

On the middle-level, the analysis of function, usability, and behavior related to the tool focuses on transforming it from a cultural object into an innovative product for cultural education. This study explores these possibilities, from traditional to creative.

• From Living to Pleasing

At the inner level, the interaction and experience from ceremony, reflection, and emotion cause the different objectives of task-taking between daily living execution and pleasing cultural experience.

• From Circle to Cycle

The interrelations between the user, tool, and task bring with them advanced ergonomics, technology, and marketing issues. This study employs cultural ergonomics to accomplish product innovation for cultural education. The authors aim to promote cultural evolution from circle to cycle in order to launch education on cultural heritage and its sustainable development.

Integrating our previous study of theoretical references and empirical experiences, the authors suggest an efficient system of cultural ergonomics by employing the analyses of cultural levels and the extraction of cultural features to achieve a balance between technology and humanity [21]. By enhancing our understanding of cultural meaning, cultural ergonomics contributes to contemporary cultural research through improved design implementation and evaluation capabilities [57]. In addition to participating in cultural contexts, developing interactive user experiences is becoming more meaningful and vital in cultural product design [17]. Cultural ergonomics considers and discusses the experience-based variations and interactions among cultures to accomplish cross-cultural product design [31].

This study adopts a methodology-driven project practice that composes methodology-based and project-based advantages [13]. Therefore, this empirical research suggests a much more appropriate qualitative approach than quantitative statistics to evaluate and discuss the potential and paradigm in cultural product innovation for cultural education and sustainable development. One suggestion for future research is to determine how to keep the passion, sensation, and awareness for the declining tribe and community’s needs. Another suggestion is dedicated to understanding the traditional culture through residence in that local field for a more extended period to identify and sustain the essential meaning of culture more precisely. Finally, this study suggests enhancing marketing strategies for promoting the cultural products in order to make culturally sustainable development more practicable.

6. Conclusions

Learning from nature used to be the wisdom of aboriginal ancestors. In the past, following natural orientations, different tribal groups formulated the spiritual rituals and created tangible objects belonging to each unique culture. Today, many countries have continued pursuing technological modernization and economic progress. Due to the impacts of global markets and changing fluctuations, facing contemporary challenges by
employing cultural ergonomics to reach the balance between nature and culture, humanity and usability, has become an urgent issue in the design industry and design education.

There are many parallels to these questions and problems everywhere, in that native cultures are disappearing, and their arts and crafts along with them. It is strange that as these cultures diminish or vanish altogether, their old traditional art pieces become more and more sought by museums and private collectors, and consequently become more and more valuable. Beauty is the soul of the artist expressed in her art. Based on strong religious beliefs, tribal arts express that soul very strongly. It is a mystery how tribal arts can speak to someone even across cultural oceans, if not for soul-to-soul communication. As others begin to see the beauty of the art and are moved by it, they wish to possess it, even without understanding or even knowing the culture behind the art; such is the passion of the collector. Such cross-cultural attraction with consequent desire for possession is what designers of products for the international markets should hope to have their products evoke. Continuing studies of what makes tribal arts such as the weavings of the Atayal, or even a “tool” like the weaving box, so attractive cross-culturally can definitely aid in designing successful cross-cultural products. Moreover, these products or learning-aided devices with native cultural meaning can accelerate the foundation of cultural learning through a capable and affordable path and lead toward sustainable development across generations and across cultures.

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